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Research Article

First trial of production of a native cichlid *Herichthys cyanoguttatus* comparison with the tilapia *Oreochromis niloticus* in aquaculture

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ABSTRACT. Native species, in comparison to exotic species in aquaculture, such as tilapias, are an alternative with a lower risk to regional biodiversity, due to competition for resources caused by introduced species. Productivity, length-weight relationship and relative condition factor of a native cichlid *Herichthys cyanoguttatus* were investigated in comparison to tilapia *Oreochromis niloticus*. Fish with a wet weight of 0.54 ± 0.07 g were placed in 100 L tanks inside a polyethylene greenhouse during 84 days. Wet weight (g) was obtained each week and standard length once per month. Both species had a high survival rate with a relative condition factor close to 1, showing a length-weight relationship with an isometric growth, meaning that they were in good condition. A significant difference was found in growth ($P < 0.05$) from the second week, with a specific growth rate of 2.28 ± 0.07% day^{-1} for tilapia and 1.35 ± 0.02% day^{-1} for the native cichlid, tilapia reached twice the total weight gain than the native cichlid (31.26 ± 0.95 g; 83.70 ± 4.54 g). Food conversion rate was higher in tilapia than in *H. cyanoguttatus*. The survival rate of H. *cyanoguttatus,* as well as the relationship of isometric growth and condition factor of both species, suggests that *H. cyanoguttatus* has the ability to grow in aquaculture systems.

Keywords: *Herichthys cyanoguttatus*, *Oreochromis niloticus*, tilapia, condition factor, length-weight, growth, Mexico.

Primer prueba productiva de la mojarra nativa *Herichthys cyanoguttatus* en comparación con la tilapia *Oreochromis niloticus*

RESUMEN. Las especies nativas, en comparación con las especies exóticas usadas en acuicultura, como las tilapias, son una alternativa con menor riesgo para la biodiversidad regional, debido a la competencia por recursos causada por las especies introducidas. Se investigaron los parámetros de crecimiento, relación longitud-peso y factor de condición de la mojarra nativa *Herichthys cyanoguttatus* comparándola con la tilapia *Oreochromis niloticus*. Individuos con un peso de 0,54 ± 0,07 g se colocaron en estanques de 100 L en un invernadero de polietileno durante 84 días. El peso (g) se obtuvo cada semana y mensualmente la longitud parcial. Ambas especies presentaron alta supervivencia con un factor de condición relativo cercano a 1 y una relación longitud-peso con crecimiento isométrico, significando que se encontraban en buena condición. Se determinó una diferencia significativa ($P < 0{,}05$) en el crecimiento desde la segunda semana, con tasa específica de crecimiento de 2,28 ± 0,07% día^{-1} en la tilapia y 1,35 ± 0,02% día^{-1} en la mojarra nativa; la tilapia alcanzó dos veces el peso de la mojarra (31,26 ± 0,95 g; 83,70 ± 4,54 g). La eficiencia de conversión de alimento fue mayor en la tilapia que en *H. cyanoguttatus*. La supervivencia de *H. cyanoguttatus*, así como la similitud del crecimiento isométrico y factor de condición con la tilapia, sugieren que tiene la capacidad de ser cultivada en sistemas de acuicultura.

Palabras clave: *Herichthys cyanoguttatus*, *Oreochromis niloticus*, tilapia, factor de condición, relación longitud-peso, crecimiento, México.

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INTRODUCTION

Tilapias are the most cultivated fish species in México (CONAPESCA, 2013). They are exotic to the region with high potential to damage native biodiversity due to competition for resources (Contreras-MacBeath *et al.*, 2014). Most tilapia farms in México use very basic technology in family farms, with poor regulation in their handling, thus increasing the biodiversity risk (INEGI, 2011). Implementation of native species culture has been proposed as an option to reduce the use of introduced species (CANEI, 2010; Segovia-Quintero, 2011). However, only few species have been studied with focus on aquaculture production (Teletchea & Fontaine, 2014). In the State of Querétaro, the existence of tilapia in different water bodies threatens the regional biodiversity (Gutiérrez-Yurrita & Morales-Ortiz, 2004). Currently, there is not enough information to produce any native species from the geographical area of Querétaro, although previous studies have identified the native cichlid of Panuco River (*Herichtys cyanoguttatus*) as a possible candidate for farming (Garcia-Trejo *et al*., 2014).

H. cyanoguttatus is commonly sold in aquariums with the name of "Texas Cichlid" being appreciated for its color. As a result, studies conducted in this species have focused mainly on improving appreciated features in fishkeeping and not on improving biomass production (Montajami *et al*., 2012a, 2012b). Garcia-Trejo *et al.* (2014) showed that the fingerlings have the ability to quickly adapt to captivity. They can tolerate considerable environmental changes, easily accept commercial tilapia feed and endure stocking densities of up to 375 individuals m^{-3}, with optimal temperatures of 26 and 28°C; characteristics similar to those observed in tilapia *Oreochromis niloticus* (El-Sayed, 2006). However, it has not been studied how this species responds to aquaculture conditions, such as the ones presented in the tilapia production. Overall productivity, average daily oxygen consumption, length-weight relationship and condition factor of both native cichlid and tilapia were determined under the most common greenhouse culture conditions of the semi-arid region of Querétaro, to evaluate the viability that *H. cyanoguttatus* could compete against introduced species, employing basic aquaculture technology.

MATERIALS AND METHODS

Fish

Tilapia fingerlings of mixed sex were obtained from the aquaculture unit in the Amazcala Campus of Universidad Autónoma de Querétaro, located in the Marqués Municipality of Querétaro México. *H. cyanoguttatus* fingerlings of mixed sex were obtained from the Taxhido springs upstream of the Zimapan dam in the town of Cadereyta, Querétaro, located at 20°35'18"N, 99º40'47"W. Proximity to springs favors obtai-ning smaller size fish, capturing organisms from 10 to 30 mm in length. The water from the river at Taxhido springs has a pH 8.2 with temperature of 27°C and dissolved O_2 of 6.8 mg L^{-1}. The capture took place in April using a fishnet. Specimens were transferred alive to the laboratory using 50 L plastic tanks with aerators. Upon arrival to the laboratory, they were maintained for one week at 27 to 28°C in 50 L tanks, simulating the conditions of the capture area. From the first day of arrival, food formula Api-Tilapia 1, maltaCleyton® with 50% protein, 12% lipid, 13% ash, 3% fiber and 12% moisture was provided. Tanks in the laboratory were kept with continuous aeration and every two days underwent a replacement of 30% of water using a siphon to remove excess wastes.

Fishes were transferred to tanks located within a 504 m^2 (18x28 m) polyethylene greenhouse in the Amazcala Campus of Universidad Autónoma de Querétaro. After one week of acclimatization, 81 *H. cyanoguttatus* fishes were selected with an individual average wet weight of 0.54 ± 0.07 g. Similarly, 81 tilapias with an individual average wet weight of 0.53 ± 0.07 g were selected.

Experimental conditions

Fishes with the desired wet weight were divided into 100 L tanks, three for each species. Every three days, 30% of water was replaced using a siphon. Once a week, a replacement of 80% of water in the tank was performed. Every three days, water temperature and dissolved oxygen were monitored using the multiparameter probe HQ40D by Brand Hach, USA with LDO101-03 sensor (°C and O_2 mgL^{-1}), and the pH with the waterproof pH tester 10, brand Eutech, USA Instruments. Every 15 days, the analysis of ammonia content in water was performed through spectrophotometric techniques using the spectrophotometer DR/6000 (Hach) using 380N Hach method.

The experiment lasted 84 days. During this period, wet weight of all individuals was measured weekly using an analytical balance with a precision of 0.001 g (Sartorius AY303 Milligram Scale). At the start of the experiment, and monthly, biometrics of all individuals were measured in the laboratory using a digital Vernier with an accuracy of 0.01 mm (Truper Stainless steel), a daily recording of mortality was performed. Organisms were fed the same feed formula, Api-Tilapia 1 at a daily rate of 4% of the total biomass of each tank (feed ration was adjusted weekly) distributed to once or twice per day depending on campus activities.

Average daily oxygen consumption

The average daily oxygen consumption was calculated at the end of the experimental period, with no feeding activity, in cylindrical closed individual respirometric chambers (plastic material, positioned vertically, diameter 10 cm and volume of 2 L), following the semi-closed respiration measurement methodology (Lampert, 1984; Soto-Zarazúa *et al.*, 2010). A 24 h trial was performed with dissolved O_2 samplings every four hours. The dissolved O_2 was measured at the beginning and at the end of each sampling time, filling the respirometric chambers to its maximum capacity using water with high dissolved O_2 concentrations and closing them hermetically. The temperature was maintained at 27 ± 0.7°C at all times. The water temperature and the dissolved O_2 were monitored using the multiparameter probe HQ40D by Brand Hach, USA with the LDO101-03 sensor (°C and dissolved O_2).

One randomly selected fish was placed in each chamber, with six repetitions for each species. In each trial, a control chamber was used to determine the environmental variation. During the trials, the chambers were maintained covered to reduce the stress caused by the handling. The oxygen consumption was calculated as below:

$$\text{Oxygen consumption } (\text{mg } O_2\ \text{g}^{-1}\ \text{h}^{-1}) = \left(\frac{C_i - C_a}{t_a} - \frac{C_i - C_c}{t_c}\right) x \frac{V}{W} \quad (1)$$

where C_i, C_a, and C_c are the oxygen concentrations (mg L^{-1}) of the initial samples, the chambers with animals, and the controls, respectively; t_a and t_c are the incubation periods of test chambers and controls; V is the volume of the chamber containing the organisms and W is the wet weight. The average daily oxygen consumption was obtained from the oxygen consumption of each chamber.

General productivity

Yield was evaluated as was described by Alatorre-Jacome *et al.* (2012). Total biomass wet weight (Wt) was analyzed in terms of relative density (P_{rel}) per volumetric unit (g m^{-3}), considering that:

$$W_t(g) = \sum_{i=1}^{n} W_i \quad (2)$$

where W_i is the weight of fish in the system.

$$P_{rel}(g) = \frac{W_t}{V} \quad (3)$$

where V is volume (m^3).

Total weight gain (TWG) in terms of the average daily growth rate (ADGR) by:

$$TWG(g) = M_f\text{-}M_i \quad (4)$$

where M_f is the final mass and M_i the initial mass.

$$ADGR(g\ day^{-1}) = \frac{TWG}{D} \quad (5)$$

where D are the culture days.

Specific growth rate (SGR) was estimated as:

$$SGR = \frac{100\left(l_n M_f - l_n M_i\right)}{D} \quad (6)$$

where M_f is the final weight, M_i is the initial weight, and D the culture days.

Mortality was recorded daily and calculated as the difference between the number of fish in the original stock and the fish at the time of measurement.

Food conversion ratio (FCR) was considered:

$$FCR = \frac{F}{(TWG)} \quad (7)$$

where F is the dry weight of feed.

Length-weight relationship and condition factor

Length-weight relationships for species were analyzed by linear regression, calculating the values of b from equation (Keys, 1928):

$$W = a\ L^b \quad (8)$$

where W is the total weight in grams and L the length in cm (measured from the tip of the mouth to the beginning of the caudal fin). The value obtained for b determines whether growth is isometric (b = 3), positive allometric (b>3) or negative allometric (b<3).

Condition status was estimated by Fulton index (condition factor). As suggested by Froese (2006) the relative condition factor (*K*rel) of Le Cren (1951) was used as:

$$K_{rel}=W/aL^b \quad (9)$$

where W is the wet weight of fish in grams, *a* and *b* are the values obtained from Eq. 7, and L was used as the length in cm. This equation relates length-weight with the average condition of the organism at a particular size, considering that an individual is in better condition if it has more biomass relative to its length.

Statistical analysis

Data from *a* and *b* values of the length-weight and condition factor within the same species were analyzed using a one-way ANOVA to determine significant differences. When differences were found a test of least square differences (LSD) was performed. For all comparisons between species a *t*-test was performed to determine significant differences. All statistical analyzes were performed with a reliability of 95% using the software Statgraphics routine centurion XV, v. 15.2.06.

RESULTS

The water conditions (temperature, dissolved oxygen, pH, and NH_4^+) during the experimental period were not significantly different between tanks ($P > 0.05$). The average values of all the tanks were: temperature 25.4 ± 2.3°C, dissolved oxygen 8.51 ± 1.24 mg L^{-1}, pH 8.9 ± 0.26, and NH_4^+ 0.10 ± 0.03 mg L^{-1}.

Average daily oxygen consumption

The average daily oxygen consumption of *O. niloticus* was 0.22 ± 0.05 mg O_2 g^{-1} h^{-1} and *H. cyanoguttatus* had a value of 0.21 ± 0.02 mg O_2 g^{-1} $h^{-1,}$ without a significant statistical difference between species ($P > 0.05$).

Productivity

Native cichlid showed a linear growth over time, slowly increasing its biomass compared with tilapia (Fig. 1). Initial and first-week measurements showed no significant differences, but from the second week a difference was observed on biomass gain ($P < 0.05$).

Growth performance of both species is presented in Table 1. Baseline variables had no significant differences between species. Wt obtained at the end was significantly different between species ($P < 0.05$), where tilapia obtained a greater weight, almost twice that reached by the native cichlid. TWG was higher in tilapia with more than double biomass harvested, where the native cichlid incorporate 0.372 g daily and the tilapia 1 g daily ($P < 0.05$). Likewise, the SGR was higher in tilapia with 2.28 against 1.35 in cichlid ($P < 0.05$). There was a significant difference in the EFC, where tilapia presented 2.04 while native cichlid had 3.37.

Length-weight relationship and condition factor

Both species had a negative allometric growth during the first 28 days, changing to an isometric behavior from day 56, according to the value of *b* (Table 2). Within the same species both, native cichlid and tilapia showed no significant difference ($P > 0.05$) on the values obtained from day 28. Condition factor was obtained as Krel using the average values of *a* and *b* obtained at each measurement (Fig. 2). There was no significant statistical difference ($P > 0.05$) inside the same species during the experimental period as well as no difference between species in any measurement.

DISCUSSION

This study sought to demonstrate growth capacity of the cichlid *H. cyanoguttatus* under most simple and common greenhouse aquaculture conditions for tilapia.

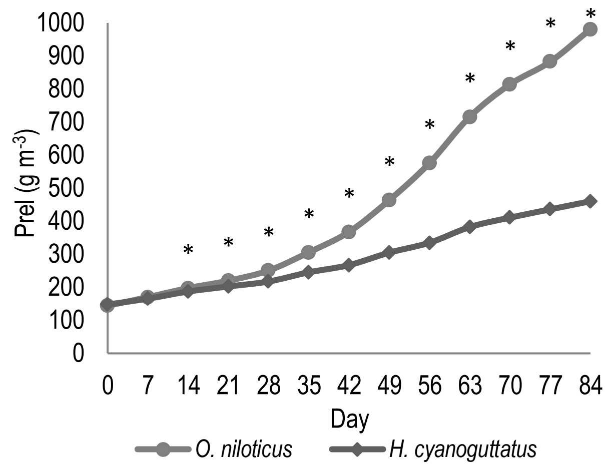

Figure 1. Wet weight gain per volumetric unit (Prel) of *O. niloticus* and *H. cyanoguttatus* during the experiment. Mean of three tanks are shown. *Indicate a significant difference between species ($P < 0.05$).

Table 1. Growth performance of *O. niloticus and H. cyanoguttatus* at the end of the experience. Values are the mean ± standard deviation (n = 3). *indicate significant differences from the *t*-test. Prel: wet weight in terms of relative density, TWG: total weight gain, ADGR: average daily growth rate, SGR: specific growth rate, FCR: food conversion ratio.

	H. cyanoguttatus	*O. niloticus*
Fish per tanks, initial (n)	27 ± 0	27 ± 0
Survival (%)	95.06 ± 5.65	100.000 ± 0.00
Prel initial (g m^{-3})	147.82 ± 0.65	144.11 ± 3.19
Prel final (g m^{-3})	*460.37 ± 9.66	*981.12 ± 43.12
TWG (g)	*31.26 ± 0.95	*83.70 ± 4.54
ADGR (g day^{-1})	*0.37 ± 0.01	*1.00 ± 0.05
SGR (% day^{-1})	*1.35 ± 0.02	*2.28 ± 0.07
FCR	*3.37 ± 0.05	*2.04 ± 0.06

Water parameters, including temperature, pH, dissolved oxygen, and NH_4^+ measured throughout the experiment were adequate for growing tilapia (El-Sayed, 2006; Timmons & Ebeling, 2010). The water used at the Amazcala Campus comes from a water well with a pH above 9, which explains the high pH presented. As to the native cichlid, temperature and dissolved oxygen were within the acceptable ranges for this species (García-Trejo *et al.*, 2014; Froese & Pauly, 2015). In the case of pH and NH_4^+, there are no previous studies indicating the adequate ranges for rearing *H. cyanoguttatus*, but the values presented are considered suitable as it had a high survival, with no significant difference from tilapia, furthermore, the pH at the site of capture had a value close to 8.2, meaning that the native cichlid was already accustomed to high pH values.

Table 2. Length-weight ratio (W = aL^b) during the experimental period for *H. cyanoguttatus* (Hc) and *O. niloticus* (On). Values are the mean ± standard deviation (n = 3), c or d: show a significant difference between the same species ($P < 0.05$), i: show an isometric growth (b = 3).

Days	*a* Hc	*b* Hc	*a* On	*b* On
0	0.137 ± 0.026	1.450 ± 0.208c	0.108 ± 0.032	1.800 ± 0.277c
28	0.051 ± 0.008	2.700 ± 0.148d	0.044 ± 0.015	2.738 ± 0.312d
56	0.040 ± 0.009	2.931 ± 0.165d i	0.041 ± 0.012	2.791 ± 0.212d i
84	0.037 ± 0.007	3.020 ± 0.129d i	0.039 ± 0.014	2.876 ± 0.207d i

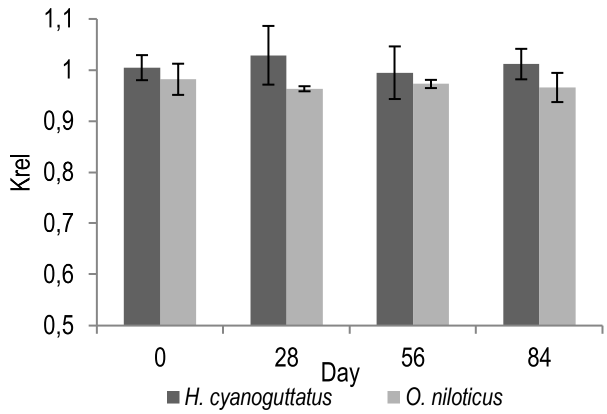

Figure 2. Relative condition factor (Krel) for *H. cyanoguttatus* and *O. niloticus* during the experimental period. Values are the mean, horizontal bars indicate ± standard deviation (n = 3). There was no significant difference between species or between measurements of the same species during the study ($P < 0.05$).

Average daily oxygen consumption

The average daily oxygen consumption is an indirect way to measure the metabolic rate and stress level of fish (Portz, *et al*., 2006; Mamun *et al*., 2012). Since during the present study there was no significant difference between species, it is considered that the fish management caused a similar stress level in both species, despite that the native cichlid had been captured, and the tilapia came from an aquaculture unit. Since no significant difference was found between environmental parameters of the rearing of both species, it is considered that the observed results are suitable for comparison.

Productivity

Tilapia had a greater increase of biomass relative to native cichlid from day 14 (Fig. 1), and in the last days of the experiment an exponential growth characteristic of this species was observed, which allows obtaining more biomass in less time, a characteristic appreciated in tilapia (Santos *et al*., 2013). The growth of Panuco native cichlid in aquaculture production has not yet been characterized, but by observing the data obtained, a linear and gradual growth is evident. It has been previously reported that *H. cyanoguttatus* has the ability to reach sizes of up to 30 cm, but the time it takes to get to this point will be greater than that required by tilapia (Page & Burr, 2011). As mentioned, tilapia has a higher weight gain in less time increasing nearly twice the total weight by tank presented by native cichlid (Table 1). Moreover, *O. niloticus* obtained a SGR of 2.28, which is indicative of a good production yield (Ogunji & Wirth, 2000; Kumar *et al.*, 2011). *H. cyanoguttatus* scored a value far below tilapia with 1.35, indicating that at least in biomass production during the study period, native species cannot compete against introduced fish. This characteristic of slow growth in native cichlid is not necessarily disadvantageous in all models of aquaculture production. Indeed, this species could become useful for small scale production, as is the case with most of the aquaculture units presented in México where the most important thing is not getting the greatest amount of biomass but the best use of resources (INEGI, 2011).

The FCR between 1.2 and 1.5 is considered as optimal the tilapia aquaculture (De Silva & Anderson, 1995; Ogunji & Wirth, 2000; Kumar *et al.*, 2011). Although in this study a FCR of 2.04 was obtained for *O. niloticus* it was better than the 2.9 obtained in previous studies with similar pH values (El-Sherif & El-Feky, 2009). *H. cyanoguttatus* obtained a 3.37, a 60% difference with tilapia in this study, suggesting that native cichlid was not growing properly. Moreover, this FCR may be due to the fact that the native cichlid was not feeding with the algae growing in the tank, while the tilapia continuously fed on this. It was previously described that *H. cyanoguttatus* is in general consider an omnivorous fish (García-Trejo *et al.*, 2014), but the lack of consumption of algae showed that it would be necessary to modify the commercial diet for tilapia, which is formulated for omnivorous species, to increase the growing of the native cichlid.

Length-weight relationship and condition factor

Values obtained from *b* tended to an isometric growth for both species during the experiment (Table 2), considering that isometric growing species are the ones that fluctuate within the values b = 2.5 and b = 3.5 (Froese, 2006). Initial measurement for both species obtained a b < 2, value outside of the range predicted by Froese (2006). Nevertheless, those initial b values are considered incorrect because length-weight ratio is not reliable in individuals with very small sizes. From day 28, a "balance" was achieved in coefficient b as no significant differences were found in the following values, although statistically we can state an isometric growth from the measurement of day 56. The isometric growth of tilapia has been previously characterized coinciding with values obtained in this study (Olurin & Aderibigbe, 2006; Gupta *et al.*, 2012). In the case of *H. cyanoguttatus,* there are no previous reports of this coefficient, but it has a tendency to isometric growth, a desirable feature for aquaculture production as it indicates the possibility of obtaining a final product similar to tilapia, suggesting that replacement of tilapia by native cichlid may be more accepted by their current consumers.

The Krel of tilapia obtained from the standard length (Fig. 2) is equivalent to that found in other studies with an accepted production (Gupta *et al.*, 2012; Sousa *et al.*, 2013). Moreover the native cichlid showed a similar statistical trend (P > 0.05), considering that both species are in good condition because values obtained are close to 1, maintaining its condition factor during the entire experimental period (Olurin & Aderibigbe, 2006). *H. cyanoguttatus* did not improve its condition factor under aquaculture, as we had expected, but neither deteriorated, meaning that native species accepted culture conditions, but there is room for improvement in management.

CONCLUSIONS

H. cyanoguttatus under experimental culture conditions showed a lower growth over time compared to *O. niloticus,* partly caused because native cichlid came from the wild whereas tilapia has gone through an arduous selection of desirable specimens for production for years, thus having a great genetic advantage (Fuentes-Silva *et al.*, 2013).

The kinship between *H. cyanoguttatus* and *O. niloticus* in the isometric growth and Krel obtained in the experiment suggest that native cichlid has the ability to obtain a similar product to tilapia. Otherwise, the results indicate that implementation of a native cichlid culture using the same technology as the one used in the tilapia production could not obtain the best yields, although the similarity in the survival of both does not reject this possibility. The results showed that the native cichlid could not be cultured directly with the most common tilapia farming methods. Other type of farming should be considered, such as the polyculture studied for the Mayan cichlid and Nile tilapia (Hernández *et al.*, 2014). It remains to determine the time required to achieve the desirable sizes of *H. cyanoguttatus,* and perform studies to obtain better yields, aiming to use this species as an alternative to reduce the farming of exotic fish.

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