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RELATION OF LENGTH, WEIGHT AND CONDITION FACTOR OF NILOTIC TILAPIA IN HIGH DENSITY CROPS

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Abstract

This study analyzes the length-weight relationship and condition factor (k) of Nilotic Tilapia (Oreochromis niloticus) during the different stages or phases of its cultivation cycle, as well as determines other useful biometric variables for pattern analysis of the species' growth. For this purpose, 2188 data were processed, obtained from three production processes under the same management conditions in a fish farming company located in the Maracayo district, municipality of Montería, Colombia. Data was collected using biometrics from the months of June through November, 2019. The results obtained when analyzing the length-weight relationship shows isometric growth in nilotic tilapia, with slight variation during the three stages of cultivation. The values of the condition factor K varied according to the phase, increasing as individuals' weight grew. The correlation of some morphometric variables with environmental variables fundamentally associated with water quality was analyzed.

Keywords: *Condition factor, biometrics, water quality, growth.*

1. Introduction

The nilotic tilapia, *Oreochromis niloticus*, after avoiding market problems for not obtaining the desired commercial sizes due to the lack of knowledge of ecological and cultivation parameters, boomed in the aquaculture trade due to the establishment of monosexual cultures which resulted in populations with uniform commercial sizes. Due to these advances, the global massification of this production system was achieved, to the point that nilotic tilapia is considered the most economically important (FAO, 2005-2017).

In Colombia, the aquaculture sector is largely represented by the cultivation of tilapia (*Oreochromis niloticus* and *Oreochromis sp.*). It contributes to more than 50% of national production (Aquaculture Chain, Ministry of Agriculture and Rural Development, 2018), being the result of the implementation of hybridization processes of species of African origin of the genus *Oreochromis*, which, given its great adaptability and tolerance to adverse factors, is present not only in Colombia, but in a large number of tropical countries without fish farming traditions.

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There are numerous studies on the genetic improvement, nutrition and development of farming systems for fish of this genus, however, there is little information regarding their growth dynamics both in their natural habitat and under cultivation conditions. Thus, investigating the biometric aspects (length-weight relationship and condition factor) has become of interest, which are of immense utility when evaluating aspects such as population stock (Gulland, 1983; Beyer, 1987; Benedito et al., 1997), frequency distributions and biomass estimation based on length.

Finally, investigations of this nature have focused on analyzing the length-weight relationship and condition factor in populations in their natural environment (Froese, 2006; Rennie & Verdon, 2008; Ramos-Cruz, 2009; Arismendi et al., 2011; Cifuentes et al., 2012; Hurtado-Herrera et al., 2013), (Hui et al., 2018), (Corrêa et al., 2018), where the ecological and environmental conditions are changing over time, an aspect correlated with the different stages of fish development, thus conditioning variables such as the length-weight relationship and condition factor.

Methodology

Location

The experimental development of this research was carried out in a fish farming company located in the town of Macayo, municipality of Montería, in the department of Córdoba, Colombia. Macayo is a small town located on the banks of the Betancí swamp, influenced by the main road that, from the municipality of Tierra Alta, Alto Sinú, communicates with the city of Montería. Due to its location, multiple generations have kept alive the fish farming tradition, using the resources of the Betancí swamp, which covers an area of around 3,400 hectares with an average depth of 4 m and a coastline extending approximately 18 km.

General cultivation conditions

This investigation kept track of an intensive scale production process, with a stocking density of 65 fish/m², implemented in HDPE geomembrane tanks, and supported by a staged feeding scheme: pre-breeding, using concentrated food with 45% protein for animals which weighted between 1 and 15 grams and with 40% protein for animals between 15.1 to 30 grams; raising, during which food with 38% protein was supplied to animals between 30.1 to 80 g, and with 35% protein to those between 80.1 to 150 grams; finally, during the fattening phase, a food with 32% protein was supplied until the final harvest weight. Similarly, the frequency of feeding was stratified in stages as follows: pre-breed, 6 times/day; raising, 4 times/day; and fattening, 3 times/day.

Sampling

To obtain the information, 22 biometrics were collected from the three phases of the culture cycle, grouping the information obtained according to stages (pre-breeding, raising and fattening).

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A total of 2,188 live nilotic tilapia fish from three environments under similar culture conditions were studied. The information used included the total length (TL), standard length (SL), dorsal length (DL) and weight (P) of the fish, for which a 50 cm acrylic ichthyometer was used with graduation in mm, a digital scale gramera with a precision level of 0.01g brand Bernalo BL-H2 SERIES. Regarding water quality, the following were monitored: dissolved oxygen concentration, oxygen saturation, temperature, pH, nitrites, alkalinity and suspended solids. A YSI-6050000 portable multi-parameter meter was used for this purpose. Measurements were taken twice a day (AM and PM). The information was systematized according to stage, which allowed calculating the length-weight relationship and condition factor K for each of them.

Method description

Biometric information was collected between the months of June until November 2019. The data processed by means of the descriptive statistics were: total length (TL), standard length (SL), dorsal length (DL), and weight (W) during the three phases of the culture: breeding, samples between 1-30 grams; raising, samples between 30.1-150 grams; and fattening, samples between 150.1-final harvest weight. The potential model was used to establish the length-weight relationship, which is interpreted with a regression that relates a linear measurement (height) with volume (weight), assuming that length is a linear magnitude and weight must be approximately proportional to the size, according to the equation proposed by Froese (2006) and Ricker (1975):

$$W = \alpha L^{\beta}$$

Where W = the total wet weight of the fish in grams; α is a regression constant equivalent to the Fulton condition factor (K); L is the total (TL) or standard length (SL) in centimeters and β is the coefficient of regression growth. For the determination of the model parameters, the method of least squares was used in which the α and β parameters were calculated, minimizing the square errors of the observed weight (W) and the weight predicted by the model (We). This adjustment was carried out using the non-linear optimization code GRG2 (Generalized Reduced Gradient).

To establish the statistical parameters of the model (confidence intervals, correlation coefficient and determination coefficient), a variance analysis (ANOVA) was performed on the logarithmic regression of the variables W and TL; W and SL. Based on all of the above and using a t-student test, the statistical difference in the isometry coefficients with respect to the isometric growth hypothesis ($\beta = 3$) was established, determining that there is isometry when p has values greater than 0.05. The length-weight relationship was analyzed using a multiple matrix regression model, calculating the correlation coefficient and the coefficient of determination using matrix operations. Control variables or independent variables were assumed to be the magnitudes of length (total length, standard length and dorsal length) and as measured or dependent variable the weight observations (W).

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Results

The analysis of the main results is presented below.

Physico-chemical parameters

The water temperature during cultivation had an average value of 29.56°C ± 1.32. The highest peaks were registered in the months of July to August, in terms of dissolved oxygen, which had an average value of 5.57 mg/lt ± 0.41 throughout the cycle, with higher values in the months of September-October, coinciding with the rainy season. The pH had an average value of 7.77 ± 0.34, showing a solid tendency towards neutrality. Alkalinity had an average of 81ppm ± 0.51. The ammonia and nitrite values ranged from 0.63 ppm ± 0.36; 0.44 ppm ± 0.14, respectively.

It is known that temperature is one of the most studied parameters in correlation with growth factors in fish (Weatherley & Gill 1987; Schreck & Moyle, 1990), given its ability to affect other parameters, such as the dissolution of oxygen. In the case of this research, the significance degree existing in the correlation between temperature and condition factor is very low, due to its little variation during the cultivation cycle. Generally, the monitored parameters fluctuated within the desirable ranges for the cultivation of nilotic tilapia (*Oreochromis niloticus*), as described by Su Hsien-Tsang (2008), even though the managed densities are relatively high (20 kg/m3 of biomass) due to the strict control kept in the growing environments, mainly associated with the mechanical oxygenation support 7/24.

Biometric variables

The organisms studied had a total length between 4.5 and 29.9 cm (17.44 ± 6.98) with a 95% confidence level of 0.30 and a coefficient of variation of 0.40%. The standard length varied between 3 and 22.1 cm (12.80 ± 5.14), with a 95% confidence level of 0.22 and a coefficient of variation of 0.40%. The dorsal length had an interval of 1.3 to 11.6 cm (6.34 ± 2.81) with a 95% confidence level of 0.22 and a coefficient of variation of 0.44%. Finally, weights were recorded between 1.65 and 654 g (183.21 ± 163.21) with a 95% confidence level of 6.98 and a coefficient of variation of 0.89%.

The entire population sampled was represented by males of nilotic tilapia, grouped as a percentage: 23.95% in pre-breed, with a total length between 4.1 and 11.5 cm (7.88 ± 1.93) and weighing between 1.65 and 29.89 g (7.99 ± o, 09); 27.60% in raising, with organisms between 11 and 19 cm (14.96 ± 2.16), weighing between 3.11 and 149.21 g (80.49 ± 34.59); 48.45% in fattening, with animals between 17.4 and 29.6 cm (23.55 ± 2.65), weighing between 152.6 and 654 g (322.21 ± 115.11). The information obtained was consolidated and categorized according to cultivation phases, performing the descriptive analysis of each of its biometric variables (weight, total length, standard length and dorsal length) (Table 1):

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Table 1.

PRE-BREED					RAISING				FATTENING			
	P (g)	**TL**	**SL**	**DL**	**W (g)**	**TL**	**SL**	**DL**	**P (g)**	**TL**	**SL**	**DL**
Mean	11.47	7.88	5.79	2.476	80.49	14.96	10.88	5.37	322.21	23.55	17.31	8.80
TE	0.35	0.08	0.06	0.029	1.40	0.08	0.06	0.03	3.53	0.08	0.06	0.03
Med	7.99	7.6	5.6	2.5	80.1	15	11	5.5	310	23.5	17.5	9
Mod	3.43	11	4	3	115.3	15	10.1	6	355.5	22.5	17.5	9
SD	8.09	1.93	1.43	0.673	34.59	2.16	1.61	0.86	115.11	2.65	1.93	1.10
Var	65.52	3.74	2.06	0.453	1196.82	4.69	2.59	0.75	13251.73	7.02	3.71	1.21
Min	1.65	4.5	3	1.2	30.1	11	7.2	3.6	142.6	18.9	14	6.2
Max	29.8	11.5	9	4	149.2	19	14	6.9	654	29.9	22.1	11.6
Conf level	0.69	0.16	0.12	0.058	2.76	0.17	0.12	0.06	6.94	0.16	0.12	0.07
N	524	524	524	524	604	604	604	604	1060	1060	1060	1060

Table 1. Descriptive values of the biometric variables in the three stages of nilotic tilapia culture. (*Oreochromis niloticus*). TE = typical error, SD = standard deviation, Min = minimum, Max = maximum, N = sample size, Med= Median, Mod= Mode, Var= Variance, W = weight, LT = Total Length, LS = Standard Length, LD= Dorsal Length.

Growth parameters

The regressions, standard length-total length, total length-dorsal length and standard length-dorsal length, throughout the crop cycle are defined by the equations TL = 0.1437 + 1.3507 SL, with a correlation of 0.995 and an R^2 = 0.9893; TL = 1.8102DL + 1.3155 with a correlation coefficient of 0.989 and an R^2 = 0.9787; and SL = 0.5412DL - 0.5838 with a correlation coefficient of 0.979, and an R^2 = 0.989 on a total of 2,188 samples.

Length-weight relationship

By means of the potential regression analysis (Graph 1) of the values corresponding to the entire crop cycle, a condition factor a=0.018 and a growth coefficient b=3.083 were established in the total length-weight relationship. Similarly, in the standard length-weight relationship, a condition factor a=0.052 and a growth coefficient b=3.050 were determined. The analysis of variance and a t-student test verified the existence of statistically significant differences between the two pairs

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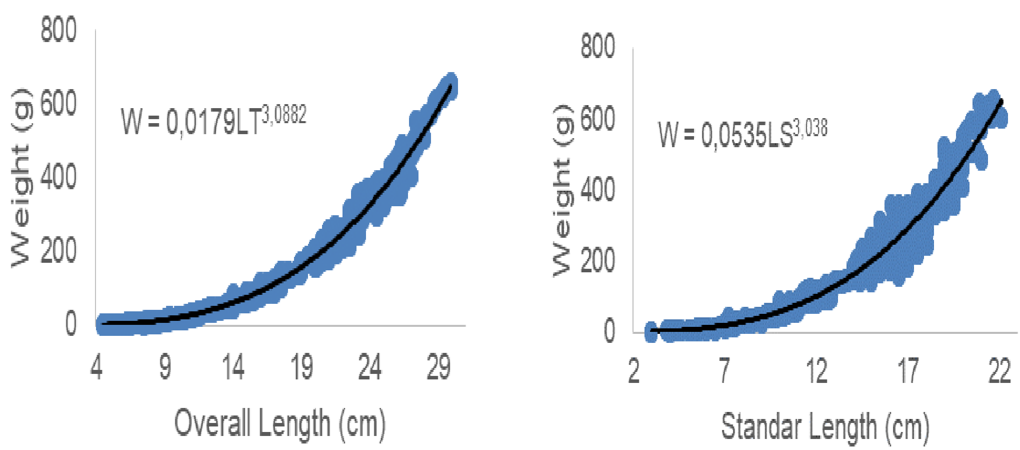
of studied variables (t = 8,338 and p <0.05, for the TL-W relationship; t = 3,548 and p <0.05, for the relationship SL-W) discarding the hypothesis of isometric growth for the species during its total production cycle.

On the contrary, these values correspond to a positive allometric growth. However, when theoretically contrasting the parameters obtained with the values proposed by Carlander (1969) and Froese (2006), who consider isometric growth species to be those that fluctuate within the values b = 2.5 and b = 3.5, it is valid to affirm that the species *Oreochromis niloticus* presents an isometric growth throughout its production stage, under the conditions of this study, since its growth coefficient is within this range.

Finally, the potential equations that explain the length-weight relationship of the species are as follows: W = 0.018 [LT] ^ 3,083; W = 0.052 [LS] ^ 3,050.

1a. **1b.**



Graph 1. Potential regressions of the total length - weight relationships; Standard length-weight, throughout the production cycle of Nilotic Tilapia (Oreochromis niloticus).

Graph 1a, shows the total length (TL)-weight (W) relationship and its respective potential equation; and graph 1b, presents the relation standard length (SL)-weight (W) and its explanatory equation.

Similarly, by means of a regression analysis, the length-weight relationship and condition factor were obtained for each stage of the crop (Table 2).

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Table 2.

Stage	PRE-BREED		RAISING		FATTENING	
	TL-W	**SL-W**	**TL-W**	**SL-W**	**TL-W**	**SL-W**
R^2	0.966	0.958	0.959	0.911	0.927	0.832
fd (n-2)	522	522	522	522	1058	1058
t	0.414	0.269	1.155	0.709	0.819	0.209
a	0.019	0.052	0.019	0.066	0.021	0.057
b	3.020	2.986	3.061	2.947	3.042	3.016
p	> 0.05	> 0.05	> 0.05	> 0.05	>0.05	> 0.05
Type of growth	I	I	I	I	I	I

Table 2. Parameters of the relationship Total length-Weight, Standard length-Weight, by productive stage of Nilotic Tilapia (*Oreochromis niloticus*).

Pre-breed stage

The allometry coefficients (b) obtained in the TL-W and SL-W ratios (b=3,020 and b=2,986, respectively) showed that, during the breeding stage, the species Nilotic Tilapia *Oreochromis niloticus* shows an isometric growth (p> 0.05) in both relationships (TL-W and SL-W), indicating that individuals increase their weight proportionally to their length. Regarding the condition factor (a), values of 0.019 were obtained for the TL-W relationship and 0.052 for the SL-W relationship.

Raising stage

During the raising phase and under the culture conditions previously described, Nilotic tilapia shows a condition factor a=0.019 for the relation (TL-W) and =0.066 for the relation (SL-W) with slopes or coefficients of allometry (b) of 3,061 (TL-W) and 2,947 (SL-W). Similarly, when applying the student t test, it was found that the allometry coefficient values were not significantly different from 3 (t = 1.155; p> 0.05 for the TL-W relationship and t = 0.709; p> 0, 05 for the SL-W relationship), which shows that this species has an isometric behavior (b = 3) during its raising stage, determining that the individual proportionally increases its length and weight. When contrasting the values obtained with other studies, it can be affirmed that the results differ significantly, a fact attributable to the fact that the latter are supported by analyses under natural conditions, as in the case of Samy A. & Leyton F. (2015), where the authors relate values of the condition factor for *O. niloticus*, between 0.7 and 1.32 with an average of 1,008, where additionally the ecosystem reports significant degrees of disturbance.

Authors such as Santoyo (2019) report that this same species in natural conditions (with low densities) in five bodies of water in the state of Jalisco, Mexico, present slope values b between

2.10 and 2.78 within the range of negative allometry b <3. These values are most likely associated with the ecological variability in the ecosystems where the study was conducted.

Fattening stage

When the variables TL-W and SL-W were related for the fattening stage, a determination coefficient of 0.832 and 0.927 was obtained, respectively. For the same relationships, a slope or allometry coefficient of 3.042 and 3.016 was obtained, indicating an isometric growth for the species ($t = 0.819$ and $p > 0.05$ for the TL-W relationship; $t = 0.209$ and $p > 0.05$ for the SL-W relationship). Additionally, a condition factor of 0.021 was obtained for the TL-W ratio and 0.057 for the SL-W ratio. Finally, a multiple linear regression analysis was performed, where the weight was considered as a dependent variable, and the total lengths, standard and dorsal length as independent or explanatory variables. A coefficient of determination $R^2=0.876$ was obtained, which indicates goodness of fit for the applied model, determining that about 88% of the weight variance is explained by the regression model; as well as a correlation coefficient of 0.936, which assures that length has a 94% incidence or a relationship in the dependent variable-weight.

Conclusions

By correlating the measurements of the standard length to total length, total length to dorsal length and standard length to dorsal length throughout the crop cycle, a linear type relationship was found, obtaining correlation coefficients between 0.979 and 0.995. These are considered high, thus indicating the close relationship between these morphometric variables. Similarly, nilotic tilapia under the cultivation conditions described above shows an isometric growth throughout the entire production process, with a slight tendency to positive allometry in the fattening phase. This is justified by the fact of stability of environmental parameters such as temperature, dissolved oxygen, and pH, in addition to the availability of food during all stages of cultivation.

Keeping the temperature of the water at a small variable range positively impacts growth since fish are poikilothermic animals, so their metabolism is subject to environmental conditions, especially temperature.

A trend of an increase in condition factor K was observed, associated with an increase in height and weight (somatic development of nilotic tilapia).

The results of this research can be used to model biomass prediction systems in the management of populations of nilotic tilapia (Oreochromis niloticus), under high density captive conditions.

he main contribution for generated by this research for the world, is its contribution to the optimization of tilapia nilotica crops, where the results obtained serve as the basis for designing biomass prediction models through control of length, weight and condition factor. K, and in

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addition the conditions are optimized so that the growth processes of the treated species in crops of high densities are improved, becoming a solution in countries that present lack of food for their inhabitants, obtaining a high quality product, great content food and that does not pollute the environment and that current conditions are not optimal to obtain tilapia with the length and weight to improve production in high-density crops.

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