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Effects of Temperature and Salinity on the Growth Performance and Survival of Blue Tilapia Oreochromis Aureus (Steindachner, 1864)

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تأثير درجة الحرارة وتركيز الملوحة في نمو أسماك البلطي الأزرق Oreochromis aureus (Steindachner، 1864) وبقائها

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تركيز الملوحة، درجة الحرارة، معدل البقاء، نسبة التحويل الغذائي، نظام تدوير المياه، النمو

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ABSTRACT

The present study evaluates the effects of temperature (18 and 30°C) and salinity (1.2, 10, and 20 g/l) on the growth and survival rate of blue tilapia *Oreochromis aureus* (Steindachner, 1864) fingerlings. The average weight of 5.19 ± 0.09g of each fingerling was cultured in the Recycle Aquaculture System (RAS), which consisted of 18 plastic tanks with a water volume of 54 litres, for 70 days (December 18th to February 23rd). The results showed that more than 80-100% of the fish survived at 1.2 to 20g/l salinity and at both temperature treatments. The results showed an increase in the growth of tilapia with increased temperature in low salinity (1.2 and 10 g/l) and a decrease in growth with higher salinity (20g/l). The best food conversion rate (FCR) was 2.6157 ±0.2002 and 2.9865 ±0.0114 at treatments of 30 and 18°C respectively with salinity of 10g/l. The study concluded that temperature and salinity have an effect on the growth performance and survival rate of blue tilapia fingerlings. The ability of blue tilapia to use saline water up to 10g/l makes it an ideal candidate for brackish water production. Therefore, blue tilapia may be an alternative species for aquaculture in southern Iraq.

الملخص

أجريت هذه الدراسة لتقييم تأثير درجة الحرارة (18 و30 °م) وتركيز الملوحة (1.2و 10.0 و20.00جم/لتر) في نمو اصبعيات أسماك البلطي الأزرق *Oreochromis aureus* (Steindachner,1864) وبقائها. استخدمت 180 سمكة بمتوسط وزن 5.019 ± 0.09 جم. تم تربيتها في نظام إعادة تدوير الماء Recycle Aquaculture System (RAS) والمتكون من 18 حوض بلاستيكي بحجم 54 لتر. استمرت التجربة لمدة 70 يوما (18 ديسمبر –23 فبراير). أوضحت النتائج أن معدل البقاء تراوح بين 80-100٪ عند تركيز ملوحة 1.2 - 20.0 جم / لتر. أظهرت النتائج زيادة في نمو اسماك البلطي مع زيادة درجة الحرارة في تركيز الملوحة (1.2و10.0 جم / لتر) وانخفاض في النمو مع تركيز الملوحة (20.0جم / لتر). بلغ أفضل معدل تحويل غذائي 2.6157 ± 0.2002 و2.9865 ± 0.0114 في درجة حرارة 30 و18 °م على التوالي عند تركيز ملوحة 10.0 جم / لتر وأعلى معدل بقاء 100% في درجات الحرارة (18 و30°م) وتراكيز الملوحة (1.2 و10.0جم/ لتر). استنتجت الدراسة وجود تأثير ملحوظ لدرجة الحرارة وتركيزات الملوحة على أداء النمو ومعدل البقاء لأسماك البلطي الأزرق، وأنه يتحمل مديات ملوحة واسعة، مما يجعل لهذا النوع من الأسماك إمكانية جيدة للنمو في مياه ذات درجات ملوحة مختلفة، وأن قدرة هذه الاسماك على النمو في مياه ذات درجة ملوحة تصل حتى 10 جم / لتر، يجعلها من الأسماك المرشحة للاستزراع المائي في جنوب العراق.

1. Introduction

Land-based and offshore aquaculture operations are on the increase worldwide (Peterson *et al.*, 2005: Stickney 2017). Iraq is one of the least developing countries lacking aquaculture in brackish or semi-saline waters, and the aquaculture is restricted to freshwater only. Due to the scarcity of fresh water, especially in southern Iraq, fish species living in brackish or semi-saltwater have been selected for improved aquaculture production. Tilapia, of the genus *Oreochromis,* are commonly distributed in the wild and grown in fish farms due to their hardy disposition, fast growth rates and resistance to different salinity conditions (Pullin, 1991). Blue tilapia (*O. aureus*, Steindachner, 1864) have entered Iraqi water in the last few years (Mutlak and Al-Faisal, 2009) and been targeted to test the validity of its culture in the waters of Basrah in southern Iraq. Therefore, the first candidate that one may consider for aquaculture in brackish water and seawater is tilapia. Blue tilapia is known to be one of the most popular aquaculture species in many countries around the world (Jauncey and Ross, 1982: El-Sayed, 2006) that can feed from low on the food chain and accept artificial feed (El-Sayed and Teshima,1992). They also have a high resistance to temperature, salinity and dissolved oxygen depletion; they can survive within a thermal range of 8-41° C. (Trewavas, 1983). This species can culture in freshwater, brackish, semi-saltwater and seawater of 36ppt. (McGeachin *et al.*, 1987), which makes their culture an alternative solution to the challenges of freshwater depletion and pollution in estuaries and coastal waters. This genus is described as herbivores accompanied by phytoplankton, a small proportion of zooplankton and a small section of vertebrates. (De Moor and Bruton 1988; Lamboj, 2004). They also have a female nursery for larvae in the mouth (mouth breeder) existing in warm waters, rivers, lakes and springs (Page and Burr, 1991; Suresh and Lin, 1992). However, limited information is available on the cultivation of this species of tilapia in brackish water and seawater compared to the vast volume of knowledge available on their cultivation in freshwater. This study aims to determine the effects of the combined factors of temperature and salinity for the cultivation of blue tilapia fingerlings and investigate their growth performance and survival rate, in turn, to provide an additional source of income.

2. Material and Methods

2.1. Description of the Experiment:

One hundred and eighty blue tilapia fingerlings (Steindachner, 1864) were collected from earthen ponds at the Marine Sciences Centre, University of Basrah, Iraq. On December 4th, the fish were transferred to the marine vertebrate laboratory and kept in 54-litre plastic tanks for acclimation, each of which was stocked with ten fingerlings, using 2×3 factorial experiments of six treatments, two different temperatures (18 and 30°C) and three levels of salinity (1.2, 10 and 20g/l) as follows: T1(temperature 18°C/salinity 1.2g/l), T2 (temperature 18°C/salinity 10g/l), T3 (temperature 18°C/salinity 20g/l), T4 (temperature 30°C/salinity 1.2g/l), T5 (temperature 30°C/salinity 10g/l) and T6 (temperature 30°C/salinity 20g/l). Sea salt was used to prepare the required level of salinity at 10 and 20g/l by adding it to the local municipal water. To adjust the water temperature in the experiment, automatic heaters with thermostats were used to obtain the required temperatures. The study was

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conducted at a Recycle Aquaculture System (RAS) consisting of 18 plastic tanks of 54 litres supplied with both mechanical and biological filtration for each treatment. The experiment lasted for 70 days, from December 18th to February 23rd. The fish were fed an artificial diet containing 35% protein, 8.84% lipid, 0.26% moisture, 13.26% minerals and 42.64% carbohydrates once daily at 5% of their body weight for five days a week. Changes in their weight were measured every 14 days from the beginning of the experiment; growth performance parameters were estimated per treatment as weight gain (WG), specific growth rate (SGR), relative growth rate (RGR), food conversion ratio (FCR) and food conversion efficiency (FCE), based on the following standard formulas:

- WG (g) = final mean weight – initial mean weight. SGR (%/day) = [ln (final weight) – ln (initial weight) / total days of experiment] × 100.
- RGR (%) = final weight – initial weight/initial weight) × 100
- FCR = (weight of food/fish/day) x total days of feeding) / WG.
- FCE (%) = WG / [(weight of food/fish/day) × total days of feeding] × 100
- Survival rate (SR%) = number of surviving fish/number of fish at the beginning of experiment ×100.

Temperatures (°C), pH, and dissolved oxygen (mg/l) were recorded during the experiment period once daily. Means of the water quality parameters measured throughout the experimental period are summarized in table 1. Water temperature and salinity were relatively stable and varied by less than 1.1ºC and 1.18g/l. The measured dissolved oxygen (7.30 ± 0.81 to 8.54± 1.04mg/l), and the pH (7.24 ±0.19 to 7.93 ± 0.72).

Table 1. Water quality parameters during the experimental period (Mean ± SD).

Treatments	Temperature °C	Salinity (g/l)	Dissolve Oxygen (mg/l)	pH
T1	18± 1.1	1.2 ± 0.6	8.54± 1.04	7.24 ±0.19
T2	18 ± 1.1	10 ± 1.4	8.37 ± 0.88	7.48 ± 0.03
T3	18 ± 1.1	20 ± 1.8	8.04 ± 0.09	7.65 ± 0.16
T4	30 ± 0.9	1.2 ± 0.6	7.76 ± 1.05	7.74 ± 0.71
T5	30 ± 0.9	10 ± 1.4	7.59 ± 0.27	7.79 ± 0.19
T6	30 ± 0.9	20 ± 1.8	7.30 ± 0.81	7.93 ± 0.72

2.2. Statistical Analysis:

All statistical analyses were performed with IBM SPSS version 22 (Arlington, Virginia) and complete randomized design (CRD), at a significant level of ≤ 0.05, and the least significant difference (LSD) was used to compare different treatments.

3. Results

3.1. Effects of Temperature and Salinity on Survival Rate:

There was some mortality (3–4 fingerlings) during the trial time. During the 70-day rearing period, treatments of 1.2 to 10g/l showed the highest survival levels, while 20g/l showed the lowest survival rate of 80–85% (table 2).

Table 2. Survival rate (%) of O. aureus fingerlings at different temperatures (°C) and salinity (g/l) levels.

Treatments	Survival rate (%)
T1	100
T2	100
T3	80
T4	100
T5	100
T6	85

3.2. Effects of Temperature and Salinity on Fish Weight Gain:

Weight of fish was significantly (P<0.05) influenced by water temperature and salinity. Initial mean weights did not differ significantly (P>0.05) among treatments. Over the 70-day experimental period, the final body mean weight was highest (P<0.05) in the T5 and T2 treatments, followed by the T4 and T1 treatments, and the lowest final body weight was recorded in the T6 and T3 treatments (table 3). Mean weight gain was lowest (P<0.05) in the T3 treatment, followed by the T6 treatment. No significant differences (P<0.05), in weight gain were observed between the T5 and T2 treatments. Fish in the T5 treatment showed a weight gain that was approximately double that of the other treatments (T1, T3, T4, and T6) over the experiment period.

Table 3. Initial, final, and weight gain (g) of O. aureus fingerlings at different temperatures (°C) and salinities (g/l).

Treatments	Initial weight (g)	Final weight (g)	Weight Gain (g)
T1	5.26±1.36	9.79±1.09^{bc}	4.53 ±0.27^{c}
T2	5.01±0.38	11.86±1.34^{ab}	6.85 ±0.96^{ab}
T3	5.17±0.31	8.41±1.33^{c}	3.24 ±1.02^{c}
T4	5.22±0.16	10.17±1.53^{bc}	4.95 ±1.46^{bc}
T5	5.19±0.16	13.71±1.62^{a}	8.52 ±1.46^{a}
T6	5.30±0.28	8.89±1.45^{c}	3.59 ±0.94^{c}

The values above are means of triplicate data; mean ± SD within the same column with different superscripts is significantly different (P<0.05).

3.3. Effects of Temperature and Salinity on the Fish-Specific Growth Rate (SGR) and Relative Growth Rate (RGR):

The highest SGR was found in *O. aureus* fingerlings (1.3814 ±0.1256, and 1.2203 ±0.0544%g/day) at T5 and T2 than other treatments. The SGR value markedly decreased in T3; however, the lowest SGR (0.6847 ±0.1423%g/day) %g/day) was observed in T3 (table 4). The average relative growth rate (RGR) of *O. aureus* similarly decreased like SGR in T3, T1, and T6. The highest RGR (163.6872 ±23.0957) was found in T5 compared with other treatments. No significant differences (P<0.05) of RGR values were observed between T5 and T2. The lowest RGR was detected (62.0284 ±16.0387) in T3.

Table 4. Specific growth rate (SGR %g/day), and relative growth rate (RGR %) (Mean ± SD) of O. aureus fingerlings at different temperatures (°C) and salinities (g/l).

Treatments	Specific growth rate (SGR % day)	Relative growth rate (RGR%)
T1	0.9011 ±0.2179^{bc}	89.3902 ±29.2092^{b}
T2	1.2203 ±0.0544^{a}	135.0772 ±8.9419^{a}
T3	0.6847 ±0.1423^{c}	62.0284 ±16.0387^{b}
T4	0.9409 ±0.1377^{b}	93.8144 ±23.0957^{b}
T5	1.3814 ±0.1256^{a}	163.6872 ±23.0957^{a}
T6	0.9071 ±0.0711^{b}	88.8541±9.3711^{b}

The values above are means of triplicate data; mean ± SD within the same column with different superscripts is significantly different (P<0.05).

3.4. Effects of Temperature and Salinity on Feed Utilization:

Increasing trends of feed conversion ratio (FCR) were found with decreasing temperature. Significantly lower FCR was found in *O. aureus* reared at 20g/l salinity and 18°C (5.1835 ±0.8146) than that of other treatments. The better (lower is better) FCR values were 2.6157 ±0.2002 and 2.9865 ±0.0114 in T5 and T2 treatments respectively (table 5). The average food conversion efficiency (FCE) of *O. aureus* decreased at a similar rate to food conversion ratio (FCR) in T3, T1, and T6 when compared with other treatments. The highest FCE (38.3786 ±2.9084%) was found in T5. No significant differences (P<0.05) in FCE values were observed between T5 and T2. The lowest RGR (19.6019 ±2.9712 %) was detected in T3.

Table 5. Feed conversion ratio, FCR (Mean ± SD) and food conversion efficiency, FCE%, (Mean ± SD) of O. aureus fingerlings after 70 days of the rearing period.

Treatments	Food Conversion Rate (FCR)	Food Conversion Efficiency (FCE%)
T1	4.0385 ±0.4817^{c}	25.0011b ±3.0254^{c}
T2	2.9865 ±0.0114^{ab}	33.4837 ±0.1286^{a}
T3	5.1835 ±0.8146^{d}	19.6019 ±2.9712^{c}
T4	3.9794b ±0.7966^{c}	25.7880 ±4.9663^{b}
T5	2.6157 ±0.2002^{a}	38.3786 ±2.9084^{a}
T6	3.7647±0.3447^{bc}	26.7089 ±2.4114^{b}

The values above are means of triplicate data; mean ± SD within the same column with different superscripts is significantly different (P<0.05).

4. Discussion

Physicochemical factors impacting tilapia in the wild or under aquaculture conditions include salinity, temperature, dissolved oxygen, ammonia and nitrite, pH, photoperiod and water turbidity. Nonetheless, salinity and temperature are the two most important considerations (El-Sayed, 2006). The effects of the relationship between salinity and temperature on fish growth efficiency, survival rates, and associated physiological parameters are complex and usually not well understood (Imsland *et al.*, 2001). The cold resistance of tilapia produced under various salinities is unique to the genus. *O.*

aureus demonstrated reduced growth and survival at lower temperatures (El-Sayed, 2006). The present study shows that there is a lower growth efficiency observed at a water temperature of 18°C, compared to 30°C. Watanabe *et al.* (2007) found that the growth and survival of fish are not affected at various salinity levels when the temperature reaches 27°C, but the salinity has a major impact at temperatures below 25°C. Likongwe (2002) stated that temperature has an effect on salinity tolerance because they fluctuate in nature together and may have a positive or negative effect on the growth and survival rate of cichlids. The results of this study show that *O. aureus* can tolerate an environment of 1.2 to 20g/l salinity. El-Sayed (2006) reported that *O. aureus* is less tolerant to saline, but can grow well at a salinity of 36 to 44g/l, while reproduction occurs at 19g/l. In contrast, Balarin and Haller (1982) reported low growth and high mortality at 36g/l. Similarly, McGeachin *et al.* (1987) found that *O. aureus* reared in seawater cages (36g/l) showed a rapid decrease in growth rates. Different growth output in terms of final body weight (FW), weight gain (WG), specific growth rate (SGR %g/day), relative growth rate (RGR %), feed conversion ratio (FCR) and feed conversion efficiency (FCE %) were reported at different salinity rates, suggesting that the fish were perfectly capable of controlling their body physiology under this regime. The survival rate of 80–100 % in 1,2, 10, and 20g/l salinity suggests that *O. aureus* can well survive in these salinity levels, which may be due to the tendency of body fluids to work abnormally in the range of internal osmotic and ion concentrations. As mentioned by Nugon (2003), juveniles of *O. aureus*, *O. niloticus* and Florida red tilapia demonstrated excellent survival (> 81%) in salinity regimes of up to 20g/l, with modest survival of *O. aureus* (54%) at 35g/l salinity. The FCR values found in fish reared at 1.2, 10, and 20g/l indicate a strong growth rate. Better FCR (2.6157 ±0.2002 and 2.9865 ±0.0114) was obtained with 10g/l at 30 and 18°C. The efficiency of feed conversion depends on several factors, but the best method is to customize the environment to approximate that to which the fish is adapted (Bashamohideen and Parvatheeswararao, 1976). In terms of specific growth rate (SGR), the highest SGR (1.3814 ±0.1256) was detected in T5, but SGR decreased with increasing salinity above 10g/l (0.6847 ±0.1423 at 20g/l salinity at 18°C). This result is similar to the observation made by Ficke *et al.* (2007) that each species of fish has an optimum temperature range for growth performance; for warm water fish or fish in tropical regions, the optimum temperature for growth usually varies from 20 to 32°C. The relationship between temperature and growth is defined by the influence of the thermal growth coefficient (Schulte, 2011), by which metabolic rates increase in warmer temperatures, resulting in faster growth rates at higher temperatures. Higher RGR (163.6872 ±23.0957%) was recorded in 10g/l salinity at 30°C and lower RGR (62.0284 ±16.0387 %) was found in 20g/l salinity at 18°C. The higher RGR of the fish shows that the fish were able to control the osmotic pressure of the body fluid; this follows the recommendations suggested by Nikolsky (1963); the greater the osmoregulatory adaptation, the smaller the difference between the concentrations and pressures of the internal fluid of the body and the external environment. For aquaculture purposes, the results of this study indicate that *O. aureus* fingerlings can be cultivated in an aquatic environment with salinity levels ranging from 1.2 to 20g/l, which indicates high production and improved economic return. However, the most favoured salinity was 10g/l. This may be the reason for isosmotic water that reduces the use of osmoregulation energy compared to freshwater and saltwater. This energy saving is being used for growth purposes.

5. Conclusion

It can be assumed from this study that the growth efficiency, food consumption and survival rate of blue tilapia, *O. aureus* are influenced by salinity and temperature, as well as the combination of these factors. As a result, the present study has shown that blue tilapia can tolerate salinity of up to 20g/l with a reasonable survival rate. It was recommended that growth rate and food utilization at 10g/l salinity are better than in freshwater. The ability of blue tilapia to use low and moderate salinity water up to 10g/l makes it the ideal candidate for brackish water production. Therefore, tilapia, *O. aureus* may be an alternative species for aquaculture in southern Iraq.

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