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Preliminary study of the growth of *Oreochromis niloticus var. Rocky Mountain* and *Lycopersicum esculentum* L. cultured in aquaponic/Biofloc system

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Abstract
Aquaponic cultures control the residual nutrient accumulation that come from aquaculture activity, which reduces the fertilizer and water consumption without affecting culture demean quality and productivity. Twenty-five juvenile stage of *Oreochromis niloticus var. Rocky Mountain* juveniles with a mean total length of 6.15 to 6.55 cm and mean weight of 5.51 to 9.87 g were cultured in 200 L plastic beakers with 160 L of freshwater (0.80 x1.0 m). Tomato plants were sown in PVC tower aquaponic system. Every 15 days, total length of tomatoes stem and fishes were measured. Organisms with longest total length were those fed with Tilapia pellet with fertilized plants with 24.68±0.20 cm, meanwhile lowest values were for Tetracolor® without fertilized plants with 16.31±0.37 cm. The tallest stem was found with Tilapia pellet and fertilized plant with 271.56 ±0.48 cm and the smallest stem was for Tetracolor without fertilized plants with 192.03 ±0.26 cm. The results show a tilapia and tomato plant growth and weight increase in aquaponic/Biofloc integrated culture system.

Keywords: *O. niloticus*, *Licopersicum sculentum*, Aquaponics, Biofloc.

1. Introduction
In the last few decades inside the aquaculture sector, production systems are design to culture different aquatic organisms oriented to decrease the space and water waste, and increasing culture density of organisms (Timmons *et al*., 2002) [1]. One of this new culture system is the Biofloc technique, that consist in the management of Carbon:Nitrogen relation to help the growth of heterotrophic bacterial communities or microbial flocs which agglomerated in water culture medium and use the nitrogen compounds like total ammoniacal nitrogen (TAN) and transformed it into useful nitrogen compounds for plants (nitrates and nitrites) (Monroy *et al*., 2013) [2].
This beneficial bacteria production is produced using continuous vigorous aeration in water column and the addition of a carbon source as organic matter substratum which allow aerobic decomposition and maintain high levels of flocs concentration (Monroy *et al*., 2013, Avnimelech *et al*., 1986) [2, 3]. These flocs can be used as disponible bacterial biomass to feed fishes in culture medium (Hargreaves, 2006) [4]. This biomass can be 20 to 25% of total retained nitrogen in fish culture, leaving in culture medium, 40 to 60% of total metabolized nitrogen to produce new bacterial populations which decrease nitrogen compounds like ammonia (NH_4), principal nitrogen waste of fishes, and recycling the fishes waste to nitrates (NO_3), and nitrites (NO_2), which can be used as fertilizers for pslants (Azim y Little, 2008) [5].
The Biofloc system shows great advantages in urban aquaculture, because it can respond to lack of space and water source like Mexico city, but also to high densities or biomass production in plants and fishes in little spaces and so cover this essential resources for maintenance of family needs. Biofloc system is a viable alternative to improve different urban biotechniques to develop this activity, protecting the water source, inert food waste, obtaining organic fertilizer for different orchards, and obtaining fish, plants (aromatics or ornamental), vegetables or fruits biomass in this culture system (Avnimelech *et al*., 2009) [6].
Nile tilapia or mojarra is a freshwater fish, originally from Africa and was introduced in Mexico in 1964, with a length of 10 to 30 cm, with different color according to specie.

Tilapia has an elongated body and narrow type shape with a small mouth which do not reach the eyes margin. It can be distinguished by their dorsal fin with a crest spine form type and terminal radios, with a rounded and trunk caudal fin. Tilapia fish occupy de second place in aquaculture production worldwide and some different species are cultured in Mexico, produced principally in aquaculture farms for human consumption (Gómez *et al*., 2008; Yuan *et al*., 2010; SAGARPA, 2016) [7, 8, 9].

Tilapia culture was popularized because of their attributes like as fast growth, physical resistance, high reproductive capacity, high adaptative captivity survival, and high densities cultures. Also, it accepts a great variety of foods, and their organic waste can be used as fertilizer to vegetables as tomatoes (*Lycopersicum esculentum*), which can be cultured in hydroponics and aquaponics systems, therefore is highly profitable.

Aquaponic system have advantages over other production systems, like recirculating aquaculture system and hydroponic system which uses inorganic nutrients. In aquaponic system, the hydroponic system is used as biofilter, so it is not necessary to use another filter like recirculating systems. The aquaponic culture systems control the accumulation of residual nutrients proceeding from aquaculture ponds and reduce the fertilizer and water consumption without demerit product quality and culture productivity (Roosta and Mohsentan, 2012; Villalobos y González, 2016) [10, 11]. Even though fish food supply almost every nutrient compound required for plant growth, decomposition of nitrogen compounds in water from organic matter (not consumed food), as well as nitrogen fish waste can favor plants growth by using directly nitrogen compounds transformed by nitrifying bacteria community produced in Biofloc system (Collazos and Arias, 2015; Ramírez *et al*., 2019) [12, 13].

For the above, the present study shows the preliminary results of tilapia and tomato culture in aquaponic/Biofloc system in a $5m^2$ space in laboratory conditions in Live Food and Biofloc Production Laboratory from Universidad Autónoma Metropolitana Xochimilco.

2. Materials y methods

2.1 Fish experimental design

Twenty-five *O. niloticus var. Rocky Mountain* juveniles with a mean total length of 6.15 – 6.55 cm and mean weight of 5.51 – 9.87 g, were placed in 200 L plastic beakers with 160 L of water (0.80 x 1.0 m). Measured biometrical values were total length, height, width, and weight. The plastic beakers were maintained whit constant vigorous aeration to maintain movement in all water column (Fig. 1). Temperature was maintained at 23±2 °C and chemical parameters (nitrates, nitrites, ammonia, phosphates, pH, and chloride) were measured every 10 days with a Multiparametric Hanna® No. HI83300-01 with pH meter equipment.

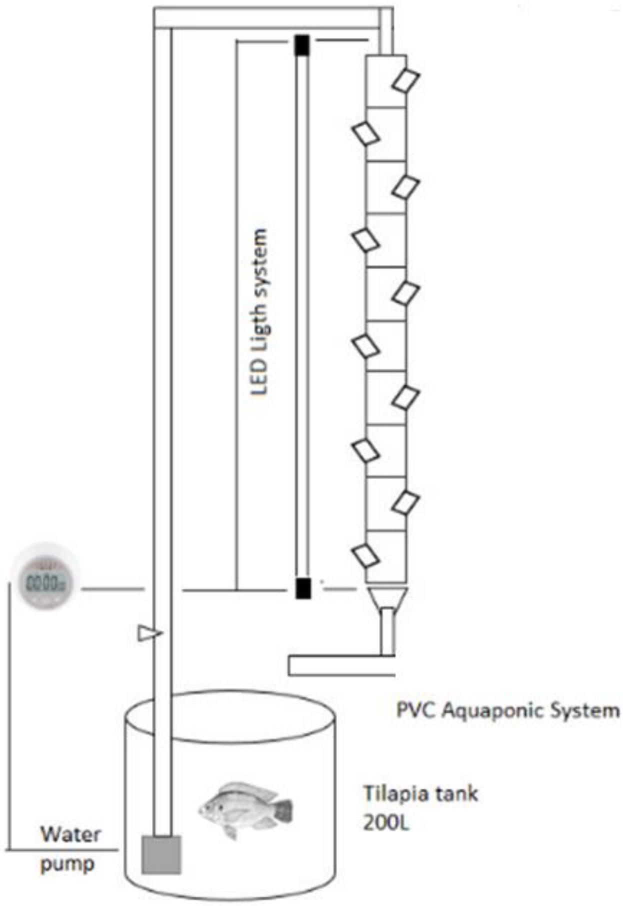

Fig 1: Culture system of *O. niloticus var. Rocky Mountain* for each experimental treatment.

2.2 Experimental plants design

L. esculentum seeds were sow in 250 mL plastic beakers filled with 200 mL of peat moss. Fifty plastic beakers with three seeds each one. In each container, four bottom holes were made to allow absorption of water. All beakers were placed in plastic tray (60x40x2 cm), with 18 watts LED white light tube for 12:12 hours light/darkness period. Four treatments were made with Tilapia and Tetracolor pellets and plants with and without fertilizer.

When stem reached 5 cm tall length, with adequate branched root, the peat moss was retired and the plant was placed in a sponge cylinder (4 cm diameter and 5 cm tall), and laid again in the250 mL plastic container (previously washed) and placed in a PVC 45° elbow. Ten 45° PVC elbows per aquaponic tower were settled (Fig.1). Measured biometrical value was stem total length.

2.3 LED light and water movement

Every tower had one 18 w LED white tube. A recirculation system was made with one fountain pump (Simple Deluxe 400 GPH UL) and placed in fish culture tank (Fig. 1). Light and pump were connected to a Timer Digital GE programable from seven days, they were turned on for three hours and turned off for two hours.

2.4 Food (Tilapia and Tetracolor pellets) and Moringa (carbohydrate source) supply

The fishes' weight was used to apply 5% of total organism weight from each 200 L plastic container. Four treatments were made: a) Tetracolor pellets and plants with fertilizer (Diet 1), b) Tetracolor pellets and plants without fertilizer (Diet 2), c) Tilapia pellets and plants with fertilizer (Diet 3), and d) Tilapia pellets and plants without fertilizer (Diet 4). Tilapia pellets contain 35% of crude protein and a size of 0.8 mm. Tetracolor pellet contain 47.5% of crude protein and a size of 2 mm. Total organisms' weight from each 200 L plastic container was used to supply the 0.1% of Moringa as carbohydrate source to produce Biofloc.

2.5 Information process

At the beginning of experiment and every seven days until 140 culture days, fishes were measured with a Digital Vernier (Truper® ±0.001 mm) and plants with a 5 m flex meter. Fishes were weighted with a Digital Balance (Nimbus® ±0.01 g). All biometrical values were placed in a database made in Excel 2010 to obtain their descriptive analysis and their tendency curves. Also, gain, absolute growth rate (AGR), and instantaneous growth rate (IGR) values were obtained from each experimental diet.

To obtain gain value, the following formula was used:

G = Final value – Initial value

To obtain AGR, the following formula was used:

$$AGR = \frac{\text{Final value} - \text{Initial value}}{\text{Total experimental days}}$$

To obtain IGR, the following formula was used:

$$IGR = \frac{\ln(\text{Final value}) - \ln(\text{Initial value})}{\text{Total experimental days}} \times 100$$

2.6 Statistical analysis

ANOVA analysis was made to determine significant differences ($p < 0.05$) between experimental diet treatments. When significant differences were founded, a multiple mean comparison analysis was made by Tuckey test to determine significant differences ($p < 0.05$) between treatments.

3. Results

3.1 Chemical water parameters

In the four experimental treatments the temperature was controlled at 23±2°C; the pH value fluctuated between 7-8; chlorine between 0.10-0.48 mg L^{-1}; ammonia values between 0.19 to 6.83 mg L^{-1}; nitrates between 9 to 285 mg L^{-1}; nitrites between 3 to 209 mg L^{-1}; and phosphates between 0.46 to 0.76 mg L^{-1}, in all experimental period.

3.2 Tilapia survival

Fishes fed with Tetracolor and Tilapia pellet with plants fertilized obtained after 140 culture days a survival of 75%. The fishes fed with Tilapia pellet and plants without fertilizer obtained 32% survival at end of experiment.

3.3 Biometric values of fishes

3.3.1 Total length

Table 1 show the mean data values (±S.D.) of the total length of fish cultured in aquaponic/Biofloc system with four treatments; and Fig.2 shows the total length growth tendency curves. All curves were lineal type curve.

Table 1: Mean values of total length growth (±S.D.) of fishes in the experimental diets. Values in centimeters.

Culture days	Diet 1	Diet 2	Diet 3	Diet 4
0	6.43 ±0.44	6.55 ±0.63	6.15 ±0.28	6.25 ±0.82
7	7.26 ±0.28	7.04 ±0.73	6.95 ±0.25	7.17 ±0.34
14	8.09 ±0.26	7.53 ±0.42	7.75 ±0.21	8.09 ±0.37
21	8.93 ±0.25	8.02 ±0.72	8.55 ±0.31	9.01 ±0.38
28	9.76 ±0.51	8.51 ±0.20	9.36 ±0.68	9.94 ±0.30
35	10.59 ±0.46	8.99 ±0.60	10.16 ±0.83	10.86 ±0.48
42	11.42 ±0.45	9.48 ±0.29	10.96 ±0.45	11.78 ±0.38
49	12.25 ±0.57	9.97 ±0.52	11.76 ±0.28	12.70 ±0.23
56	13.09 ±0.20	10.46 ±0.71	12.56 ±0.43	13.62 ±0.23
63	13.92 ±0.52	10.94 ±0.82	13.36 ±0.71	14.54 ±0.83
70	14.75 ±0.41	11.43 ±0.62	14.16 ±0.54	15.46 ±0.23
77	15.58 ±0.56	11.92 ±0.66	14.96 ±0.46	16.39 ±0.54
84	16.42 ±0.72	12.41 ±0.37	15.76 ±0.40	17.31 ±0.69
91	17.25 ±0.77	12.89 ±0.79	16.56 ±0.69	18.23 ±0.57
98	18.08 ±0.30	13.38 ±0.69	17.36 ±0.67	19.15 ±0.19
105	18.91 ±0.27	13.87 ±0.42	18.16 ±0.74	20.07 ±0.42
112	19.74 ±0.51	14.36 ±0.54	18.96 ±0.75	20.99 ±0.73
119	20.58 ±0.69	14.85 ±0.21	19.76 ±0.35	21.91 ±0.55
126	21.41 ±0.29	15.33 ±0.82	20.57 ±0.65	22.83 ±0.50
133	22.24 ±0.39	15.82 ±0.61	21.37 ±0.42	23.76 ±0.44
140	23.07 ±0.50[a]	16.31 ±0.37[b]	22.17 ±0.20[c]	24.68 ±0.20[d]

Organisms which reached the highest total length were those fed with Diet 4 treatment with 24.68±0.20 cm, meanwhile lowest values were found in Diet 2 treatment with 16.31±0.37 cm.

ANOVA analysis and multiple mean value comparison test by Tukey technique showed significant differences ($p < 0.05$) between treatments,

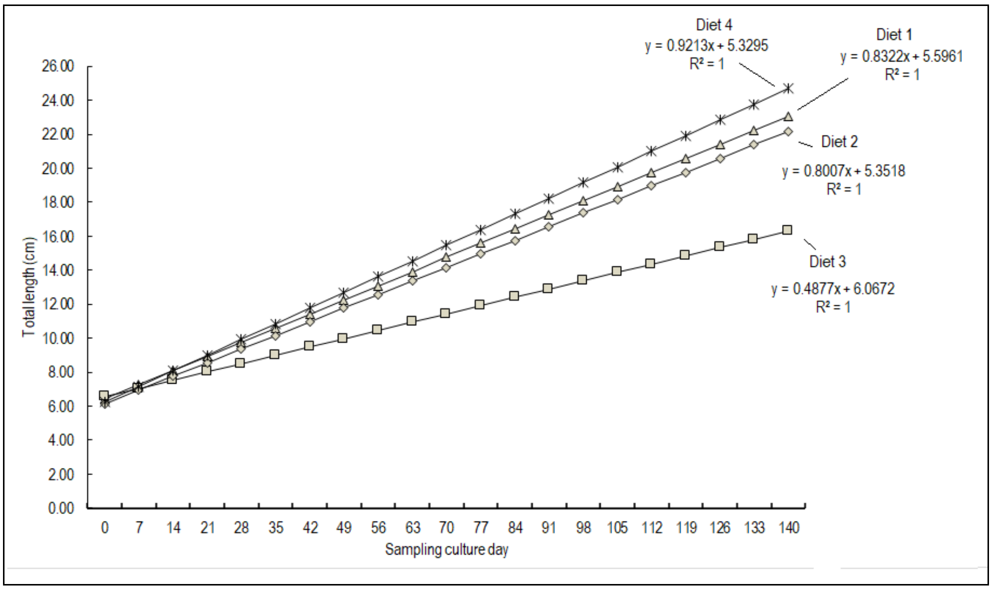

Fig 2: Tendency curves of total length growth in the experimental treatments in aquaponic/Biofloc culture system.

It is shown in Table 2 the gain, AGR, IGR values of cultured organisms in the aquaponic/Biofloc system. The highest values were presented in fishes cultured in Diet 3 with 18.43 cm, 0.13 cm day^{-1} cm, 0.98% day^{-1} respectively. The lowest values in those three variables were shown in Diet 2 treatment with 9.75 cm, 0.07 cm day^{-1}, 0.65% day^{-1}.

Table 2: Gain, AGR, IGR (%) values of total length of fishes cultured in the experimental treatments.

Experimental treatment	Gain (cm)	Absolute Growth Rate (AGR) (cm day^{-1})	Instantaneous Growth Rate (IGR) (% day^{-1})
Diet 1	16.64	0.12	0.91
Diet 2	9.75	0.07	0.65
Diet 3	16.01	0.11	0.92
Diet 4	18.43	0.13	0.98

3.3.2 Height

The mean value (±S.D.) of organisms' height are shown in Table 3. Highest values were found in Tilapia pellets and plants without fertilizer treatment with 11.93±0.63 cm. The lowest values were with Diet 1 treatment with 9.02±0.33 cm. Tendency curves are shown in Fig.3. Diet 3 show exponential type curve, the other three experimental curves shown lineal type curves.

ANOVA analysis show significant differences (p< 0.05), but multiple mean comparison analysis by Tukey technique only show significant differences (p< 0.05) between Diet 2 treatment, regarding to the other three treatments. Diet 1, Diet 2 and Diet 3 did not show significant differences between them (p>0.05).

Table 3: Mean values (±S.D.) of organisms' height cultured with the experimental treatments cultured in aquaponic/Biofloc system. Values in centimeters.

Culture days	Diet 1	Diet 2	Diet 3	Diet 4
0	2.55 ±0.57	2.34 ±0.38	2.59 ±0.53	1.17 ±0.33
7	2.72 ±0.67	2.68 ±0.60	2.93 ±0.59	1.71 ±0.50
14	2.89 ±0.63	3.02 ±0.21	3.27 ±0.65	2.25 ±0.60
21	3.08 ±0.14	3.36 ±0.57	3.61 ±0.20	2.79 ±0.40
28	3.28 ±0.24	3.70 ±0.33	3.96 ±0.64	3.33 ±0.49
35	3.50 ±0.32	4.04 ±0.06	4.30 ±0.63	3.86 ±0.61
42	3.72 ±0.60	4.38 ±0.57	4.64 ±0.12	4.40 ±0.66
49	3.97 ±0.25	4.72 ±0.38	4.98 ±0.17	4.94 ±0.42
56	4.23 ±0.50	5.06 ±0.66	5.32 ±0.18	5.48 ±0.45
63	4.50 ±0.22	5.41 ±0.19	5.67 ±0.62	6.02 ±0.14
70	4.80 ±0.44	5.75 ±0.59	6.01 ±0.52	6.55 ±0.34
77	5.11 ±0.45	6.09 ±0.32	6.35 ±0.32	7.09 ±0.14
84	5.44 ±0.20	6.43 ±0.19	6.69 ±0.36	7.63 ±0.31
91	5.80 ±0.43	6.77 ±0.66	7.04 ±0.54	8.17 ±0.58
98	6.17 ±0.51	7.11 ±0.25	7.38 ±0.46	8.70 ±0.25
105	6.58 ±0.46	7.45 ±0.12	7.72 ±0.48	9.24 ±0.33
112	7.01 ±0.20	7.79 ±0.07	8.06 ±0.24	9.78 ±0.65
119	7.46 ±0.42	8.13 ±0.58	8.40 ±0.55	10.32 ±0.28
126	7.95 ±0.49	8.47 ±0.13	8.75 ±0.61	10.86 ±0.56
133	8.47 ±0.12	8.81 ±0.12	9.09 ±0.28	11.39 ±0.53
140	9.02 ±0.33	9.15 ±0.64	9.43 ±0.55	11.93 ±0.63

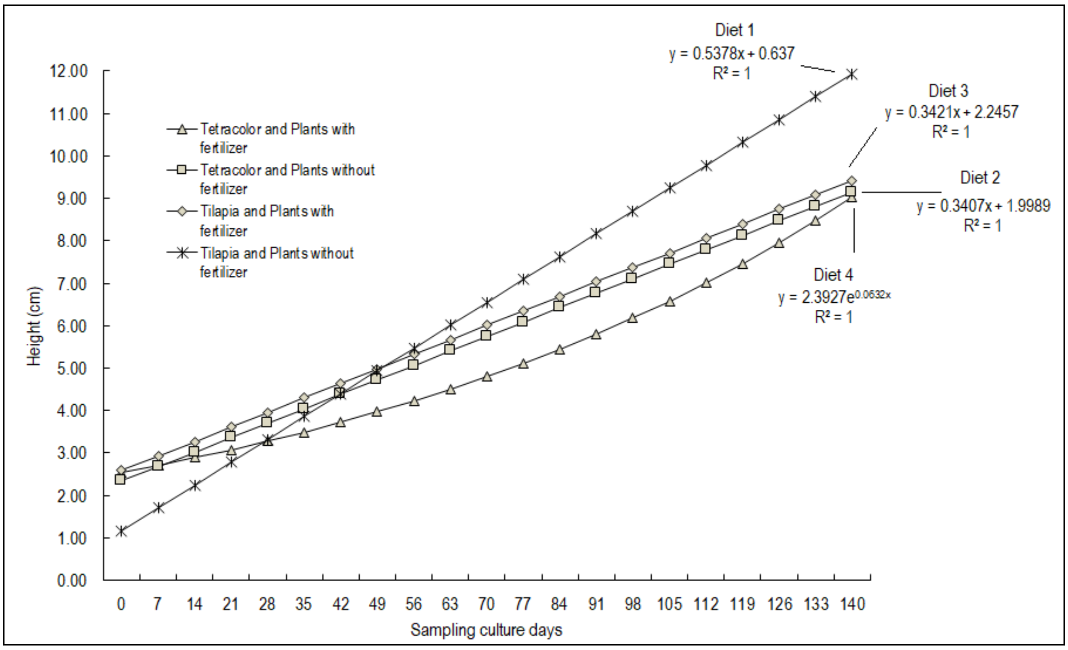

Fig 3: Tendency curves of height growth of organisms cultured in the two experimental treatments in aquaponic/Biofloc system.

In Table 4 are shown the gain, AGR, and IGR values. The highest values were presented in Diet 3 with 10.76 cm, 0.08 cm day^{-1} cm, 1.66% day^{-1} respectively. The lowest value in gain and IGR value were in Diet 1, but in AGR lowest value was found in Diet 1, Diet 2 and Diet 3 with 0.05 cm day $^{-1}$.

Table 4: Gain, AGR, and IGR (%) values of fishes' height cultured in the experimental treatments.

Experimenta treatment	Gain (cm)	Absolute Growth Rate (AGR) (cm day^{-1})	Instantaneous Growth Rate (IGR) (% day^{-1})
Diet 1	6.47	0.05	0.90
Diet 2	6.81	0.05	0.97
Diet 3	6.84	0.05	0.92
Diet 4	10.76	0.08	1.66

3.3.3 Width

The mean values (±S.D.) of organisms' width are shown in Table 5. Highest values were found in Diet 4 with 8.02±0.16 cm. Lowest values were found in Diet 2 with 4.54±0.47 cm. Tendency curves of growth width are shown in Fig.4. Diet 2 and 3 show exponential curve type and Diet 1 and 4 show lineal curve type.

ANOVA and Tukey test analysis showed significant differences ($p < 0.05$) between all treatments with this biometric value.

Table 5: Mean values (±S.D.) of organisms' width cultured in the experimental treatments in an aquaponic/Biofloc system. Values in centimeters.

Culture days	Diet 1	Diet 2	Diet 3	Diet 4
0	1.31 ±0.15	1.18 ±0.57	1.23 ±0.39	0.82 ±0.50
7	1.41 ±0.50	1.35 ±0.43	1.48 ±0.12	0.92 ±0.50
14	1.52 ±0.49	1.52 ±0.32	1.73 ±0.46	1.03 ±0.25
21	1.63 ±0.35	1.68 ±0.36	1.98 ±0.24	1.15 ±0.37
28	1.75 ±0.33	1.85 ±0.46	2.23 ±0.24	1.29 ±0.21
35	1.88 ±0.24	2.02 ±0.11	2.48 ±0.11	1.45 ±0.32
42	2.02 ±0.51	2.19 ±0.58	2.73 ±0.38	1.63 ±0.36
49	2.17 ±0.34	2.36 ±0.60	2.98 ±0.44	1.82 ±0.65
56	2.33 ±0.43	2.52 ±0.22	3.23 ±0.21	2.04 ±0.19
63	2.51 ±0.55	2.69 ±0.11	3.49 ±0.22	2.29 ±0.37
70	2.69 ±0.48	2.86 ±0.27	3.74 ±0.37	2.57 ±0.22
77	2.89 ±0.31	3.03 ±0.21	3.99 ±0.39	2.88 ±0.28
84	3.11 ±0.20	3.20 ±0.49	4.24 ±0.22	3.22 ±0.25
91	3.34 ±0.50	3.36 ±0.35	4.49 ±0.31	3.61 ±0.21
98	3.59 ±0.33	3.53 ±0.15	4.74 ±0.43	4.05 ±0.42
105	3.85 ±0.32	3.70 ±0.56	4.99 ±0.27	4.54 ±0.14
112	4.14 ±0.21	3.87 ±0.65	5.24 ±0.21	5.08 ±0.55
119	4.45 ±0.34	4.04 ±0.25	5.49 ±0.15	5.70 ±0.49
126	4.78 ±0.13	4.21 ±0.33	5.74 ±0.24	6.39 ±0.38
133	5.14 ±0.54	4.37 ±0.57	5.99 ±0.13	7.16 ±0.43
140	5.52 ±0.11	4.54 ±0.47	6.25 ±0.20	8.02 ±0.16

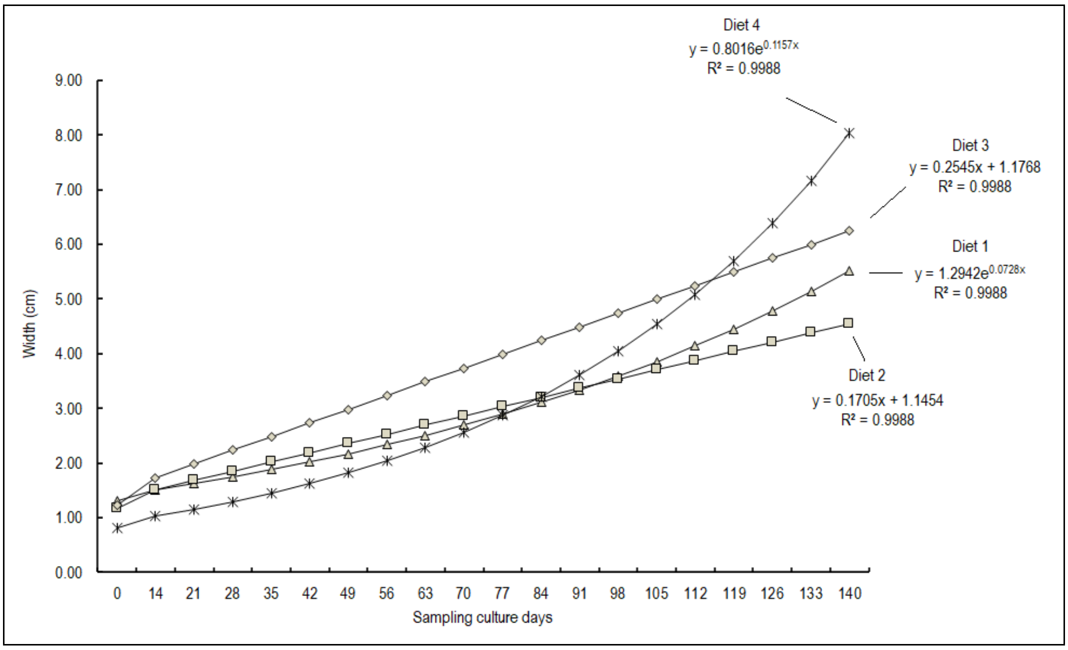

Fig 4: Tendency curves of width growth of organisms cultured in the experimental treatments in aquaponic/Biofloc system.

In Table 6 it is presented the gain, AGR, and IGR values of width organisms cultured at two treatments. The highest values were found in Diet 4 treatment with 7.20 cm, 0.05 cm day^{-1} cm, 1.63% day^{-1} respectively. The lowest values were for Diet 2 with 3.36 cm, 0.05 cm day $^{-1}$, 1.63% day $^{-1}$.

Table 6: Gain, AGR, and IGR (%) values of fishes' width cultured in the experimental treatments.

Experimental treatment	Gain (cm)	Absolute Growth Rate (AGR) (cm day^{-1})	Instantaneous Growth Rate (IGR) (% day^{-1})
Diet 1	4.21	0.03	1.03
Diet 2	3.36	0.02	0.96
Diet 3	5.02	0.04	1.16
Diet 4	7.20	0.05	1.63

3.3.4 Weight
The mean values (±S.D.) of organisms' weight are shown in Table 7. The highest values were for Diet 4 treatment with 333.61±0.23 g. The lowest values were for Diet 2 with 257.24±0.80 g. Tendency curves are shown in Fig. 5. Diet 1 show polynomic grade two curve type and Diet 2, Diet 3, Diet 4 show lineal curve type.

The ANOVA and Tukey analysis showed significant differences (*p*< 0.05) between all treatments with this biometric variable.

Table 7: Mean values (±S.D.) of organisms' weight cultured in the experimental treatments in aquaponic/Biofloc system. Values in grams.

Culture days	Diet 1	Diet 2	Diet 3	Diet 4
0	8.93 ±0.63	9.32 ±0.83	9.87 ±0.23	5.51 ±0.29
7	13.47 ±0.68	21.72 ±0.85	22.53 ±0.22	21.91 ±0.15
14	19.13 ±0.67	34.11 ±0.82	35.19 ±0.19	38.32 ±0.35
21	25.88 ±0.60	46.51 ±0.87	47.85 ±0.20	54.72 ±0.37
28	33.75 ±0.67	58.90 ±0.79	60.51 ±0.17	71.13 ±0.37
35	42.72 ±0.54	71.30 ±0.82	73.16 ±0.18	87.53 ±0.18
42	52.80 ±0.51	83.70 ±0.89	85.82 ±0.19	103.94 ±0.32
49	63.99 ±0.60	96.09 ±0.88	98.48 ±0.20	120.34 ±0.30
56	76.28 ±0.68	108.49 ±0.86	111.14 ±0.20	136.75 ±0.34
63	89.69 ±0.54	120.89 ±0.90	123.80 ±0.19	153.15 ±0.34
70	104.19 ±0.54	133.28 ±0.89	136.46 ±0.22	169.56 ±0.28
77	119.81 ±0.46	145.68 ±0.89	149.12 ±0.18	185.96 ±0.26
84	136.53 ±0.45	158.07 ±0.86	161.78 ±0.20	202.37 ±0.28
91	154.36 ±0.57	170.47 ±0.83	174.44 ±0.17	218.77 ±0.18
98	173.30 ±0.60	182.87 ±0.88	187.10 ±0.22	235.18 ±0.30
105	193.35 ±0.47	195.26 ±0.86	199.76 ±0.20	251.58 ±0.38
112	214.50 ±0.51	207.66 ±0.83	212.42 ±0.18	267.99 ±0.27
119	236.76 ±0.55	220.06 ±0.87	225.08 ±0.17	284.39 ±0.35
126	260.12 ±0.61	232.45 ±0.87	237.74 ±0.21	300.80 ±0.30
133	284.60 ±0.53	244.85 ±0.87	250.40 ±0.16	317.20 ±0.38
140	310.18 ±0.65	257.24 ±0.80	263.06 ±0.22	333.61 ±0.23

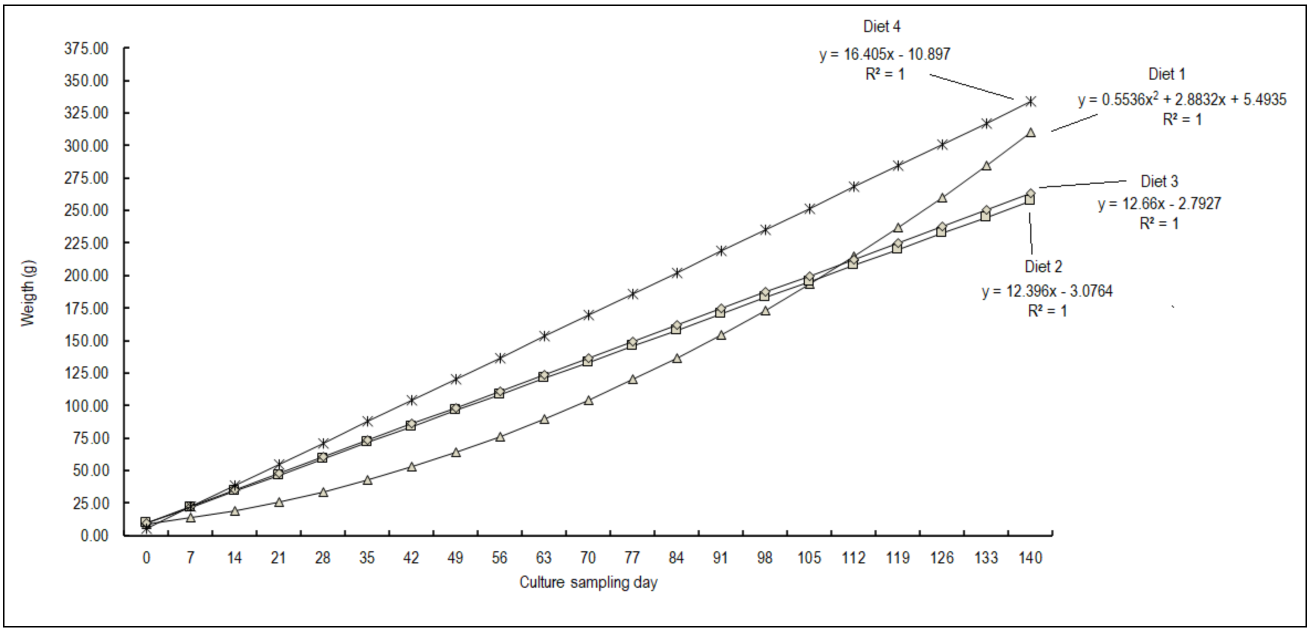

Fig 5: Tendency curves of weight growth of organisms cultured in the experimental treatments in aquaponic/Biofloc system.

In Table 8 were shown the gain, AGR, and IGR values of weight organisms. The highest values were found at Diet 4 with 328.10 g, 2.34 g day^{-1}, 2.93% g day^{-1} respectively. The lowest values were found at Diet 2 with 247.92 g for gain, and 1.77 g day $^{-1}$ for AGR, but for IGR value it was found in Diet 3 treatment with 2.35% g day $^{-1}$.

Table 8: Gain, AGR, and IGR (%) values of fishes' weight cultured in the experimental treatments

Experimental treatment	Gain (g)	Absolute Growth Rate (AGR) (g day^{-1})	Instantaneous Growth Rate (IGR) (% g day^{-1})
Diet 1	301.25	2.15	2.53
Diet 2	247.92	1.77	2.37
Diet 3	253.19	1.81	2.35
Diet 4	328.10	2.34	2.93

3.4 Tomato plant
3.4.1 Total length of stem
Total length of tomato stem plants and tendency curves are shown in Table 9 and Fig. 6. Highest length stem was found in Diet 3 treatment with 271.56 ±0.48 cm and the lowest value were in Diet 2 treatment with 192.03 ±0.26 cm.
ANOVA and Tukey analysis showed significant differences (p< 0.05) between all treatments in this biometric variable.

Table 9: Mean values (±S.D.) of organisms' weight cultured in the two experimental treatments in aquaponic/Biofloc system. Values in centimeters.

Culture days	Diet 1	Diet 2	Diet 3	Diet 4
0	4.63 ±0.39	3.73 ±0.41	4.16 ±0.38	4.02 ±0.56
7	14.57 ±0.35	13.15 ±0.45	17.53 ±0.24	16.44 ±0.42
14	24.51 ±0.48	22.56 ±0.27	30.90 ±0.43	28.87 ±0.52
21	34.45 ±0.33	31.98 ±0.33	44.27 ±0.38	41.29 ±0.48
28	44.39 ±0.27	41.39 ±0.32	57.64 ±0.37	53.72 ±0.52
35	54.33 ±0.41	50.81 ±0.48	71.01 ±0.20	66.14 ±0.38
42	64.27 ±0.43	60.22 ±0.35	84.38 ±0.24	78.57 ±0.22
49	74.21 ±0.19	69.64 ±0.53	97.75 ±0.41	90.99 ±0.25
56	84.15 ±0.54	79.05 ±0.55	111.12 ±0.52	103.42 ±0.45
63	94.09 ±0.40	88.47 ±0.37	124.49 ±0.42	115.84 ±0.43
70	104.03 ±0.48	97.88 ±0.33	137.86 ±0.38	128.27 ±0.32
77	113.97 ±0.35	107.30 ±0.26	151.23 ±0.28	140.69 ±0.43
84	123.91 ±0.33	116.71 ±0.45	164.60 ±0.24	153.12 ±0.40
91	133.85 ±0.45	126.13 ±0.51	177.97 ±0.28	165.54 ±0.41
98	143.79 ±0.35	135.54 ±0.40	191.34 ±0.35	177.97 ±0.19
105	153.73 ±0.50	144.96 ±0.40	204.71 ±0.33	190.39 ±0.26
112	163.67 ±0.35	154.37 ±0.51	218.08 ±0.36	202.82 ±0.22
119	173.61 ±0.54	163.79 ±0.25	231.45 ±0.51	215.24 ±0.22
126	183.55 ±0.28	173.20 ±0.41	244.82 ±0.29	227.67 ±0.30
133	193.49 ±0.54	182.62 ±0.37	258.19 ±0.51	240.09 ±0.42
140	203.43 ±0.44	192.03 ±0.26	271.56 ±0.48	252.52 ±0.56

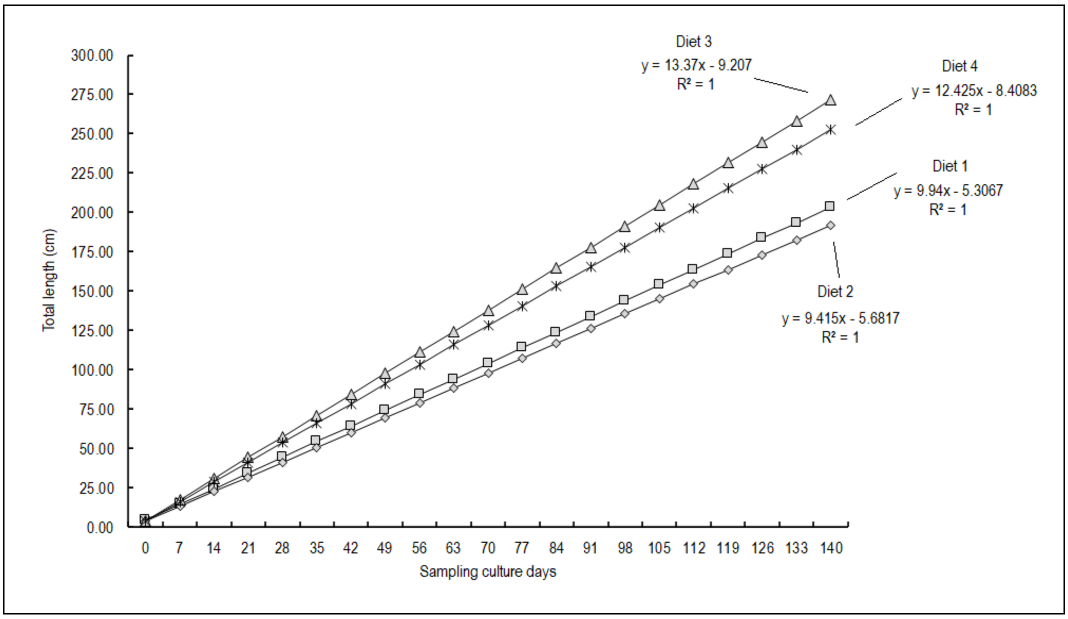

Fig 6: Tendency curves of total length of tomato stem in the experimental treatments in aquaponic/Biofloc system.

In Table 10 it is shown the gain, AGR, and IGR values of tomato stem. The highest values were found in Diet 3 with 267.40 cm, 1.91 cm day^{-1} cm, 2.98% day^{-1} respectively. The lowest values were found in Diet 2 with 188.30 cm, 1.35 cm day^{-1} for gain and AGR values, and for IGR value was Diet 1 with 2.70% cm day^{-1}.

Table 10: Gain, AGR, and IGR (%) values of total length tomato stem at the experimental treatments.

Experimental treatment	Gain (cm)	Absolute Growth Rate (AGR) (cm day^{-1})	Instantaneous Growth Rate (IGR) (% day^{-1})
Diet 1	198.80	1.42	2.70
Diet 2	188.30	1.35	2.81
Diet 3	267.40	1.91	2.98
Diet 4	248.50	1.78	2.96

4. Discussion

4.1 Water quality

pH culture medium values were maintained between 7-8. Similar results were reported by Long *et al*. (2015) [14], which evaluated the Biofloc technology effect in *O. nilotiucus* obtaining positive data with respect to fish growth, digestive enzymatic activity, and immunology respond. Likewise, authors like El-Sherif *et al*. (2009) [15], mentioned that pH values between 7-8 are optimal for Tilapia culture, because organisms shown better growth and survival. In other way, Tyson *et al*. (2008a) [16] mentioned that pH in aquaponic systems need to be maintained between 7.5 and 8.

Regarding to nitrogen compounds, nitrates values obtained higher concentration values. However, this compound is the final product of nitrification and is not relatively toxic to tilapias (Tyson *et al*., 2007; El Sayed, 2006) [17,18]. Authors like Souri *et al*. (2009) [19], founded a positive correlation between nitrate concentration in plant culture medium and the transpiration and water consume of plants, proving that nitrates are the most adequate nitrogen source for tomato plants.

Regarding to ammonia and nitrites, the results of this study were higher than others like Tyson *et al*. (2008b) [20] which obtained mean values between 0 to 2.1 mg L^{-1} in an aquaponic system with *O. niloticus* with *Cucumber sativa*. Authors like Rodriguez-González *et al*. (2015) [21], obtained ammonia values between 0.93 and 3.5 mg L^{-1} in a culture medium with *O. niloticus* with *Lactuca sativa*. But also, Long *et al*. (2015) [14], reported high levels of ammonia with 1.8 mgL^{-1} and nitrites with 1.62 mgL^{-1} in a Biofloc system with *O. niloticus.* High levels of ammonia and nitrites in aquaponic systems can be caused by an overfeed to fishes, or a high-density level, and/or being an indicator of low plant density in the aquaponic system (Sallenave, 2016) [22]. Also, Avnimelech *et al*. (1986) [3], mentioned that development of a bacterial community which transform nitrogen compounds in the Biofloc system, have low growth and can take from 2 to 3 weeks long. This causes a nitrites accumulation period when the first step of ammonia to nitrates oxidation begins and the step nitrites to nitrates is evolving. This can explain the high levels of these nitrogen compounds obtained in this study, which reach mortality levels in culture medium (Benli *et al*., 2008; Daud *et al.*, 1988; Atwood *et al.*, 2001) [23, 24, 25], causing the low survival in tilapia culture (El-Sayed, 2006) [18].

4.2 Tilapia

Biometrical values of fishes (total length, height, width, and weight) were significant higher in the treatment with Tilapia pellet and Plants without fertilizer, meanwhile low values were found with Diet 2. These results were like those obtained by Escobar *et al*. (2006) [26], where the use of diets with high content of protein caused low weight gain in tilapia fry. This study can probe the same effect with Diet 1 and Diet 2 because their protein content is higher and Torres *et al*. (2012) [27], mentioned that optimal protein level for Tilapia culture must be between 26.8 to 41.3% of protein, depending the life stage cycle. Likewise, Green *et al*. (2019) [28], found out in a Biofloc system which cultured hybrid tilapia (*O. aureus x O. niloticus*), that the protein diet content can be reduced to 27.7% without affecting productivity due to the use of microbial flocks as diet.

The final tilapia weight was similar to the reported by Rodríguez-González *et al*. (2015) [22], which obtained a mean weight value of 364.64 g after 160 culture aquaponic days, while the highest value in this study was 333.61±0.23 g in 140 culture days. The IGR values were higher to those reported in traditional culture systems with *O. niloticus* (El-Sayed *et al*. 1996, Brown *et al*. 2002, Bahnasawy *et al*. 2003) [29, 30, 31]. However, were similar values with respect to other studies made with Biofloc technology (Zhang *et al.* 2016; Luo *et al.* 2014) [32, 33]. Avnimelech (2007) [34], Azim and Little (2008) [5] and Long *et al.,* (2015) [14], mentioned that Biofloc technology contributed significantly to fish's growth, because it allow that organisms have an *in situ* natural food source (Monroy *et al.* 2013) [2].

4.3 Tomato stem

The total tomato stem length values were higher to those reported by Ortega-López *et al.,* (2015) [35] made in aquaponic system too, which obtained total length stem of *S. lycopersicum* nearby 50 cm after 85 days after transplant; also, with those values obtained by Salam, *et al.* (2014) [36], which founded maximal length of stem of 85.58±1.53 cm after 116 culture days with tilapia. However, study values were similar with those reported by Márquez *et al* (2006) [37], in a *Lycopersicon esculentum* var. *cerasiforme* culture, which obtained a mean length of 288 cm. All these authors mentioned that for an optimal yield with this tomato plant it is need a high content of nutrients in the compost.

The higher mean value of stem length was presented in Diet 3, meanwhile the lowest value was in Diet 2. Best results were found in plants with fertilizer in both diets. These significant differences can be due to the use of nutrient solution (fertilizer) in both treatments and the different nutrient composition of fish diet, as mentioned by Maucieri *et al.* (2019) [38]. In aquaponic system, nitrates levels are good enough to allow good growth in plants, but the addition of other mineral elements in fertilizer liquid must be considered for maximum plant development (Nicoletto *et al.* 2018; Nozzi *et al.* 2018) [39, 40]. Other authors like Robaina *et al.* (2019) [41], mentioned that supplied food to fish must cover the nutrient needs for fish and plants, because the fish waste and not consumed food increase the accumulation nutrient in this system type.

5. Conclusion

Results shown a favorable growth in length and weight of tilapia in the aquaponic/Biofloc system and a good stem length growth in a small scale aquaponic system production. Pointing out that the use of external plant fertilizer presented better results. It is necessary to maintain constant monitoring of physical and chemical parameters, specifically nitrogen compounds, to maintain an equilibrium in this aquaponic/Biofloc system to maintain organism's well-being.

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