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Comparison of growth (length and weight) gain, TCA, TIC, KM, and feed efficiency of Pargo tilapia, UNAM cultured in Biofloc at 10 gL^{-1} salinity at different densities

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Abstract
Tilapia Pargo UNAM fry was cultured in five 250 L containers at a salinity of 10 gL^{-1} and a density of 50, 75, 100, and 125, and their weight and length gain, TCA and TIC, KM and FCA, and ECA were determined. The highest weight (658.45±0.43 g) and length (38.22±0.38 cm), with a gain of 657.28 g and 35.09 cm at the 50 org $250L^{-1}$ density. However, the greatest gain in length was for the 50 and 75 org $250L^{-1}$ densities (35.09 and 34.53 cm, respectively). The highest TCA was for the 50 org 250 L^{-1} treatment with 6.26 g day^{-1} and the highest TIC value was 0.33% daily increment for both the 50 and 75 org 250 L^{-1} densities. The FCA was between 0.0873-0.1052 and the ECA was between 950.20-1,146.04%. It should be noted that survival in all four treatments was above 96%. In this experiment, it was observed that when passing from the density of 75 org 250 L^{-1} problems in growth and weight and size gain began to occur.

Keywords: Pargo UNAM, density, salinity, growth, Biofloc

1. Introduction
Since the year 2000, aquaculture has shown an annual increase of 6.7% worldwide in the production of the different aquaculture products it produces. Among all the organisms produced in this aquaculture sector is Tilapia and within this group, red tilapia, which is commonly known as "red mojarra" [1]. The main producers are Asian countries with 80% of total world production [2].
Tilapia is considered one of the fish groups that are used both in commercial farming, as well as in subsistence programs by the governments that carry it out since it can easily adapt to different farming systems ranging from freshwater, brackish, and even seawater [3, 4, 1]. Tilapia have characteristics such as high physical resistance, rapid growth, disease resistance, high productivity, culture at high densities, withstand shallow values of dissolved oxygen in the culture medium, and with the capacity to feed with natural and artificial food [5]. Currently, the species that have been most used in aquaculture due to their high productivity and higher egg production are *Oreochromis aureus*, *O. niloticus*, and *O. mossambicus* [6, 4, 1].
Authors such as Castillo [7], *O. mossambicus* (red variety) mention that this variety was created in Taiwan in 1968 from a hybrid of *O. mossambicus* with *O. nilotica*. Thus, four coloration patterns have been established: pink, pink mottled with red, red and black spotted [8]. These varieties are considered to be related species because they maintain a high percentage of muscle mass, absence of intramuscular spines, rapid growth, adaptability to the environment, resistance to diseases, excellent meat texture and coloration that is well accepted in the market [9]. However, in 2003, researchers from the Centro de Enseñanza, Investigación y Extensión en Ganadería Tropical (CEIEGT) belonging to the Faculty of Veterinary Medicine and Zootechnics of UNAM, Mpo. Martínez de la Torre, in Veracruz, Mexico, developed a red tilapia that has a growth like wild-type Nile tilapia and can reach a weight 40 to 60% higher than another red tilapia [10] and was named Pargo UNAM.

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This tilapia is considered a synthetic hybrid and has the characteristic that it is sufficient to cross with each other to obtain subsequent generations in each fattening cycle, without the need for crosses between its ancestors [11, 12]. It is omnivorous, so it feeds on some insects, vegetables, and algae, but also accepts inert food. It also presents the same physical and chemical characteristics of the culture concerning the other tilapia species (20 to 30 °C, oxygen levels above 3 mg/L, and pH between 7 and 8) [4].

Unfortunately, the impact of their cultivation on the environment is the same, so it is necessary to develop an alternative culture system with less environmental impact due to water use and contamination, as well as lower fish feeding costs. For this purpose, the Biofloc technique was used [13, 14] in which an external carbon source is added to produce heterotrophic bacterial biomass, which produces beneficial substances for the organisms and helps in the elimination of nitrogenous compounds, especially ammonium, transforming it into usable compounds (nitrites and nitrates). As a consequence, fish survival would be high, as well as growth and weight gain [13, 14].

Therefore, a preliminary study was conducted on the culture of the Tetra-hybrid Pargo-UNAM (Red Tilapia) in a Biofloc system, whose carbohydrate source is moringa, using different culture densities and a salinity of 10 g L^{-1}.

2. Material and methods

2.1 Experimental design

The experiment was carried out in the facilities of the Alimento Vivo laboratory at the Universidad Autónoma Metropolitana Unidad Xochimilco. Five vats with a capacity of 250 liters were used, measuring 0.80 m high and 0.70 m long (Figure 1), filled with 200 liters of water each, with a salinity of 10 gL^{-1}, water temperature of 28.8-29.5 °C, 4.3 to 6.5 mL O2 L^{-1} and a pH between 6.2-8.8. The experimental treatments were at four different densities: a) 50 org 250 L-1, b) 75 org 250 L-1; c) 100 org 250 L^{-1} and d) 125 org 250 L^{-1}. For Biofloc production, moringa (0.01% of the total fish biomass) was used as a carbon source. It was added only once a day (9:00 hrs) and the inert tilapia feed was added at 10% of the total biomass of the fish, divided into two portions (9:00 hrs and 16:00 hrs) per day.

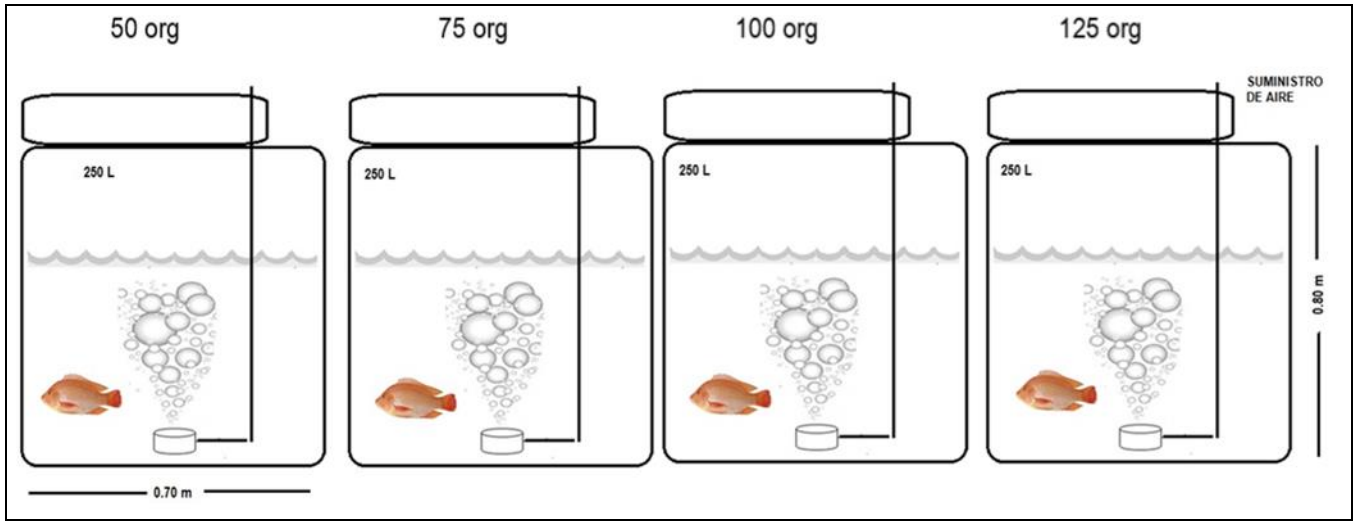

Fig 1: Culture vessels and density of organisms.

2.2 Feed supply

The inert feed used was 2.6 mm in diameter, with 36% protein, 4% fat, 5% fiber, and 12% humidity. At the beginning and every 15 days, the organisms were weighed to obtain 10% of their biomass to supply the feed. The total weight of the feed was rationed in two portions per day (9:00 hrs and 16:00 hrs).

2.3 Biometry of the organisms

The fish obtained from a farm in the State of Morelos, Mexico were measured and weighed before being introduced to each of the ponds and subsequently every 15 days. These biometrics were performed with the aid of a digital Vernier (0.001 mm precision) and an Ohaus analytical balance (0.001 g precision).

2.4 Data processing

All values obtained were entered into a database in Excel 2019 to obtain the descriptive analysis. Growth trend curves were also obtained for each biometric variable. In addition, the following were obtained.

Length and weight gain.

Length = Final Length-Initial Length.

Weight = Final Weight-Initial Weight

Absolute Growth Rate (AGR)

$$AGR = \frac{\text{Final length or weight} - \text{Initial length or weight}}{\text{Number of days of experimentation}}$$

Instantaneous Growth Rate (IGR)

$$IGR = \frac{\text{LogN(Final length or weigth)} - \text{Log N(Initial length o weigth)}}{\text{Number of day of the experiment}}$$

Degree of well-being (KM)

KM=Weight * Correlation coefficient (Weight: Length) * Length

Feed conversion factor (FCF)

$$FCF = \frac{\text{Total amount of feed supplied}}{\text{Amount of final biomass obtained}}$$

Feed Conversion Efficiency (FCE)

$$FCE = \frac{1}{FCF} * 100$$

2.5 Statistical analysis of data

A single-factor analysis of variance was applied to the data obtained to find significant differences (p<0.05) between treatments. When differences were found, a multiple mean comparison test was applied using Tukey's technique to determine between which treatments there were significant differences (p<0.05).

3. Results

The average values of the length and weight of the organisms cultured with Biofloc are presented in Table 1.

As can be seen, the organisms that obtained the highest weight were those cultured in the 50 org 250 L^{-1} treatment with 658.45±0.43 g, as well as a maximum length of 38.22±0.38 cm. The lowest value was presented by the treatment with 150 org 250 L^{-1}, with a weight reached 264.86±0.41 g. All treatments showed significant differences (p<0.05) among them. Regarding the total length reached, treatments 50 and 75 org 250 L^{-1}, presented the highest value (38.22±0.38 cm and 38.08±0.38 cm respectively), not finding significant differences between them (p>0.05). The lowest value was found for the 125 org 250 L^{-1} treatment with 27.88±0.35 cm. This value and that of the 100 org 250 L^{-1} treatment were significantly different (p<0.05) from each other and from the 50 and 75 org 250 L^{-1} treatments.

Table 1: Mean values (±D.S.) of weight and length of cultured organisms in the four experimental treatments

Sample days	Experimental treatments							
	50 org 250 L^{-1}		75 org 250 L^{-1}		100 org 250 L^{-1}		125 org 250 L^{-1}	
	Weight	Length	Weigth	Length	Weight	Length	Weigth	Length
0	1.17±0.50	3.12±0.38	1.17±0.50	3.53±0.38	1.17±0.50	5.43±0.31	1.17±0.50	3.96±0.28
7	1.84±0.62	9.13±0.27	1.82±0.55	9.21±0.19	1.78±0.42	8.06±0.39	1.72±0.41	6.00±0.31
14	2.89±0.16	9.48±0.24	2.83±0.40	11.73±0.25	2.71±0.61	12.04±0.12	2.54±0.36	6.23±0.38
21	4.55±0.39	12.84±0.23	4.39±0.59	13.19±0.25	4.13±0.23	14.25±0.12	3.74±0.45	7.52±0.29
28	7.14±0.18	14.34±0.38	6.82±0.60	17.49±0.20	6.28±0.31	18.10±0.20	5.51±0.29	9.00±0.24
35	11.23±0.43	16.93±0.19	10.60±0.40	18.39±0.39	9.56±0.60	18.71±0.33	8.11±0.62	13.68±0.36
42	17.66±0.24	17.49±0.37	16.48±0.57	19.26±0.13	14.54±0.49	19.84±0.24	11.95±0.37	15.51±0.27
49	27.76±0.21	18.07±0.21	25.61±0.26	21.18±0.13	22.14±0.52	20.46±0.33	17.60±0.30	17.59±0.29
56	43.63±0.33	18.58±0.23	39.79±0.31	22.11±0.26	33.69±0.27	20.46±0.35	25.93±0.37	20.26±0.18
63	68.59±0.26	28.03±0.30	61.84±0.59	27.22±0.37	51.28±0.16	21.56±0.21	38.20±0.44	23.58±0.20
70	107.82±0.52	30.27±0.29	96.09±0.47	30.25±0.23	78.04±0.29	22.89±0.34	56.26±0.32	23.75±0.32
77	169.50±0.47	30.66±0.31	149.33±0.36	31.24±0.15	118.78±0.21	25.48±0.31	82.87±0.33	24.42±0.23
84	266.45±0.55	33.08±0.37	232.06±0.54	33.92±0.14	180.78±0.28	25.90±0.20	122.07±0.48	25.88±0.12
91	418.86±0.28	37.25±0.33	360.62±0.41	35.56±0.30	275.15±0.47	28.07±0.35	179.81±0.25	26.78±0.26
98	658.45±0.43	38.22±0.38	560.40±0.56	38.08±0.38	418.78±0.34	32.94±0.20	264.86±0.41	27.88±0.35

Figure 2 shows the growth curves of the organisms in culture with Biofloc

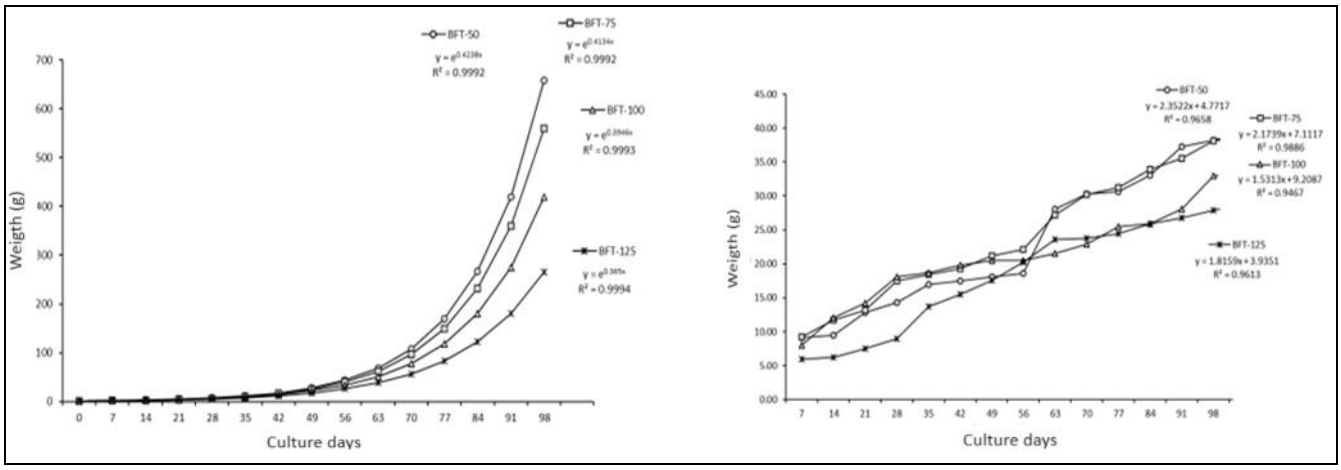

Fig 2: Weight and length growth curves of the organisms in the experimental treatments.

Figure 3 shows the values of length and weight gain

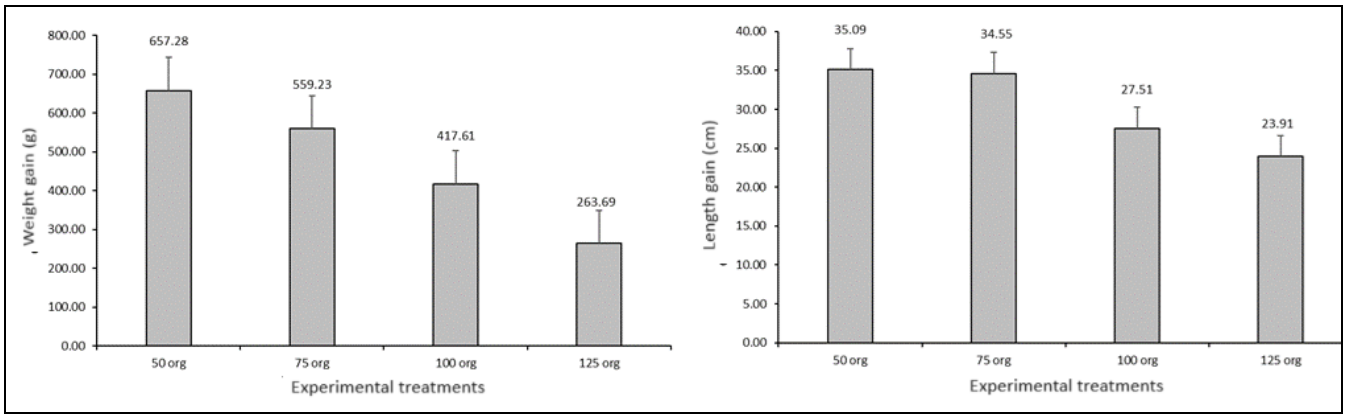

Fig 3: Length and weight gain of the organisms in culture in the experimental treatments.

The highest weight gain of the organisms was observed in the 50 org 250 L^{-1} treatment with 657.28 g, and the lowest value was for the 125 org 250 L^{-1} treatment with 263.69 g. Significant differences (p<0.05) were found among all treatments. Regarding the gain in length, the highest value was for treatments 50 and 75 org 250 L^{-1} with 35.09 34.55 cm respectively. The lowest value was for the 125 org 250 L^{-1} treatment with 23.91 cm. Treatments 50 and 75 org 250 L^{-1} did not show significant differences between them (p>0.05) but did show significant differences concerning the other two treatments (p<0.05). Between treatment 100 and 125 org 250 L^{-1} there are significant differences (p<0.05) in length gain.

The values of Absolute Growth Rate (AGR) and Instantaneous Growth Rate (IGR) are presented in Figure 4.

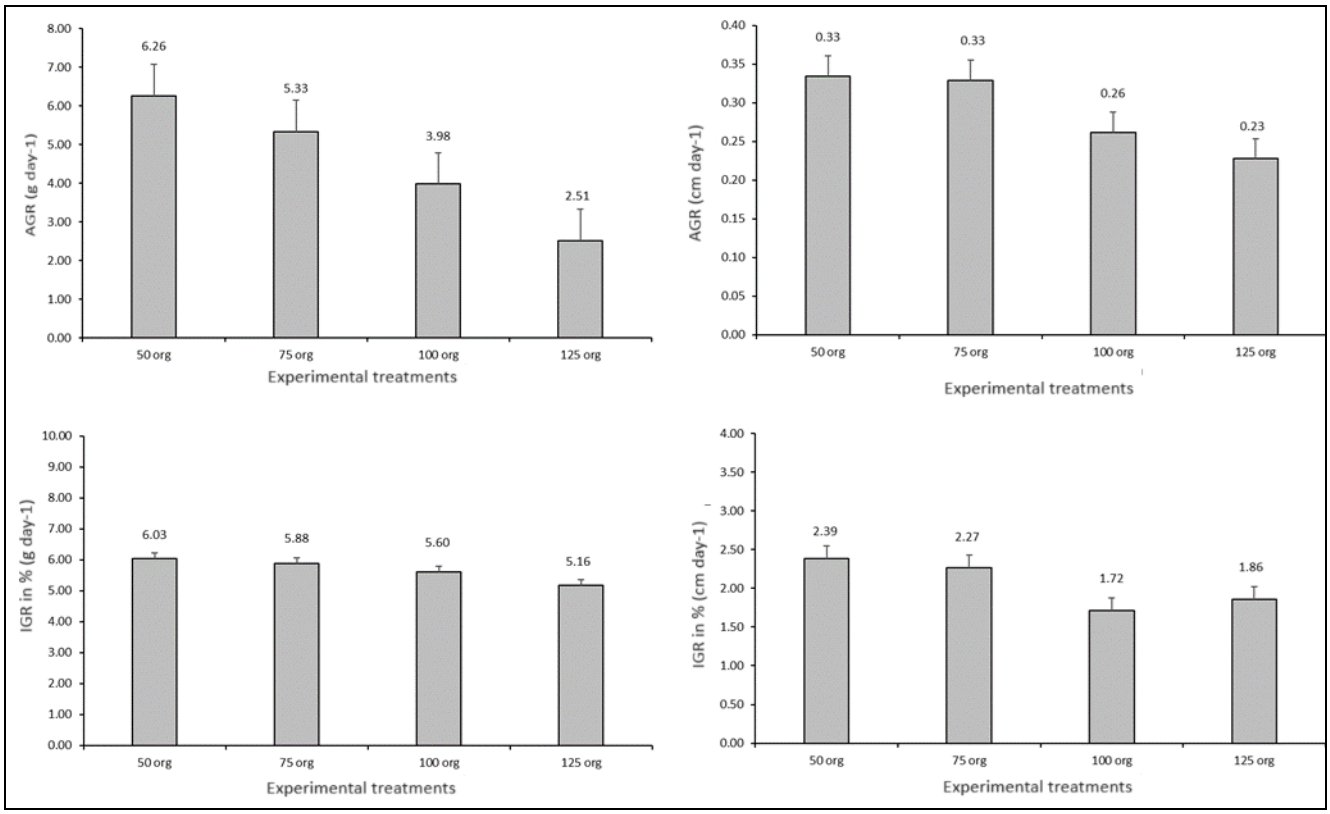

Fig 4: Absolute Growth Rate (AGR) and Instantaneous Growth Rate (IGR) values of fish weight and length in the different treatments

The highest AGR values were found in the 50 org 250 L^{-1} treatment in both weight and length. However, in length, the same daily increase was also reached in the treatment with 75 org 250 L^{-1}. For weight, the AGR of 50 org 250 L^{-1} presented significant differences (p<0.05) with the other treatments. For length, the AGR of the 50 and 75 org 250 L^{-1} treatments did not show significant differences (p>0.05). The lowest AGR, both for weight and length, was obtained in the 125 org 250 L^{-1} treatment, being significantly different (p<0.05 from the other three treatments. The IGR shows the same behavior for the weight variable, but not for length, where the lowest value of increase was shown in the 200 org 250 L^{-1} treatment with 1.72%. This value is significantly different (p<0.05) concerning the other treatments.

Figure 5 shows the curves of the degree of well-being (KM) of the organisms, where it is observed that the culture conditions in all treatments allowed the organisms in the culture to maintain their weight-length ratio adequately. All the organisms in the treatments had weight and size gain adequate to the culture density.

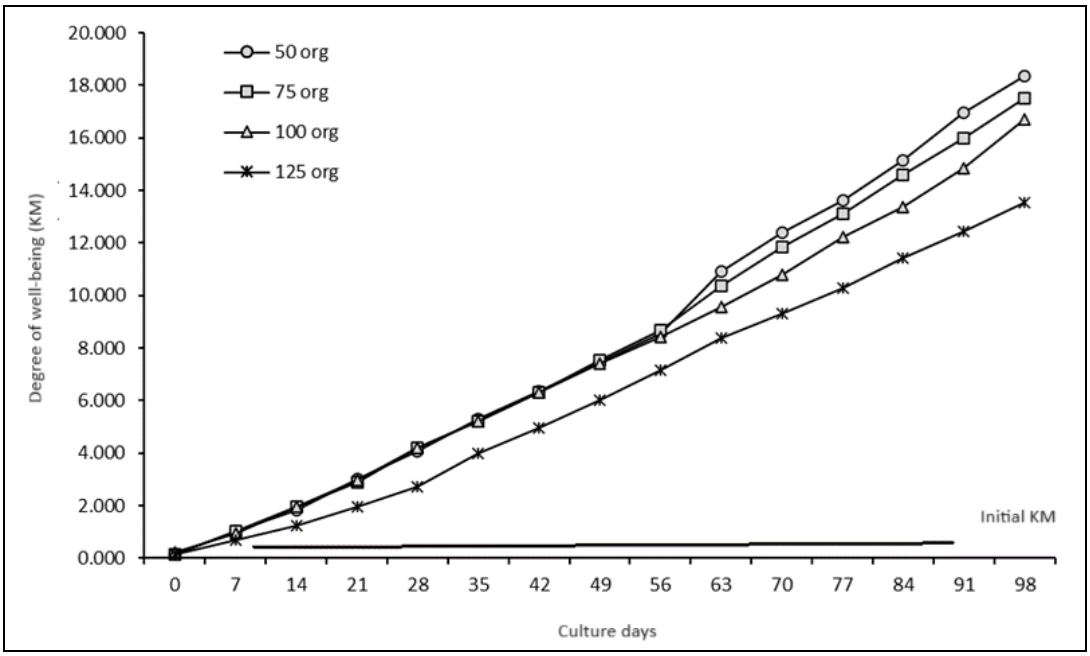

Fig 5: Degree of well-being of organisms cultured with Biofloc and low salinity under the experimental treatments

Figure 6 shows the Feed Conversion Factor (FCR) and Feed Conversion Efficiency (FCE) values.

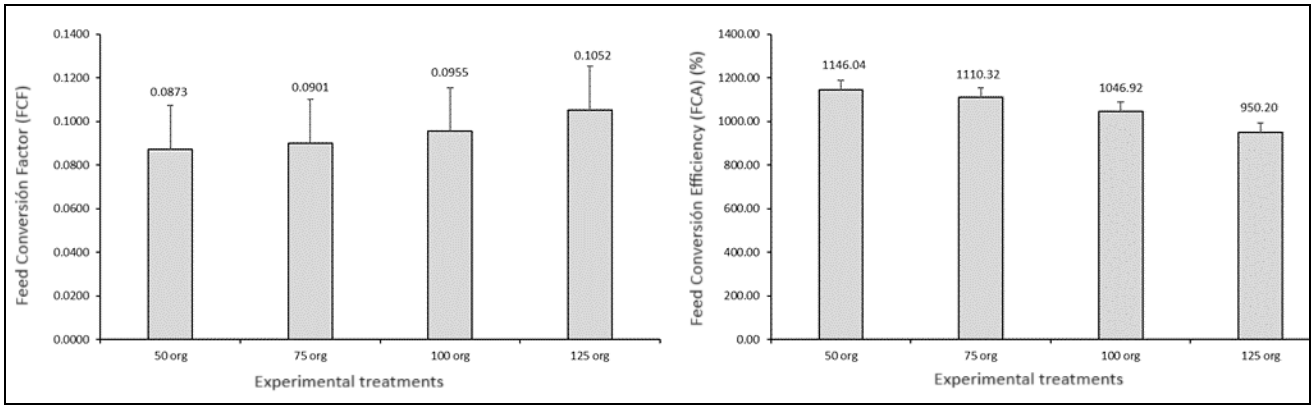

Fig 6: Feed Conversion Factor (FCF) and Feed Conversion Efficiency (FCE) values.

As can be seen, the 50 org 250 L^{-1} treatment was the one that presented the best FCF and FCE (0.0873 and 1,146.04% respectively), while the lowest value was for the 125 org 250 L^{-1} treatment with 0.1052 and 950.20%.

4. Discussion

In any fish culture system, it is important to consider the factor density per unit volume of the system that allows us to obtain the maximum benefit and minimize the problem of water quality, which the production of heterotrophic bacteria can control by cultivating them in a Biofloc system, which allows the formation of bacteria that decompose nitrogenous compounds and therefore the reduction of constant water replacement in these systems, having considerable energy savings by not using pumps for water extraction and incorporation during the longer time that the culture lasts [13, 14]. This can be observed in this experiment, since in the four treatments a survival above 96% was presented.

On the other hand, it is important to note that the increase in salinity in Tilapia cultures up to 10 gL^{-1} causes an increase in energy expenditure that must be diverted for osmotic regulation in freshwater fish such as Tilapia [15], and therefore all fish farmers must consider this expense in the quality of feed supplied to cover this energy need. These same authors point out that the energy expenditure due to the increase in culture salinity of a freshwater fish is 20 to 50% because it must have a better osmoregulation capacity and the energy expenditure is diverted to cover this need and it is not energy that is channeled for weight and size gain in tilapia [15]. Therefore, it is necessary to incorporate foods rich not only in nutrients but also in energy so that growth is not diminished, as well as the increase of a higher feed conversion factor by the fish. For this, the incorporation of lipids in the diet is important, since their low or null incorporation increases stress in the organisms, causing changes in their homeostasis and consequently a modification of all physiological responses in the animal. Some studies indicate that the incorporation of lipid-rich microalgae could provide this necessary nutrient to complement the diet of this species [16-18].

Works such as that of Al-Zahrani *et al.*., [19] who carried out 56-day cultures in 500 L tanks, filled with 400 L of water and worked with densities of 3, 6, and 9 Kg m^3 obtained a survival of 92.40% in the lowest density, a higher weight gain of 26.11±1.55 g, an IGR of 1.79% and an FCF of 1.46, values below those found in the four treatments of this experiment.

Although these authors [19] mention that increasing the density modifies the size of the fish, the health of both the fish and the system increases the use of water and the replacement to maintain a good quality, the sedimentation of organic matter increases and consequently increases mortality and decreases the efficiency of growth and productivity of the system. The same is demonstrated in the work done by Mohamed *et al*.., [20], Robiul *et al*.., [21], and Sapkota *et al*..,[22], where all productive and survival values decrease with increasing planting density. In the case of this experiment with Biofloc, all of the above is not reflected in a great way neither in the growth efficiency of the organisms nor in the productivity of the system because the system used produces a continuously present food biomass on which the fish can feed, in addition to the formation of a heterotrophic bacterial biomass capable of decomposing nitrogenous compounds that can be detrimental to both the water quality of the system and the physiology of the fish.

Authors such as Do Valle *et al*.. [23] who conducted work with tilapia larvae during the masculinization process at different salinities (0, 2, 4, 6, 8, 10 and 12 g L^{-1}) in a Biofloc system observed that the best results occurred when these were cultured at 10 g L^{-1} salinity, since at this salt concentration better survival was observed when nitrate peaks increase chloride ions not only protect but also compete with these nitrate ions in the gills. Authors such as Alvarenga *et al*.. [24], mention that the adequate salinity for the early stages of fish should be 6 g L^{-1}, while for the following stages (juvenile and adult) salinities of 5 to 15 g L^{-1} can be maintained.

Nur *et al*.., [25] mention that increasing the planting density in tilapia cultures causes greater stress in the population and consequently low food consumption, increases competition for space, and decreases fish mobility. These authors worked with densities of 4, 6, and 8 org in 10 L containers. They found the best survival (91.67%) at densities of 4 org 10 L^{-1}, a value below that found in this experiment, which was above 96% in the four treatments, regardless of the density managed. For the experiment of Nur *et al*.., [25], they did not work with Biofloc, but with spinach water to reduce the ammonium concentration, unlike this experiment in which they placed a Biofloc system with moringa flour as a carbon source, which allowed the formation of heterotrophic bacteria, which were responsible for decomposing the nitrogenous compounds in the system.

5. Conclusion

It can be concluded that it will always be better to work at densities of 50 org in 250 L and at a salinity of 10 g L^{-1}, to obtain good growth in weight and length, AGR, IGR, FCF, and FCE, as long as Biofloc technology is used in the system to improve the use and quality of the water using heterotrophic bacteria that decompose organic matter and nitrogen compounds, as well as the contribution of biomass using the flocs that form in the system and from which the organisms can be constantly feeding.

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