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Effects of Tilapia Stocking Densities on Fish Growth and Water Quality in Tanks

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Abstract

The effects of feed input and stocking density (1, 5, 10 and 15 $kg \cdot m^{-3}$) of hybrid tilapia (*Oreochromis niloticus x O. aureus*) on growth and water quality were investigated. Each density treatment was replicated three times, and stocking densities were restored by removing fish at 14-day intervals. Fish were fed a 34% protein tilapia feed to satiation within 30 min twice daily. Both feeding rates (% body weight$\cdot day^{-1}$) and percentage increase in biomass decreased significantly with increasing stocking density, but feed conversion efficiency was not significantly affected. Ammonia nitrogen, nitrite nitrogen and total phosphorus increased while DO decreased as the stocking density of fish and feed input increased. There were no significant effects of stocking densities and feed input either on nitrate nitrogen concentrations or pH of the water.

Introduction

In Saudi Arabia tilapia farming is mostly intensive it being practiced in concrete and fiberglass tanks with 100% artificial feed input and usually with a target production of 10-15 kg fish$\cdot m^{-3}$. Under these intensive conditions, the tanks are aerated, and 20 to 100% of water is exchanged daily, depending on the stocking density of the fish (Siddiqui and Al Najada 1992). Production targets are frequently not met, and many tilapia farmers report reduced fish growth and production in a high density culture. Siddiqui et al. (1991) reported that water quality (ammonia, nitrite, dissolved oxygen) deteriorated and the growth of *Oreochromis niloticus* decreased when rates of water exchange were reduced. Further, Siddiqui and Al-Harbi (1999) reported that feed conversion efficiency of hybrid tilapia (*O. niloticus x O. aureus)* was low in a high density culture, and much of the feed input appeared as toxic metabolites.

The present study was conducted to examine the effects of stocking density and feed input on fish production and water quality parameters in tanks with a water residence of 24 h.

Materials and Methods

Twelve fiberglass indoor tanks (1.5 m x 1 m x 1 m), each filled with 500 l water were stocked with F_1 hybrids of tilapia (*Oreochromis niloticus x O. aureus)* ($\bar{x}$ = 81 g) at stocking densities of 1, 5, 10 and 15 $kg \cdot m^{-3}$. The fish were fed a 34% protein tilapia feed (protein 34%, fat 4%, fiber 3%, ash 11%) in floating pellet form to satiation within 30 min twice daily (0900 and 1500 hr.), six days a week. All tanks were uniformly aerated. Each tank was drained and filled with freshwater every morning between 0700 and 0800 hr. After 14 days rearing, all the fish in each tank were caught and weighed. Original stocking density was restored by removing fish from each tank at 14 day intervals. This procedure was repeated five times. No fish were removed in tanks with 1 kg $fish \cdot m^{-3}$ in the second (26.11 to 10.12) and the fourth (24.12 to 7.1) repetitions, as increase in biomass were only 60 g and 50 g, respectively.

Maximum-minimum temperatures were recorded daily in one tank. For water analysis, samples from the inflow pipe and culture tanks (before any exchange of water) were collected on alternate days before the water exchange. Dissolved oxygen (DO) and pH were measured using Hach Oxygen and pH meters (Hach Co., Loveland, Colorado). Ammonia nitrogen (NH_3-N), nitrite nitrogen (NO_3-N), nitrate nitrogen (NO_2-N) and total phosphorus (TP) were determined following the methodology of APHA (1989).

The results were subjected to a one way analysis of variance (ANOVA) while least significant difference (LSD) range test was used to compare treatment means. Percentage data were arcsine transformed prior to analysis (Zar 1974). The correlations between daily feed input and ammonia, nitrite, total phosphorus and oxygen concentrations were investigated by using at least 40 data sets employing simple linear regression. A Statgraphic's software package was used for data analysis at 0.05 significance level.

Results

The feed consumption (% body $weight \cdot day^{-1}$) significantly decreased with increasing density of tilapia (Table 1), but the daily feed input in the tanks progressively increased, being 10.2 g, 45.9 g, 81.2 g and 94.9 g for tanks stocked with 1 kg, 5 kg, 10 kg and 15 kg $fish \cdot m^{-3}$, respectively. Increase in biomass in 14 days was the highest (12.2%) for fish stocked at the lowest density (1 $kg \cdot m^{-3}$), and was significantly different from fish stocked at 10 and 15 $kg \cdot m^{-3}$. No significant difference was found in biomass increase between fish stocked at 1 and 5 $kg \cdot m^{-3}$, and between 5 and 10 $kg \cdot m^{-3}$. Feed conversion ratios (FCR) were almost the same in all treatments (Table 1).

Water quality measurements are given in table 2, which show that water quality was significantly influenced by fish stocking density. Dissolved oxygen concentration was recorded to be decreasing with increasing density and feed input. The relationship between DO and feed input is described by the equation:

$$Y = 5.71 - 0.0254\ X, \quad r = -0.92$$

where Y is DO and X is daily feed input. The concentration of both NH_3-N and NO_2-N increased linearly with increasing fish density and daily input of feed. The correlation between daily feed input and NH_3-N and NO_2-N is described by the following equations:

$$Y1 = -0.0348 + 0.0048\ X, \quad r = 0.94$$

$$Y2 = 0.1739 + 0.0037\ X, \quad r = 0.87$$

where Y1 and Y2 are ammonia and nitrite nitrogen and X is daily feed input. The concentration of nitrate nitrogen did not vary significantly among tank

Table 1. Mean + SD (range) increase in biomass, feed consumption rate and feed conversion ratio (FCR) of hybrid tilapia cultured at four stocking rates. Means are from five average values of five 14 days experiments. Means in a column with different letters are significantly different ($P < 0.05$).

Stocking rate ($kg \cdot m^{-3}$)	Increase in biomass (%)	Feed consumption rate (% $bw \cdot day^{-1}$)	FCR
1	12.2 + 2.1 a	2.0 + 0.3 a	2.0 + 0.3 a
	(9.7 - 15.6)	(1.8 - 2.5)	(1.9 - 2.2)
5	10.6 + 2 ab	1.8 + 0.2 b	2.0 + 0.4 a
	(8.6 - 12.7)	(1.7 - 2.1)	(1.9 - 2.3)
10	9.9 + 1.9 b	1.6 + 0.1 c	2.0 + 0.2 a
	(8.1 - 10.7)	(1.5 - 1.7)	(1.9 - 2.1)
15	7.8 + 1.6 c	1.3 + 0.1 d	2.2 + 0.1 a
	(5.7 - 10.4)	(1.0 - 1.3)	(1.6-2.4)

FCR = dry feed fed (g) / wet weight gain (g).

Table 2. Effect of stocking density on water quality. Measurements are averages of five repeated experiments. Means in a row with different letters are significantly different ($P < 0.05$).

Parameters	Inflow water	Stocking rate ($kg \cdot m^{-3}$)			
		1	5	10	15
Feed Consumption	-	10.2	45.9	81.2	94.5
Max. temp., °C	27.1 + 1.0	25.2 + 1	-	-	-
	(25.9 - 27.3)	(23 - 27)	-	-	-
Min. temp., °C	-	17.8 + 1.5	-	-	-
		(16-24)			
DO, $mg \cdot l^{-1}$	4.8 + 0.3 b	5.5 + 0.3 a	4.6 + 0.5 b	3.7 + 0.3 c	3.3 + 0.2 c
	(4.4 - 5.0)	(4.9 - 5.8)	(3.9 - 5.30)	(3.2 - 4.0)	(3.0 - 3.5)
pH	7.3 + 0.1 b	8.2 + 0.1 a	8.0 + 0.1 a	7.9 + 0.1 a	7.9 + 0.1 a
	(7.2 - 7.4)	(8.1 - 8.2)	(7.8 - 8.2)	(7.7 - 7.9)	(7.7 - 7.9)
NH_3-N	0	0.04 ± 0.01 d	0.14 ± 0.02 c	0.31 ± 0.10 b	0.47 ± 0.10 a
		(0.02 - 0.06)	(0.11 - 0.18)	(0.25 - 0.41)	(0.39 - 0.52)
NO_2-N	0	0.20 ± 0.02 c	0.36 ± 0.04 b	0.46 ± 0.10 a	0.52 ± 0.10 a
		(0.17 - 0.24)	(0.30 - 0.42)	(0.34 - 0.56)	(0.41 - 0.61)
NO_3-N, $mg \cdot l^{-1}$	16.8 + 0.6	16.6 + 0.8 a	17.2 + 0.6 a	17.4 + 0.1 a	17.4 + 0.6 a
	(16.2 - 17.7)	(15.5 - 17.4)	(16.5 - 18.1)	(16.8 - 18.0)	(16.6 - 18.5)
TP, $mg \cdot l^{-1}$	0.06 + 0.01	0.14 ± 0.04 c	0.45 ± 0.20 b	0.72 ± 0.20 a	0.85 ± 0.20 a
		(0.08 - 0.19)	(0.15 - 0.69)	(0.45 - 1.08)	(0.59 - 1.00)

water of different treatments indicating that the main source of nitrate nitrogen was inflow water. Total phosphorus concentration was positively correlated with feed input as described by the following equation:

$$Y3 = 0.0619 + 0.0083\ X, \quad r = 0.84$$

where Y3 is total phosphorus and X is daily feed input. The pH of the inflow water was lower than the pH of tank water, and there was no significant difference in the pH of different tanks (Table 2).

Discussion

Decline in fish growth rate and feed utilization with increasing levels of stocking densities has been observed in several studies (Vijayan and Leatherland 1988; Suresh and Lin 1992). Similarly, an increase in net yields with increasing levels of stocking densities has also been recorded (Honer et al. 1987; Suresh and Lin 1992).

In this study the feed consumption rate was found to be affected by the stocking density of fish and decreased with increasing levels of fish density. However, the amount of feed input increased with the increasing density. Vijayan and Leatherland (1988) have also observed a similar reduction in feed consumption with increasing fish stocking densities and suggested that this might directly lead to growth depression. It has been observed that animal under stress need to spend more energy for homeostatic processes (Scherek 1982). The decreased feed utilization, therefore, might be an indicator of the higher level of stress encountered by the fish at higher densities. Maximum increase in fish biomass was found at the lowest stocking density and decreased with increasing density because of better feed utilization and unstressed conditions at low stocking levels. The feed conversion ratios were recorded to be almost the same for different density treatments. Suresh and Lin (1992) have reported similar findings where feed conversion ratios of the individual fish were not significantly different and suggested that stress beyond a level might elicit response of equal magnitude.

Dissolved oxygen concentrations in tanks of different stocking densities were never recorded below 3 $mg \cdot l^{-1}$ because the tanks were continuously aerated. For *O. niloticus* reared under different culture systems, oxygen levels of 3 $mg \cdot l^{-1}$ and above have been recommended (Coche 1982; Ross and Ross 1983). Siddiqui et al. (1991) reported a decrease in DO concentrations with decreasing rates of water exchange in *O. niloticus* tank culture, whereas no effect of three stocking densities (final biomass 5.3 kg, 10.4 kg, 13.2 $kg \cdot m^{-3}$) was found on dissolved oxygen concentrations when a continuous water flow of 1 $l \cdot min^{-1} \cdot kg^{-1}$ biomass was maintained through the tanks (Siddiqui et al. 1989).

NH_3-N exists in ionized (NH_4^+) and unionized (NH_3) forms in the water and is a highly toxic metabolic waste of fish particularly in its later form. The proportion of NH_3-N to ionized form depends upon the pH and temperature of the water. The higher are the pH and temperature, the higher is the percentage of toxic unionized ammonia (Lawson 1995). During this study, NH_3-N values significantly increased as the fish density and feed input increased and average NH_3-N concentrations ranged from 0.04 to 0.47 $mg{\cdot}l^{-1}$. We can calculate the value of NH_3-N at maximum pH and temperature recorded during this study by using the formula of Huguenin and Colt (1989) as follows:

unionized ammonia ($mg{\cdot}l^{-1}$ as NH_3-N) = (a) (TAN)

where (a) = mole fraction of unionized ammonia; and (TAN) as NH_3-N

The range of unionized ammonia at maximum temperature and pH recorded during this study is calculated to be 0.002 - 0.030 $mg{\cdot}l^{-1}$ that is well below the lethal level reported for *O. aureus* (Redner and Stickney 1979).

Average NO_2-N concentrations ranged from 0.2 to 0.52 $mg{\cdot}l^{-1}$ in the tanks of different density treatments that is lower than the lethal level. Lethal levels of nitrite nitrogen for *O. aureus* are reported to be 16 $mg{\cdot}l^{-1}$ to 96-h LC_{50} and 31 $mg{\cdot}l^{-1}$ to 24-h LC_{50} (Palachek and Tomasso 1984). *O. aureus* and channel catfish are reported to be similar in nitrite nitrogen sensitivity (Lewis and Morris 1986), and a concentration of 0.30 mg NO_2-$N{\cdot}l^{-1}$ caused 20% methemoglobin in channel catfish (Tomasso et al. 1979). Therefore, in high density tilapia culture the effect of nitrite nitrogen on the oxidation of hemoglobin to methemoglobin, which is not an effective oxygen carrier, need to be investigated.

Results of this study show that the density of fish and rate of feed input had significant influence on water quality and a high density culture accompanied by intensive feeding may result in high concentrations of ammonia nitrogen, nitrite nitrogen and phosphorus, and low concentrations of dissolved oxygen in the tank water. Higher stocking density negatively affects the feeding rates and percentage increase in biomass, however, feed conversion ratios is not significantly affected, therefore, higher net yields could be expected at higher densities provided that water quality is properly managed.

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