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Tilapia Culture in South Latitudes: First Report of Successful Fattening in Hot Springs of Buenos Aires Province, Argentina

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Abstract

In the present work, the feasibility of fattening *Oreochromis niloticus* specimens on a pilot scale in a geothermal water resource located in the Southeast of the province of Buenos Aires was analyzed. Before placing the culture units, physical and chemical characteristics of hot spring were studied to evaluate its suitability for tilapia farming. In the experimental stage, two hundred specimens with an average weight of 14.5 ± 1.8g were placed in two floating cages (1.30x1x1m) (100 individuals per cage) and they were harvested at 140 days. The specimens were fed 3 times a day with a commercial pelleted feed with a content of 35% of proteins. Monthly samplings were carried out to evaluate growth (weight and total length), survival, and water samples were collected to measure their physical-chemical characteristics. The results of the water analysis showed a high quality in the hot springs (Simplified Water Quality Index=88). The fattening results showed an average final weight of 423-435.9 g, a survival of 87-91%, SGR 1.47- 1.49%/day and the FCR was estimated at 1.05-1.07 for each cage respectively. We can conclude that this hot spring has the necessary water conditions to obtain excellent weight gains during the fattening period for the *O. niloticus* specimens. The present study represents the first Nile tilapia culture in the southernmost thermal waters, setting a precedent for future ventures in the area.

INTRODUCTION

Over the past decades, tilapia culture has been widely developed around the world and Latin-America has not been the exception (FAO, 2020). In recent years, tilapia culture has increased in the aquaculture industry, the Nile tilapia *Oreochromis niloticus* is the species that currently represents 70% of this cichlid genus cultured worldwide (Fitzsimmons, 2004). However, tilapia culture in natural systems might be limited in higher latitudes where cold water is not suitable for its growth and survival. There is evidence that tilapia's activity and feeding become reduced when the temperature falls below 20 °C and fish stop feeding at temperatures below 16°C, with temperatures above 26 ° C being optimal. (Azaza *et al*., 2008). Thus, using thermal waters in tilapia culture seems to be a good alternative, mainly in subtropical areas, where winter prevents their growth since this is a warm water species with a geographically limited distribution (Lund and Boyd, 2016). Dan and Little (2000) reported the possible utilization of geothermal waters in combination with other factors of control and management for the aquaculture development of these organisms.

In Argentina, tilapia culture is still incipient but has great potential due to the great freshwater resources. The production of *O. niloticus* reached 23.7 tons in 2019 and was mainly centralized in the North-East region of the country (Panné Huidobro, 2019), which has Sub-Tropical climate conditions. Buenos Aires is the most populated province where there is an increased demand for food. However, owing to its winter low temperatures, tilapia culture is limited to intensive recalculating systems where the water temperature can be controlled but the production costs are increased. Fortunately, several natural hot springs are located in this province, which might be used as culture media to farm this specie. Thus, the present research aims to study the feasibility of *O. niloticus* fattening in a pilot-scale at geothermal water resource located in the South-East of Buenos Aires province. Likewise, hot springs water quality, and time required to reach commercial size were evaluated.

METHODOLOGY

Place and Time

This study was conducted in the "Complejo Termas de Médanos" situated in Médanos, Province of Buenos Aires, Argentina (38º50.37'04" S - 62º 44'21" W) (Fig.1). This place presents a continuous hot spring of approximately 90,000 L/h through a cooling system that flows into canals (100m long, 20m wide and an average depth of 1m). Previous to the growing trial, the water body quality was assessed during December 2012. The experiment was carried out from January to May of the following year.

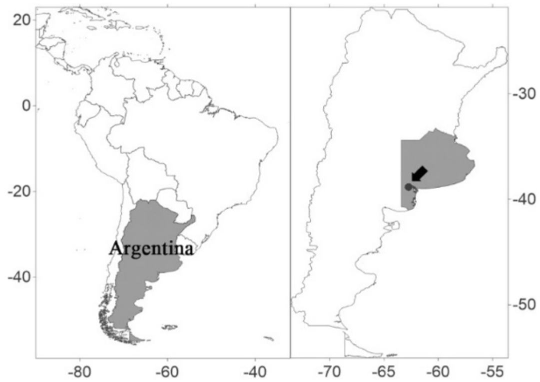

Figure 1. Location of the hot spring at Buenos Aires Province, Argentina.

Research Material

The tools used in the study include a water quality "Horiba U 10" multi-sensory, portable battery-operated fish tank aquarium air pump, plastic tanks, PVC floating cages, benzocaine, digital scale EK4150, ichtyometer and hand nets. The fish species used to support this study was Nile Tilapia (*Oreochromis niloticus*).

Research Design

Two hundred juveniles of Nile Tilapia (weight 14.5±1.8 g, total length 9.8±0.8 cm, standard length 7.5±0.6 cm) were transported from the Aquaculture Laboratory (UTN-FRMdP) to the experimental facilities at "Complejo Termas de Medanos". On arrival, the fish were stocked in two plastic tanks of 100 L each, with constant aeration. Before farming, specimens were acclimated to the tank conditions. One hundred percent of the animals survived. Then, two P.V.C. frame cages (1,30 x 1 x 1 m) (Fig. 2) covered with 1 cm mesh nylon nets were built. In each cage, 100 juvenile tilapias were placed and the fattening trial started.

Work Procedures

Evaluation of the Physical and Chemical Characteristics of Hot Springs

First, a two-day campaign was conducted to evaluate water characteristics and suitability for tilapia culture. Sampling sites were located over the whole area of the water body (Fig. 3), to determine the most appropriate site for cages culture. In each sampling site, water quality parameters were recorded *in situ* (temperature, pH, salinity, and DO) at a depth of 50 cm using a "Horiba U 10" multi-sensory at different times (07:00 and 16:00) to observe the variations throughout the day. A water sample was also taken to determine the presence and amount of nutrients (nitrates, nitrites, un-ionized ammonia, phosphates, chlorophyll a and b, etc.). Chemical determinations were conducted according to APHA (1998).

The results of water conditions measurement were used to evaluate the characteristics of the water body using the Simplified Water Quality Index (SWQI) (Bazzini, 2012; Ocampo-Duque *et al.*, 2006). This index ranges from 0 (minimum quality) to 100 (maximum quality).

Figure 2. Floating cages employed during Nile tilapia fattening.

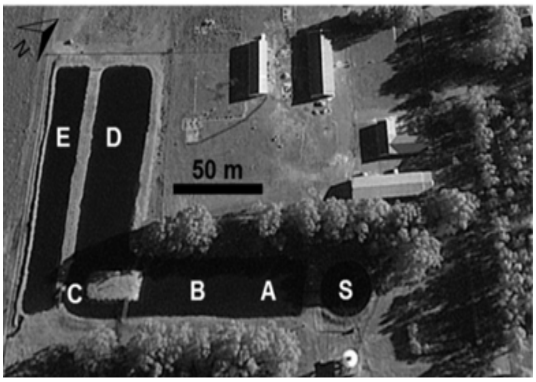

Figure 3. Location of the sampling sites "A", "B", "C", "D" and "E" defined in the water body. Cooling pool of the thermal spring "S".

Feeding and Sampling Protocols

The tilapia cultivation was carried out from January to May 2013. The nutritional requirements, amount of food and the feeding frequency were carried out according to Li *et al.* (2006), Riche *et al.* (2004), and Camacho-Berthely *et al.* (2000). The animals were fed with granulated commercial feed (Ganave S.A., Argentina) with 35% protein and grain size that varied from 5 to 10 mm, this feed complies with what was suggested by the aforementioned authors. The daily feed ration was divided into three portions (08:00, 12:00, and 17:00 hs). The biomass of the cages was determined every month to adjust the amount of food.

Specimen sampling was carried out monthly to evaluate growth, survival, and diet adjustment. In each sampling, 30 individuals per cage were randomly captured, after fasting for 24h. The specimens were anesthetized with an aqueous solution of benzocaine (1:10000). Fish size and weights were recorded. In addition, temperature, pH, and DO were determined *in situ*.

Data Analysis

Growth performance and feed utilization were assessed by the specific growth rate (SGR) and feed conversion ratio (FCR) as follows:

$$SGR = \frac{\ln FBW - \ln IBW}{T} \times 100$$

Note:
FBW = final body weight (g)
IBW = initial body weight (g)

$$FCR = \frac{FI}{WG}$$

Note:
FI = feed intake (g)
WG = wet weight gain (g)

The SWQI is the function of 5 most relevant physical and chemical parameters as follow:

$$SWQI = E(A + B + C + D)$$

Note:
E = water temperature with values ranging from 0.8 to 1 according to:
$T \leq 20°C$, E = 1
$T > 20°C$, E = 1-(T-20)·0.0125
A = particulate organic matter (POM) with values from 0-30 according to:
POM ≤ 5 mg/L, A = 30-POM
12 mg/L ≥ POM > 5 mg/L, A = 21-(0.35·POM)
POM > 12 mg/L, A = 0
B = suspended particulate matter (SPM) with values ranging from 0 to 25 according to:
SPM ≤ 100 mg/L, B = 25-(0.15·SPM)
250 mg/L ≥ SPM > 100 mg/L, B = 17-(0.07·SPM)
SPM > 250 mg/L, B = 0
C = dissolved O_2 (DO) with values ranging from 0 to 25 according to:
DO < 10 mg/L, C = 2.5·O_2
DO ≥ 10 mg/L, C = 25
D = conductivity (CE at 18 °C). If conductivity is measured at 25 °C, to obtain the conversion at 18 °C will be multiplied by 0.86 with values ranging from 0 to 20 according to:
CE ≤ 4000 µS/cm, D = (3.6-logCE)·15.4
CE > 4000 µS/cm, D = 0

Data on the individual weight recorded from each fish at the final sampling in both cages then compared to evaluate differences in the final weight gain using the Independent Samples t-Test (Sokal and Rohlf, 1995).

RESULTS AND DISCUSSION

Characterization of the Water Body

Selection for sites is likely to be the most important factor to determine the viability of experiments in aquaculture projects, being water quality and availability also essential to optimize production.

The most relevant criteria of water quality are temperature, dissolved oxygen concentration, acidity, alkalinity, and pH; however, the magnitude of these variable effects will depend on the species and the environmental conditions. The results of the campaign conducted in December 2012 showed that the water body the characteristics vary with the distance to the hot springs (Table 1 and Fig. 3). This variation is related to cooling undergone by water from the hot spring when it mixes with water in the pond. Parameter variation throughout the day does not show a wide range of values. In addition, the results of laboratory analysis on water quality do not show abnormal or dangerous (Table 2) (Bazzini, 2012). These findings demonstrate that water quality is suitable for the semi-intensive fish cage culture of *O. niloticus* because the physical and chemical parameters were at acceptable levels for the species (Azaza *et al*., 2008; El-Sayed, 2019).

Table 1. Results of the physical and chemical analyses "*in situ*" of the sampling sites (A-E) conducted during the evaluation of the physical and chemical characteristics of hot spring.

	Sampling sites									
	A		B		C		D		E	
	07:00 hs	16:00 hs	07:00 hs	16:00 hs	07:00 hs	16:00 hs	07:00 hs	16:00 hs	07:00 hs	16:00 hs
T (ºC)	45.8±1.6	40.0±1.7	31.5±5.8	32.0±0.5	27.7±3.2	27.8±0.5	22.0±0.1	24.1±1.2	23.4±0.2	25.8±1.7
DO (mg/l)	6.1±0.4	8.3±0.3	7.0±2.7	10.0±2.1	8.2±2.5	13.1±2.2	9.1±1.1	17.6±1.7	7.7±3.1	16.8±0.8
pH	8.7±0.2	8.8±0.1	9.2±0.1	9.0±0.5	9.2±0.1	9.5±0.1	10.1±0.1	9.9±0.4	9.5±0.2	98±0.2

Values are given as mean ± SD. n = 3 for all parameters. Variables recorded: dissolved oxygen (DO), temperature (T) and pH.

Also, the SWQI was estimated as 88, indicated a very good condition (APHA, 1998; Bazzini, 2012). Such an index includes the most important indicators to determine the ecological condition, under the criteria of the Water Quality Assessment (WHO, 1996). Considering the data obtained, the cages were placed in site B as a preselected location according to the physical and chemical characteristics of the water.

Table 2. Results of the laboratory analysis of the hot spring samples.

Parameters	Results
Total suspended solids	<10 mg/l
Fixed suspended solids	<10 mg/l
Volatile suspended solids	<10 mg/l
Chlorophyll *a*	4.0μ/l
phaeopigment	<1,0μ/l
Nitrate	4 mg/l
Nitrite	0.2 mg/l
Total Nitrogen	5 mg/l
Total Phosphorous	<0,1 mg/l
Ammonia	0.09g/l

Growth and Feed Utilization

Tilapia specimens (Fig. 4) were harvested in May 2013, after 140 days of fattening. Table 3 shows the results recorded for each cage. A comparison of mean values obtained by the t-Test for final weights of the specimens in each cage showed no significant differences between cages (p = 0.44; α = 0.05).

No differences were observed between the growth curves for each cage during the fattening period (Fig. 5). Harvested biomass was 39.8 kg and 39.1 kg for cages 1 and 2, respectively. The feeding rate in both cages ranged from 5% to 1.5% of the biomass according to Camacho-Berthely *et al.* (2000). FCR was 1.05 and 1.07, while SGR was 1.47 and 1.49 %/day for cages 1 and 2, respectively.

Figure 4. Tilapia harvest.

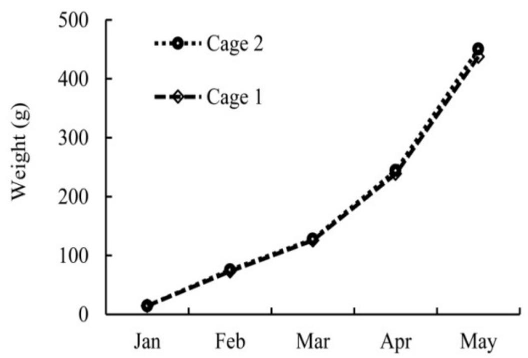

Figure 5. Growth curves in average weight throughout the experiment, fattening was carried out during 140 days. Model fit and quality indices.

Table 3. Tilapia *O. niloticus* weight, length, and survival at the end of the fattening trial.

	Weight (g)	Average weight gain (g)	TL (cm)	SL (cm)	Survival (%)
Cage 1	437.5±68.1	423.0	27.9±1.6	22.3±1.2	91
Cage 2	450.4±60.1	435.9	28.1±1.8	22.4±1.2	87

Values are given as mean ± SD. n = 30. TL (Total Length), SL (Standard Length).

The SGR values obtained revealed an optimal fish growth. These values were higher than those reported by Ridha (2006) and Githukia *et al.* (2015) of 1.01 %/day and 1.47 %/day, respectively. In addition, the FCRs observed in the present study indicate an excellent conversion compared with those reported by Ridha (2006), Githukia *et al.* (2015) and Ruiz Velazco Arce *et al.* (2006) of 1.40, 1.98 and 1.21, respectively. Also, after 140 days of fattening the weights, lengths and survival obtained were suitable for the experimental period. Moreover, the comparison of these results with those reported in other papers on similar fattening systems indicates our results are highly satisfactory (Yi *et al.*, 1996; Ruiz Velazco Arce *et al.*, 2006) since it would be possible to perform at least to annual harvests. It should be highlighted that the present study represents the first Nile tilapia culture in thermal waters conducted in Argentina and the southernmost experimental culture of this species.

CONCLUSION

The experimental fattening carried out during 140 days revealed that the thermal waters of the analyzed region are suitable (temperature, pH and DO) for cultivating Nile Tilapia, obtaining commercial weights in a short time. However, an experimental fattening of approximately one year should be carried out to observe the behavior of the species in terms of growth and survival at other times of the year and evaluate its feasibility on a larger scale.

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