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Suitable stocking density of tilapia in an aquaponic system

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Abstract
An aquaponic system was studied through the integrated culture of mono-sex GIFT and two types of vegetables *viz.* morning glory, *Ipomoea reptans* and taro, *Colocasia esculenta* in a recirculating system for 15 weeks. Tilapia fry of uniform size of 0.76 g were released in three treatments (stocking densities): 106 fish/m^3 (T_1), 142 fish/m^3 (T_2) and 177 fish/m^3 (T_3) to assess the effect of stocking density on the growth performance of fish. Fish were fed with a commercial feed containing 25% protein. Weight gain (g) of tilapia ranged from 19.41 to 32.67 g and was inversely related with stocking density. Percent weight gain varied between 2553.99 and 4298.68 % and was significantly different among the treatments. SGR ranged from 3.09 to 3.59 % per day and varied significantly. FCR varied from 2.19 to 2.69 and had a positive correlation with stocking density. The highest survival rate (%) was achieved in T_1 (99%) followed by T_2 (98%) and T_3 (96%). Production of fish ranged from 3.43 to 3.52 kg/m^3 and was inversely related with stocking density. The present study demonstrated that 106 fish/m^3 was the best stocking density in terms of growth, food conversion ratio, survival and production for tilapia culture in the aquaponic system.

Key words: Aquaponics, Mono-sex tilapia, Stocking density

Introduction

Aquaponics is a bio-integrated system that links recirculating aquaculture with hydroponic (growing plants in a media without soil) vegetable, flower, and/or herb production. In aquaponics, nutrient-rich effluent from fish tanks is used to fertilize hydroponic production beds. This is good for the fish because plant roots and rhizobacteria remove nutrients from the water. These nutrients– generated from fish manure, algae, and decomposing fish feed– are contaminants that would otherwise build up to toxic levels in the fish tanks, but instead serve as liquid fertilizer to hydroponically grown plants. In turn, the hydroponic beds function as a biofilter– stripping off ammonia, nitrates, nitrites, and phosphorus– so the freshly cleansed water can then be recirculated back into the fish tanks. The nitrifying bacteria living in the gravel and in association with the plant roots play a critical role in nutrient cycling; without these microorganisms the whole system would stop functioning. The stocking density of fish in the aquaponic system is very important for the proper functioning of the system. Stocking density of fish should be optimum to maintain the water quality suitable for fish and plant growth. Hence, the present study was conducted to observe the effects of stocking density on the growth and production parameters of tilapia in an aquaponic system and to determine a suitable stocking density.

Materials and methods

The experiment was carried out in an existing recirculating aquaculture system located at Faculty of Fisheries, Bangladesh Agricultural University, Mymensingh. The duration of the experiment was 15 weeks during April to August' 2009. Fry of mono-sex tilapia (*Oreochromis niloticus*) belonging to the same age group were collected from local hatchery of Mymensingh. The fry were acclimatized for seven days prior to the experiment. Two common vegetables (Morning glory, *Ipomoea reptans* and Taro, *Colocasia esculenta*) were selected for the experiment.

Experimental system

The system consisted of 12 equal sized cisterns and 2 smaller ones. Each cistern had inlet and outlet facilities connected to the bio-filter system which was located along the east and south sides of the system. The substrates of the bio-filter consisted of styrofoam, gravels, PVC nets and shells of mussels. The pump house was located at the south-eastern side of the system. The pumping unit consisted of two water pumps which ran alternatively for six hours to ensure continuous water flow and aeration.

Nine cisterns of uniform size were selected for conducting the experiment. The cisterns had a length, width and depth of 2.06 m, 1.8 m and 0.94 m respectively. So each cistern had an area of 3.708 m^2 and a volume of 3.486 m^3. Water level in the cisterns was adjusted at a depth of 0.76 m to maintain the water volume of 2.82 m^3. The desired level of water in the system was maintained by continuous recirculation of water at a rate of 15 l/min. In each cistern, water level was controlled by a PVC pipe placed at the opening of the outlet located at the middle of the cistern. The pipe was covered by a larger pipe (in terms of diameter and height) with four notches at the bottom which facilitated easy removal of waste materials from the cisterns. Water loss from the cisterns due to evaporation was adjusted every week by adding groundwater. The cemented cisterns were cleaned thoroughly with washing powder and washed with freshwater. After complete drying they were filled with groundwater up to a level of 0.76 m which was maintained throughout the experiment. Polyester net was placed over each cistern to prevent fish from predatory birds.

Preparation of media

Fifty four 5 l soybean oil containers were collected. The top of the containers were cut off. They were cut in the sides in rectangular shapes (2 cm×8 cm) and holes were made at the center of their bottoms to facilitate root growth and inflow of nutrients

(Plate 1). Three quarters of the containers were filled with decomposed water hyacinths and a thin layer of soil was placed on top of the water hyacinths to stabilize the plant seeds and stolons when planted. Six containers were then placed in each cistern. They were then half suspended into the water by hanging them from the cistern walls.

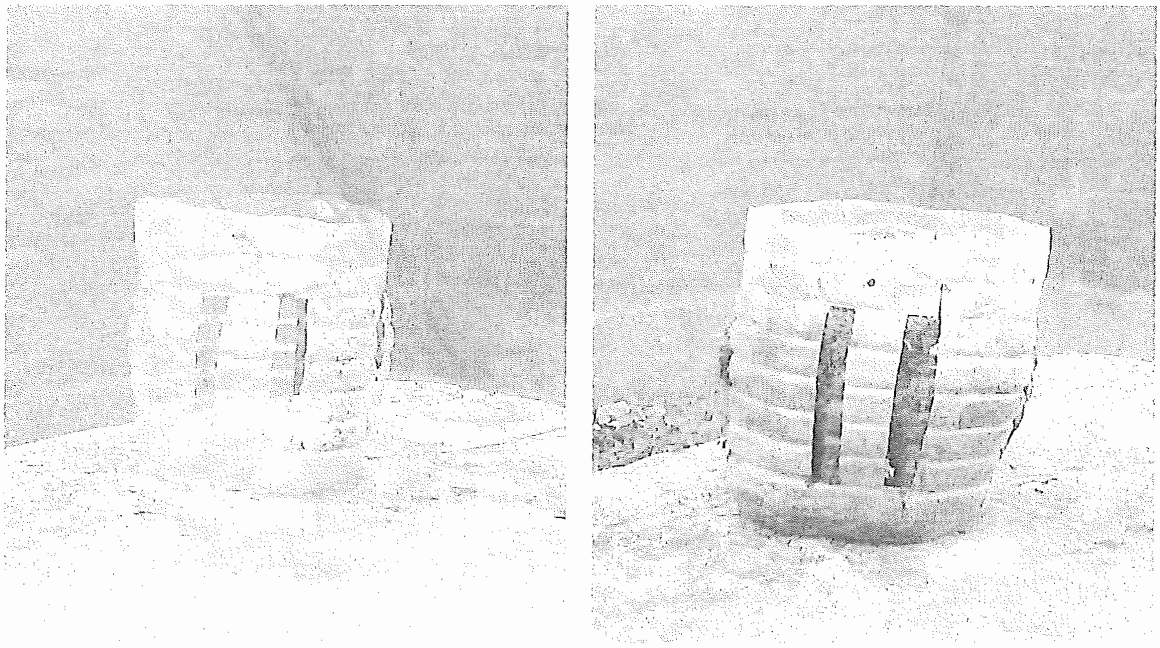

Plate 1. Container cut through the sides to facilitate nutrient flow and root growth and container filled with planting media.

Stocking and feeding of fish

Mono-sex tilapia fry of uniform size (0.76 g) were stocked in three treatments (stocking densities): 106 fish/m^3, 142 fish/m^3 and 177 fish/m^3 which were designated as T_1, T_2 and T_3 respectively. Fish were supplied with commercial feed made by Quality Feeds Limited having an average protein content of 25%. They were first supplied with starter feed for ten days, then nursery feed for twenty days and finally grower feed for rest of the days. At the beginning of the experiment feed was applied daily at a rate of 15% of body weight which was gradually reduced to 6% of body weight towards the end of the experiment. Feed was supplied three times a day, one-third at 9.00 AM, one-third at 1.00 PM and the rest at 5.00 PM.

Plantation

After one week of fry release, vegetables were introduced to the system. There were six containers in each cistern, three for morning glory and three for taro. Ten seeds of morning glory were sewed in each container, the seedlings were placed into the holes evenly spaced 3-4 cm apart and planted with two seeds per hole. Stolons of taro were planted, one in each container.

Water quality parameters

The water quality parameters observed were water temperature (°C), dissolved oxygen (mg/l), pH, alkalinity (mg/l) nitrite-nitrogen (mg/l) and nitrate-nitrogen (mg/l). Water temperature was measured everyday. Dissolved oxygen and pH were recorded at 15 days interval. Nitrite-nitrogen, nitrate-nitrogen and alkalinity were recorded at the beginning, middle and end of the experiment. The number of observations was limited due to economic deficiency. Water temperature was taken by an alcohol thermometer. Dissolved oxygen of water was measured by a dissolved oxygen meter (YSI MODEL-58, USA). Water pH was recorded with the help of a pH meter (Mettler Toledo MP 230). Total alkalinity of water samples was determined by acid titration method (APHA 1992). Nitrite-nitrogen and nitrate-nitrogen (mg/l) were measured in the Water Quality and Pond Dynamics Laboratory, Faculty of fisheries, BAU using a portable datalogging spectrophotometer HACH DR/2010, USA. Water samples were collected in small plastic bottles from the experimental cisterns on the sampling days.

Growth monitoring

Growth and production were monitored by randomly selecting ten fish from each cistern. Fish were caught by a big scoop net. The weight of fish was recorded in grams by a sensitive electronic balance. After 15 weeks of rearing the final weight of individual fish was recorded and the growth and production were calculated by the following formulae:

Weight gain (g) = Mean final weight (g) − Mean initial weight (g)

$$\% \text{ Weight gain} = \frac{\text{Mean final fish weight} - \text{Mean initial fish weight}}{\text{Mean initial fish weight}} \times 100$$

$$\text{SGR (\% per day)} = \frac{\log_e W_2 - \log_e W_1}{T_2 - T_1}$$

Where

W_1 = the initial live body weight (g) at time T_1 (day)

W_2 = the final live body weight (g) at time T_2 (day)

$$\text{FCR} = \frac{\text{Feed fed (dry weight)}}{\text{Live weight gain}}$$

$$\text{Survival rate (\%)} = \frac{\text{No. of fish harvested}}{\text{No. of fish stocked}} \times 100$$

Production = No. of fish harvested × Mean final weight of fish

Data analysis

The data obtained on the growth of fish, FCR, survival rate and production were statistically analyzed to see whether the influence of different treatments (stocking densities) on these parameters were significant or not. One way analysis of variance (ANOVA) was done with the help of SPSS (Statistical Package for the Social Sciences).

Results and discussion

Water quality parameters

The ranges of water quality parameters such as temperature, dissolved oxygen, pH, alkalinity, nitrite-nitrogen, and nitrate-nitrogen during the experiment are shown in Table 1.

Table 1. Summary of water quality parameters during the experiment

Parameters	Value range
Water Temperature (°C)	28-33
Dissolved oxygen (mg/l)	6.2-8.5
pH	8.07-8.53
Alkalinity (mg/l)	40-78
Nitrite-Nitrogen (mg/l)	0.01-0.50
Nitrate-Nitrogen (mg/l)	0.03-1.16

The water quality parameters like temperature, dissolved oxygen, pH, alkalinity, nitrite-nitrogen and nitrate-nitrogen were within the suitable ranges for tilapia culture in recirculating system as described by Drennan and Malone (1992), Masser *et al.* (1999), Rashid (2008) and Swann (2009).

Growth and production of fish

The growth and production performances of tilapia in three treatments are summarized in Table 2. The best mean weight gain (32.67 g) and percent weight gain (4298%) was observed in case of the lowest stocking density T_1 and the lowest values were observed in case of highest stocking density T_3. This indicated an inverse relationship between weight gain and stocking density. This result was similar to the findings of Roy (2002), Carro-Anzallota and McGinty (2007), Gibtan *et al.* (2008) and Rashid (2008). In the present experiment SGR (% per day) of fish in T_1, T_2 and T_3 were 3.59, 3.32 and 3.09, respectively. The highest SGR was observed in the lowest stocking density T_1 and the lowest value in the highest stocking density T_3. This indicated a negative correlation between SGR and stocking density. Ridha (2005), Rashid (2008) and Alam (2009) found similar results.

Table 3. Growth and production of tilapia in three treatments

Treatment	Weight gain (g)	(%) Weight gain	SGR (% per day)	FCR	Survival rate (%)	Production (kg/m^3)
T_1	32.67±2.19	4298.68±30.86	3.59±0.012	2.19±0.026	99±1.0	3.52±0.03
T_2	24.54±1.83	3228.95±47.39	3.32±0.01	2.41±0.015	98±1.0	3.52±0.035
T_3	19.41±1.27	2553.99±63.04	3.09±0.001	2.69±0.023	96±1.73	3.43±0.01

The FCR values varied significantly in the three treatments. The lowest value (2.19) was found in T_1 followed by T_2 (2.41) and T_3 (2.69). This finding was similar to that of Ridha (2005), Hasan (2007) and Rahsid (2008) who also found a positive correlation between stocking density and FCR. The survival rates of the fish in the present study were 99%, 98% and 96% in T_1, T_2 and T_3, respectively and did not vary significantly ($p>0.05$). However, the highest survival rate was achieved in the lowest stocking density T_1 followed by T_2 and T_3. This indicated an inverse relationship which was also observed by Yi *et al.* (1996), Hasan (2007) and Rashid (2008).

In the present study the highest production of tilapia was observed in T_1 (3.52 kg/m^3) and T_2 (3.52 kg/m^3) followed by T_3 (3.43 kg/m^3). The finding was similar to that of Alam (2009). The lowest production in the highest stocking density might be attributed to the fact that the growth and survival rate of fish in T_3 was the lowest and the increase in biomass was limited by available space and greater competition. The growth parameters, FCR, survival rate and production reveal that of the three stocking densities tested in this experiment, 106 fish/m^3 might be the most suitable stocking density for all-male GIFT tilapia production in the aquaponic system.

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