E-ISSN: 2347-5129
P-ISSN: 2394-0506
(ICV-Poland) Impact Value: 76.37
(GIF) Impact Factor: 0.549
IJFAS 2023; 11(6): 43-49

www.fisheriesjournal.com
Received: 16-09-2023
Accepted: 18-10-2023

Author's details are given below the reference section

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Length and weight gain, AGR and IGR, KM and feed efficiency of *Astronotus ocellatus*, *Melanochromis* sp, *Cyprinus carpio* and *Oreochromis niloticus* cultured in biofloc

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DOI: https://doi.org/10.22271/fish.2023.v11.i6a.2877

Abstract
The growth and feeding efficiency of *Astronotus ocellatus* (Cichlidae) *Melanochromis* sp *Cyprinus carpio* (Cyprinidae), *Astronotus ocellatus* (Cichlidae) and *Oreochromis niloticus* (Cichlidae) fed with protein levels ranging from 25-40% in a Biofloc culture, whose carbohydrate source was moringa powder (0.01%), was evaluated for 180 days. The feeding frequency was twice a day (10% of the biomass, divided into two portions). All the fish in the study showed weight and length gain and this is observed with the KM value shown. *Melanochromis* sp. showed the lowest values of AGR in length and weight gain (0.033 cm and 0.865 g day^{-1}). The IGR value showed a positive increase with 1.081-1.876% per day for length and 2.756-3.259% per day for weight. The FCF values showed values between 0.346-0.394, while for FCE values showed an increase of 253.60-289.08%. This experiment carried out on these species allows the production of ornamental species to be cultivated in the Biofloc system, considering that it is important to carry out tolerance studies on the concentration of organic matter in the cultivation of other ornamental species that are cultivated commercially.

Keywords: Biofloc, feed conversion, biomass, length and weight gain, efficiency

1. Introduction

Aquaculture consists of the production of any living being in the aquatic environment and emerges as a primary productive sector parallel to agriculture and livestock. This sector has been the fastest growing worldwide in the entire economy in the last 10 years, so it could become a strategic area of the primary sector for food production, the fight against hunger, job creation, and boosting the national economy [1].

Mexico is far below the major aquatic food-producing countries, which does not reflect, at all, the great aquaculture potential of the country [2], which, due to its physical and natural characteristics, as well as its geographical position, has all the necessary and sufficient conditions to have a world leadership in this sector [1].

One of the reasons is the lack of a well-defined State policy regarding the promotion of the activity that considers financial, regulatory, and consumption aspects, as well as the lack of technology and scientific research to develop aquaculture as a sustainable activity [1]. In this same sense, the negative environmental impact generated by water discharges from aquaculture has represented a major pollution problem [3]. In the face of these challenges, innovative technological options are emerging that improve the efficiency of crops, in favor of their environmental, economic, and social sustainability. One of these techniques is Biofloc an environmentally friendly alternative that goes with the high production of aquatic organisms [4]. In addition, the Biofloc technique has proven to be an efficient alternative to mitigate environmental impacts by decreasing the use of space and water [4]; because nutrients can be continuously recycled and reused [5], this also has benefits in the culture, as it decreases the risk of introduction of pathogens or diseases, and increases the survival and growth of organisms [6].

Biofloc is defined as a conglomerated aggregation of microbial communities (Flocs) composed of phytoplankton, bacteria, and live and dead particulate organic matter suspended in the pond water [7]. These particles encompass particulate organic matter, on which microalgae, and diverse microscopic organisms (Protozoa, rotifers, fungi) develop, in particular, a great diversity of heterotrophic bacteria [8]. The association of their aerobic microbial communities maintains the carbon and nitrogen balance in the system [9] because they can remove these compounds from the water, in the form of bacterial biomass. In this way, they keep the levels of nitrogen in the water (potentially harmful) low and the chemical parameters that depend on it are kept relatively stable [10]. These microbial populations have been defined as "Bioreactors" [5], which present a second function which is the production of biomass that serves as food for fish and shrimp [9, 11]. This allows for a reduction in the costs of the artificial diet [12] used up to 25% [13, 14].

For all the above, the present research has the goal of measuring the growth and feeding efficiency of four of the most used species in Mexico, one for consumption which is Tilapia, and the other three species of cichlids as ornamentals.

2. Material and Methods

2.1. Experimental design

The experiment was carried out in the Live Food Production Laboratory at the Universidad Autónoma Metropolitana, Unidad Xochimilco. The fish culture was set up in four 250 L capacity Rotoplas® tanks (0.80 x 100 cm) which were filled with 200 L of water and 100 juvenile fish *Melanochromis* sp., *Astronotus* sp. *Cyprinus* sp. and *Oreochromis* sp. separately (Figure 1). Each tank was fitted with an aeration system with a 10 cm diameter porous aeration stone, to move all the food, water, carbon source, and waste throughout the water column.

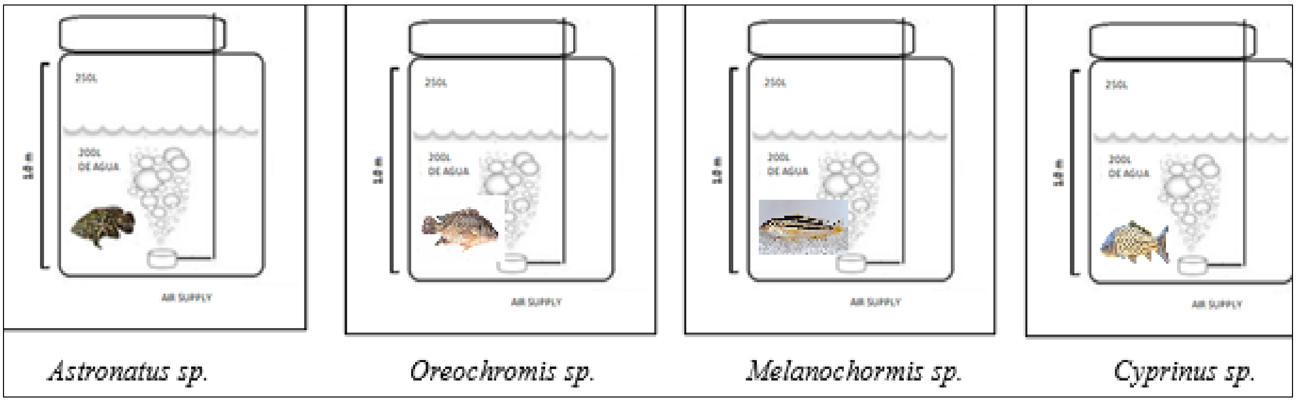


Fig 1: Culture system with the four experimental species.

2.2. Feeding of the organisms

Each species was fed a specific diet in two portions per day (9:00 and 15:00 hrs) at a ratio of 10% of the total biomass of each species in the culture. The diets consisted of a) For *Melanochromis* sp. Wardley flakes with 30% protein b) For *Cyprinus* sp. flakes vegetable-based (25% protein) c) For *Astronotus* sp. agar feed with fish as the main protein source (40-50%) and d) For *Oreochromis* sp. 0.2 mm Tilapia feed (25-30% protein). All containers were supplied with a powdered Moringa-based carbon source (0.01% of the total weight of the organisms), to produce the Biofloc. This carbon source was supplied only once a day at 9:00 am. The experiment had a duration of 180 days.

2.3 Biometry of the Organisms

Every 15 days, 30 fish taken at random from each experimental group were extracted to be weighed with the aid of a Nimbus® digital scale with an accuracy of two decimal places. In addition, total length (TL) biometry was taken with the aid of a digital Vernier® with an accuracy of three decimal places.

2.4 Water quality monitoring

The concentration of nitrites (NO_2^- mgL^{-1}), nitrates (NO_3^- mgL^{-1}), ammonium ($NH4^-$ mgL^{-1}), and phosphates (PO_4^{-3}) was determined every 15 days in the system with a HANNA® multi-parameter meter instrument.

2.5 Data processing

All the values obtained were placed into a database in Excel 2021 to obtain the descriptive analysis. Growth trend curves were also obtained for each biometric variable. In addition, the following parameters were obtained.

Length gain: Length Gain (LG) = Final Length-Initial Length.

Weight gain: Weight Gain (WG) = Final Weight-Initial Weight.

Absolute Growth Rate (AGR)

$$AGR = \frac{\text{Finnal length or weigth} - \text{Innitial length or weigth}}{\text{Experimental days}}$$

Instantaneous Growth Rate (IGR)

$$IGR = \frac{\text{LogN (Finnal length or weigth)} - \text{LogN (Innitial length or weigth)}}{\text{Experimental days}}$$

Well-being factor (KM)

KM=Weight x Correlation coefficient (Weight or Length) x Length

Feed conversion factor (FCF)

$$FCF = \frac{\text{Total ammount of food applied}}{\text{Total ammount of biomass obtained (fish)}}$$

Feed Conversion Efficiency (FCE)

$$FCE = \frac{1}{FCF} x100$$

3. Results

In the four experimental treatments, pH values were maintained at 7.13 to 7.37; ammonium (NH_4) between 0.09 to 0.42 mgL^{-1}; chlorine between 0-0.04 mgL^{-1}; while nitrates (NO_3) at 6.83 mgL^{-1}; nitrites (NO_2) at 3.67 mgL^{-1}; and phosphates (PO_4^-) at 1.68 mgL^{-1}. The survival of the organisms cultured in Biofloc was above 90% in the four experiments.

Table 1 shows the average values of the length and weight of the organisms cultured with Biofloc.

Insert Table 1

Figure 2 shows the growth curves of the organisms cultured with Biofloc.

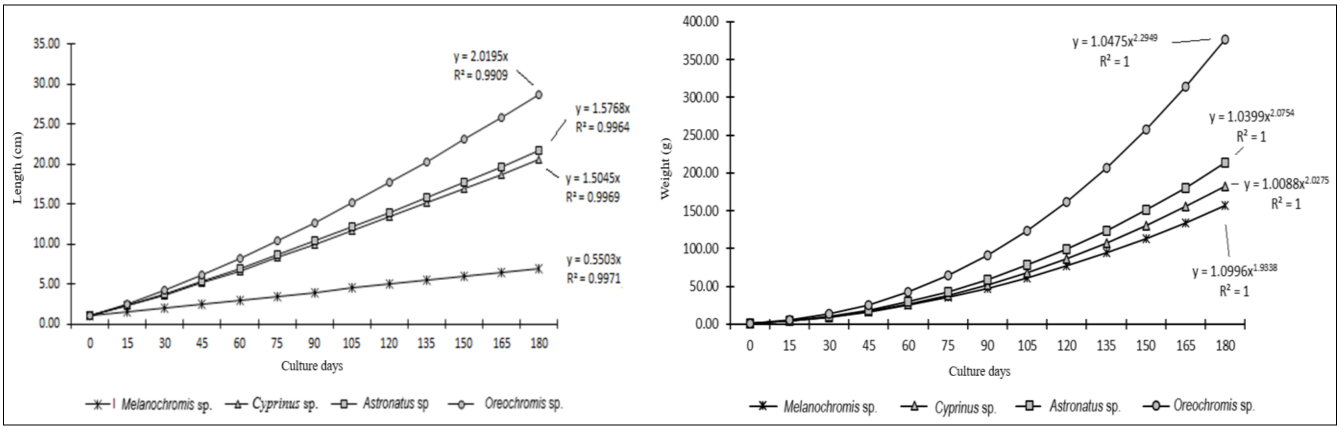


Fig 1: Growth curves of the organisms cultured in Biofloc.

Figure 3 shows the length and weight gain values. It can be seen that all four species increased their biometric value.

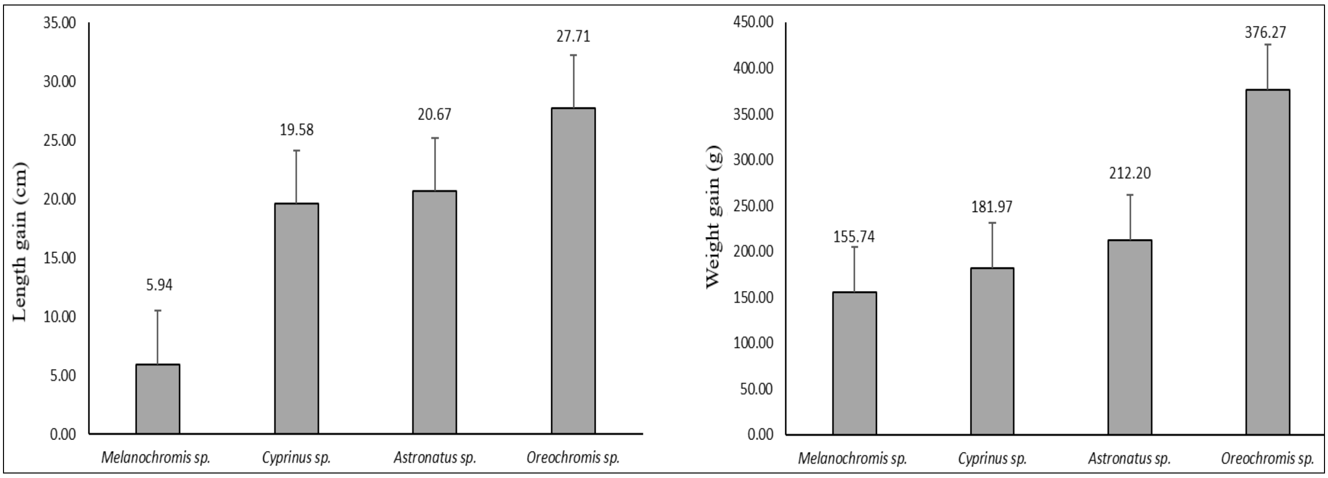
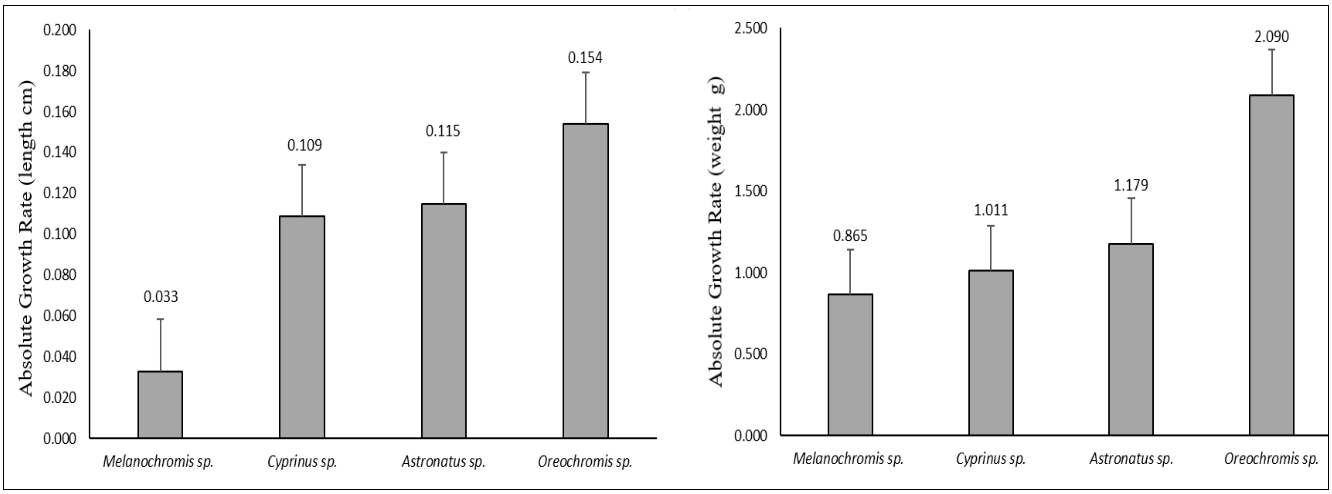


Fig 2: Length and weight gain of cichlids cultured in Biofloc.

These gain data are reflected in the cultured organisms with respect AGR and IGR values (Figure 4).



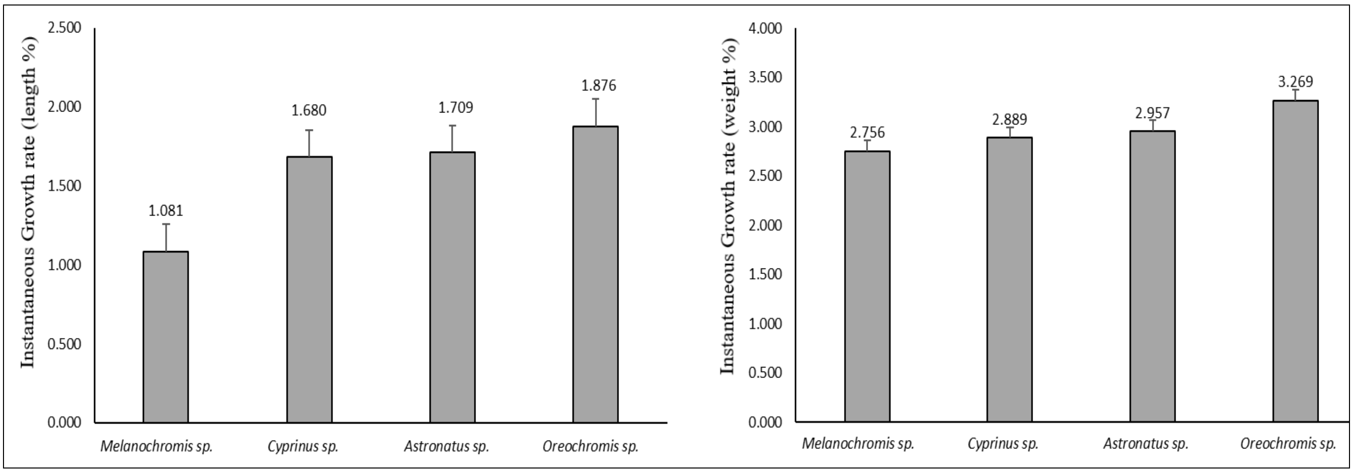


Fig 4: AGR and IGR values of the length and weight of organisms cultured in Biofloc.

Fig. 5 shows the curves of KM of the organisms. This figure showed that the diet and the conditions in Biofloc allow at each organisms to maintain the length/weight ratio.

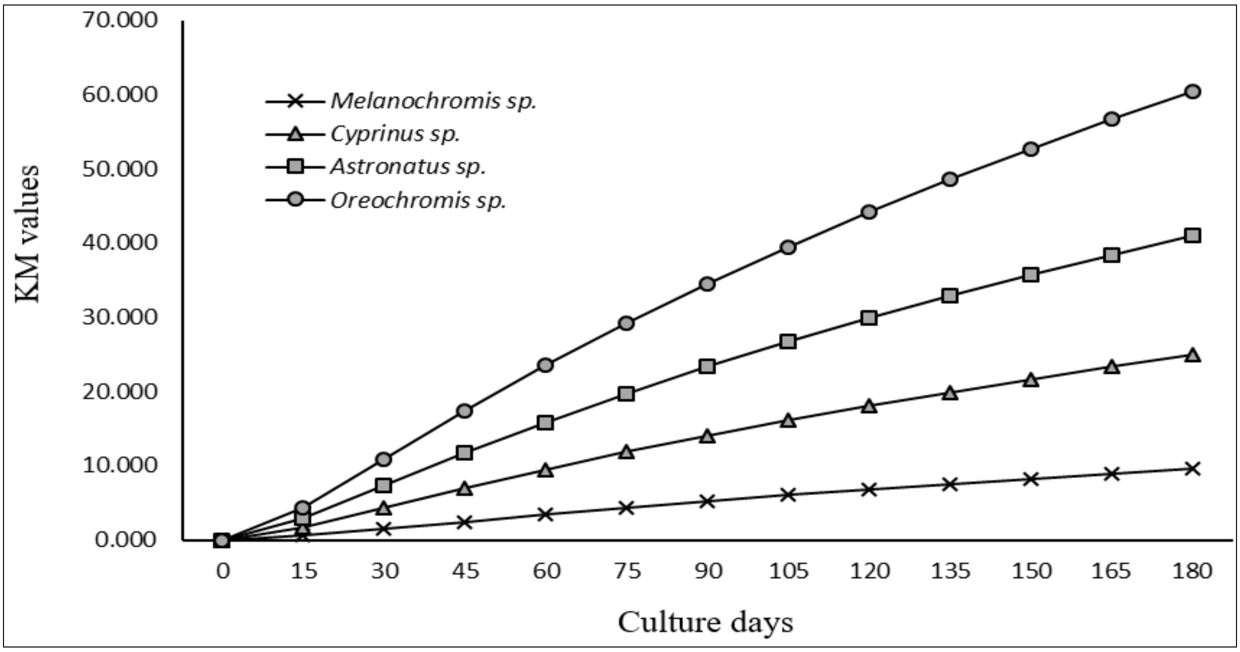


Fig 5: KM curves of organisms cultured in Biofloc.

The FCF and FCE values are shown in Figure 6. In FCF, the 10% feed of the total biomass still allows the organisms to grow and their efficiency is above 200%.

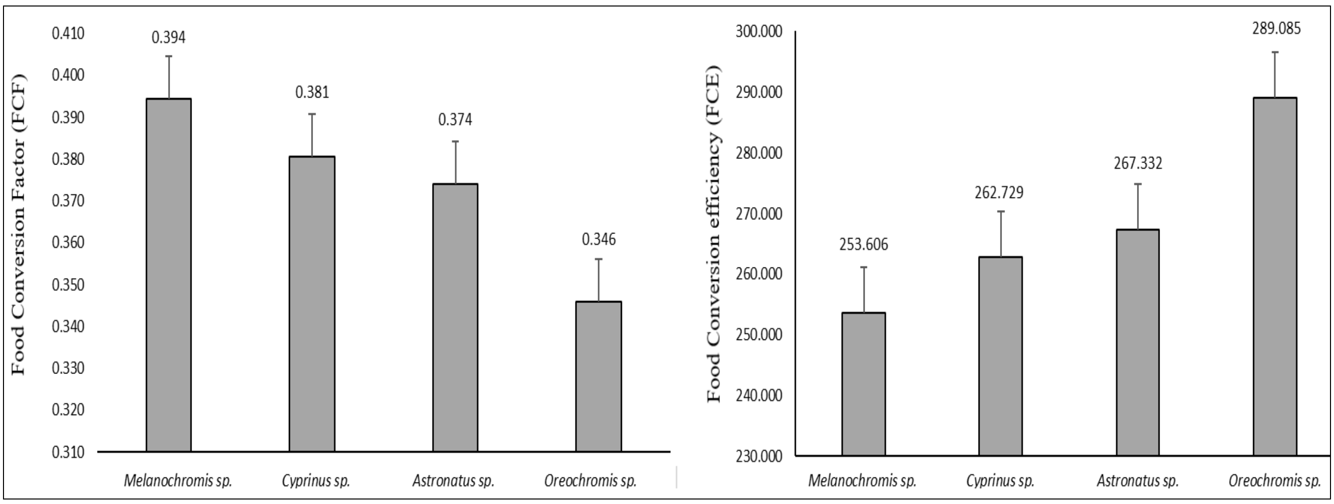


Fig 6: FCF and FCE values of the organisms cultured in Biofloc.

4. Discussion

During this experiment, water quality remained within the adequate ranges for the culture medium needed to culture these fish species, without presenting variations that affect the good growth and weight of the fish, to what was found according to [15] who worked with *A. ocellatus*, according to [16] with Nile tilapia *O. niloticus* and according to [17] who did it with white shrimp. All of them are in a Biofloc system. One of the most important variables to consider is the pH of the culture medium, which when maintained between 7.13 to 7.37 allowed the growth of nitrifying heterotrophic bacteria that resulted in greater stability of the Biofloc system according to [7], mentioned that the pH should be maintained in the Biofloc system between values of 7-9.

In a Biofloc system, the values of nitrogen compounds are related to the maturation time of the system for nitrogen fixation. At the beginning, the ammonia concentration should be increased promoting the increase of nitrosomonas-type bacteria allowing the nitrate and nitrite values to start to increase, obtaining a mature Biofloc. Nitrate concentrations, which are generally less toxic, increase and are a key nutrient for microalgae proliferation according to [18]. In many cases, high levels of nitrogenous compounds are caused by overfeeding as mentioned according to [11] in the growth of *O. niloticus* in a Biofloc system. However, nitrate is the end product of nitrification and is relatively non-toxic to tilapia [19, 20].

4.1 Survival

The high survival values (90%) in this study are in agreement with those reported by [21] in *Barbodes gonionotus* (Silver barbel) in a Biofloc system (90.32%) as opposed to when cultured in a traditional system obtaining only 84.5%. However, another study with *A. ocellatus* [7] reported a survival of 85%. High survival values are due to the heterotrophic bacteria with probiotic capacity to make many water changes and their consequence is the decrease of the introduction of pathogens into the culture system [4].

4.2 Length and Weight

The Biofloc system allowed all four experimental species to reach good weight and length. *A. ocellatus* reached an average weight of 99.42 g and a length of 13.97 cm unlike the study conducted by [15], whose organisms only reached an average weight of 28.45 g and a length of 11.31 cm in 120 days of culture. For *O. niloticus* this study showed values of 8.15 cm in length and 42.07 g in weight at 60 days of culture, unlike the work [22], at the same days of culture, the organisms reached a weight of 30.7 g in a culture system without Biofloc. For *Melanochromis* sp a length of 6.93 cm and a weight of 156.84 g reached a value below what is reported in a database with an 11 cm length [23] or with the study according to [24] conducted with four carbon sources (coffee, Yucca, macroalgae and Moringa), which obtained average lengths in a range of 11.06-14.39 cm in 120 days of culture. For *Cyprinus carpio*, values of 28 cm and 377 g were obtained in contrast to what was found by [25] who obtained length values between 40.84-43.2 cm in 75 days of culture using coffee as a carbon source.

4.3 Efficiency and feed conversion factor

Regarding the FCF, the four diets obtained values between 0.346-0.394:1 kg of biomass produced, obtaining a FCE between 253.60-289.08% values above those found by Kubitza (2011) [8] with *O. niloticus* in a Biofloc system at 135 days with an FCF 1.39-2.14 and an FCE of 71.43-46.6%.

When analyzing and comparing the biomass of the organisms with the protein level of the diets, no relationship was found, so we can infer that the Biofloc is responsible for the values obtained since it has been observed and proven that the use of this system in tilapia culture [10], *C. carpio* [26], and other organisms such as *Melanochromis* sp. [27], promotes the growth of organisms in culture due to the continuous availability of protein-rich food and therefore it is considered that 20 to 30% of the growth is given by the consumption and digestion of microbial proteins [27].

Table 1: Mean values (±S.D.) of total length and weight of organisms cultured in Biofloc

Sample days	*Melanochromis* sp. diet: Wardley flakes (30% Protein)		*Cyprinus* sp. diet: Agar medium with vegetables (25% Protein)		*Astronauts* sp. diet: Agar medium with fish (40% Protein)		*Oreochromis* sp. diet: Pellets 2 mm (30% Protein)	
	Length	Weight	Length	Weight	Length	Weight	Length	Weight
0	0.99±0.16	1.10±0.34	1.00±0.16	1.01±0.67	1.00±0.15	1.04±0.24	0.98±0.15	1.05±0.27
15	1.49±0.18	4.20±0.17	2.27±0.53	4.11±0.54	2.32±0.16	4.38±0.72	2.44±0.10	5.13±0.65
30	1.98±0.82	9.20±0.71	3.66±0.53	9.35±0.82	3.77±0.62	10.17±0.82	4.16±0.62	13.02±0.82
45	2.48±0.56	16.05±0.45	5.14±0.47	16.76±0.63	5.31±0.55	18.48±0.60	6.08±0.85	25.21±0.39
60	2.97±0.38	24.71±0.12	6.68±0.39	26.35±0.83	6.93±0.76	29.36±0.34	8.15±0.39	42.07±0.17
75	3.47±0.14	35.16±0.52	8.28±0.98	38.14±0.95	8.61±0.75	42.86±0.59	10.37±0.11	63.94±0.55
90	3.96±0.61	47.37±0.72	9.93±0.41	52.14±0.66	10.35±0.42	59.01±0.77	12.70±0.44	91.10±0.96
105	4.46±0.41	61.33±0.81	11.62±0.56	68.36±0.23	12.14±0.90	77.86±0.97	15.14±0.50	123.78±0.39
120	4.95±0.57	77.02±0.45	13.35±0.81	86.80±0.74	13.97±0.59	99.42±0.30	17.68±0.62	162.21±0.76
135	5.45±0.41	94.42±0.38	15.11±0.36	107.48±0.86	15.84±0.76	123.71±0.93	20.31±0.44	206.60±0.27
150	5.94±0.44	113.54±0.83	16.91±0.67	130.40±0.49	17.75±0.22	150.77±0.50	23.03±0.98	257.13±0.13
165	6.44±0.28	134.34±0.65	18.73±0.26	155.56±0.60	19.69±0.45	180.60±0.10	25.82±0.41	313.98±0.61
180	6.93±0.16	156.84±0.72	20.58±0.91	182.98±0.31	21.67±0.54	213.24±0.30	28.69±0.20	377.32±0.35

5. Conclusion

Cichlids are a family of organisms capable of tolerating high concentrations of organic matter in the culture medium so they can be cultured in a Biofloc system. However, it is advisable to do preliminary studies with the ornamental species with which aqua culturists want to work because the gills can be saturated by the organic matter flocs and obstruct the gas exchange in the gills of the fish.

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