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ORIGINAL RESEARCH ARTICLE

Effects of feeding regime on growth, production, and economics of Oreochromine cichlids (*Oreochromis mossambicus*) in earthen ponds of Bangladesh

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ABSTRACT

The experiment was carried out to evaluate the effects of feeding frequency on the growth, production, and economic aspects of Oreochromine cichlids (*Oreochromis mossambicus*) in nine earthen ponds for 120 days. Three different feeding regimes (T_1, T_2, and T_3) with three replications each were used. The stocking density was uniform across all treatments at 25,000 fish per hectare. The fish were fed a commercially available pelleted feed with the same feeding rate in all treatments, but the feeding frequency varied. The feeding rate was 10%, 8%, 7%, 6 %, 5%, and 4% which was consecutively adjusted after each fortnightly sampling and 3% for the last 4 weeks of the study period. Feeding frequencies were once a day for T_1, twice a day for T_2, and three times a day for T_3. The average weight gain of Oreochromine cichlids in T_3 (295±5 gm) was significantly higher (P<0.05) than those of T_2 (240.67±6.66 gm) and T_1 (217.17±7.64 gm). The survival rates were 95.20%, 96.99%, and 97.33% for T_1, T_2, and T_3, respectively. The net production of fish in T_3 (2882.00±62.00 kg/ha) was significantly higher (P<0.05) than in T_2 (2413.00± kg/ha) and T_1 (2223±30.55). Furthermore, the highest net return (USD 1163/ha with a cost-benefit ratio of 1.42) was achieved from T_3, followed by T_2 (USD 527/ha with a cost-benefit ratio of 1.19) and T_1 (USD 270/ha with a cost-benefit ratio of 1.09). The results demonstrated that increasing the feeding frequency has positive effects on the growth and production of Oreochromine cichlids.

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INTRODUCTION

Tilapia is a valuable fish used in small-scale aquaculture by resource-constrained farmers. Farmers choose it because of its aquaculture-friendly qualities, such as a higher development rate than other short-cycled fish species. Thus, tilapia farming became more technologically and economically viable (Hossain *et al*., 2017). After carp, it is the second most significant farmed fish worldwide (Ridha, 2006). The majority of tropical, subtropical, and temperate climates cultivate tilapia. Tilapia is an excellent fish to grow in shallow and seasonal waterbodies in a country like Bangladesh (Gupta *et al*., 1984; Islam *et al*., 2022). The output of tilapia in Bangladesh reached 4,07,359 MT in 2021-22 (DoF, 2023). The disadvantage of mixed-sex tilapia culture is that female tilapia reproduces prematurely, leading to inadequate growth, overcrowding, and competition for food (Lèveque, 2002; Kamaruzzaman *et al*., 2009). Apart from Bangladesh, tilapias have become one of the most economically important kinds of farmed freshwater fish and have been branded as the "Aquatic chicken" (Maclean, 1984). Fish and rice are the most important food crops for Bangladesh's 160 million inhabitants. Fish comprise over 70% of the animal protein consumed, with each person consuming 14 kg of fish annually (ADB, 2005). Fish consumption per person is less than the global average of 16.1 kg annually (Hishamunda *et al*., 2008). Tilapia has been described as the main aquaculture species of the twenty-first century (Fitzsimmons, 2000). Bangladesh's advantageous agro-climatic circumstances make it one of the world's most suited countries for freshwater aquaculture. Oreochromis cichlids (Tilapia), are native to Africa, they have been brought to numerous other nations. They eat a wide range of meals, develop quickly, are resistant to disease, and can survive in low-quality water even with low dissolved oxygen levels. Because of these qualities, tilapia is appropriate for culture in most developing nations. The interdependent factors of feeding ratio and frequency have an impact on fish size uniformity, feed intake, and efficiency, and ultimately the output, economic viability, and environmental sustainability of semi-intensive and intensive aquaculture systems (Dwyer *et al.*, 2002; Zhou *et al.*, 2003; Wu *et al.*, 2015; Muntaziana *et al.*, 2017). In aquaculture, diet is often considered as the single largest cost item and can represent over 50% of the operating cost in intensive aquaculture (El-Sayed, 1999). A proper feeding regime should consider the feeding habits of the species, the life stage of the fish, and the unique characteristics of the production system (Schnaittacher *et al.*, 2005; Costa-Bomfim *et al.*, 2014; Muntaziana *et al.*, 2017). Optimum feeding frequency that fish can show maximum growth rate, is affected by the size of fish and rearing conditions (De Silva and Anderson, 1995). The majority of research on feeding frequency and ratio for a particular species of fish is done in wet laboratories far from farms, with tightly controlled water quality parameters, low stocking densities, and only covering the early life stages. There is also little to no representation of the total amount of feed fed throughout a culture cycle, and the difficulties and interactions that arise there are not present (Anras *et al.*, 2001; Glencross *et al.*, 2023). To reduce feed costs and boost production efficiency, earthen pond farming systems should consider the natural food, which is primarily represented by the pond's planktonic community, as a valuable dietary supplement for planktivorous fish species (Biswas *et al.*, 2006; Kabir *et al.*, 2019; Boyd *et al.*, 2020; Boyd, 1982). The present study aims to investigate the effect of different feeding frequencies on growth performance in earthen ponds and getting maximum production as well as reducing feed loss.

MATERIALS AND METHODS

Study area

The study was conducted from March to June 2022 at Bangamata Sheikh Fojilatunnesa Mujib Science and Technology University (BSFMSTU), Jamalpur, Bangladesh. The experiment was carried out in nine similar earthen ponds, each 200 square meters and 1.6 meters deep.

Pond preparation

The ponds were fully emptied and left exposed to sunshine for approximately 15 days. All ponds were treated with lime at a rate of 1 kg/decimal for 14 days prior to stocking of fingerlings.

Collection of experimental fish

A local fry trader provided all of the fingerlings of Oreochromine cichlids, which had an average initial length and weight of 4.5 cm and 5.15 g.

Experimental design and feeding

The experiment was carried out with three treatments each with three replications. Oreochromine cichlid fry was provided at the same density (25,000 fish/ha) in all treatments. The feeding rate was the same in all treatments, but the frequency varied. The feed was supplied according to percent of the body weight and it was 10%, 8%, 7%, 6 %, 5%, and 4% consecutively adjusted after each fortnightly sampling and 3% for the last 4 weeks of the study period. Feeding frequency during the study period was three times a day (morning at 09:00., midday at 13:00, and evening at17:00) at T_3, twice a day (morning at 9:00 and evening at 5:00 p.m.) at T_2, and once a day (morning at 9:00 am) at T_1. A commercial pelleted feed made by "Quality Fish Feed Ltd." with 28% protein and 7% lipid was used. The feeds were spread over the pond water by hand and placed at a certain location regularly. About 20% of the total fish were sampled fortnightly by a seine net to monitor the fish growth and to adjust feeding rates. A portable digital balance was used to measure the weight of the fish during sampling.

Water quality parameters monitoring

Temperature, dissolved oxygen (DO), pH, transparency, and other water quality indicators were checked every two weeks. A thermometer, a DO meter (YSI, model 58, USA), a Secchi disc, and a pH meter (Hanna Instruments) were used to determine the temperature, dissolved oxygen, transparency, and pH of the ponds, respectively.

Economic analysis

An economic analysis was conducted to calculate the net profit arising from various initiatives. The research was based on the prices of harvested fish and all other commodities at the local market. The full figure did not include the cost of leasing ponds. The net return was determined by deducting the gross cost from the gross return per hectare. The cost-benefit ratio might also be calculated using the ratio of net benefit to gross cost.

Statistical analysis

For statistical analysis of the data, a randomized block design (RBD) was used in the single factor analysis of variance (ANOVA) of the mean values of growth, survival, and production. The significance threshold was established at 0.05%.

RESULTS AND DISCUSSION

Growth and production performances

The growth performances of Oreochromine cichlids in terms of initial weight, final weight, weight gain, specific growth rate, feed conversion ratio, survival rate, and total production are shown in Table 1. The Oreochromine cichlids showed mean weight

Table 1. Growth performance, production, and survival (mean ± SD) of Oreochromine cichlids under three treatments.

Parameters	T_1	T_2	T_3
Initial length (cm)	4.50	4.50	4.50
Final length (cm)	22±0.20	23.50±0.10	24.5±0.50
Initial weight (g)	5.00	5.00	5.00
Final weight (g)	221.67±7.64	245.67±6.66	300±5
Weight gain (g)	221.67±7.64	240.67±6.66	295±5.00
%Weight gain (g)	4333.33±152.75	4813±133.17	5900±100
SGR (% day)	3.17±0.02	3.25±0.05	3.40±0.10
FCR	1.41±0.01	1.29±0.01	1.06±0.02
Survival rate (%)	95.99±1.9	96.99±0.75	97.33±.58
Production (kg/ha/120 days)	2096±49.50	2272±75.14	2882±62

Table 2. Water quality parameters (mean ± SD) measured throughout the experimental period.

Parameters	T_1	T_2	T_3
Temperature (°C)	29.82± 0.45 (22.4-33.9)	29.95± 0.38 (23.0-33.0)	30.17± 0.46 (23.0-33.80)
Transparency (cm)	24.22± 0.76 (17.0-36.0)	24.50± 1.10 (15.0-36.0)	24.29± 0.97 (15.0-38.0)
Dissolved Oxygen (mg/L)	3.83±0.26 (3.30-4.30)	4.11± 0.31 (3.5-4.80)	4.95± 0.51 (4.10-5.60)
pH	6.78± 0.17 (5.60-7.3)	7.08± 0.12 (6.20-7.50)	7.31± 0.16 (6.60-7.80)

Table 3. Economic analysis of fish production.

Parameters	T_1	T_2	T_3
Input cost/hectare (in USD)			
Fingerlings cost	335	335	335
Feed cost	2200	2200	2200
Pond preparation and maintenance cost	210	210	210
Gross cost	2745	2745	2745
Return /hectare (in USD)			
Gross income from sale (USD 1.36/kg)	3015	3272	3908
Net income from sale	270	527	1163
Cost-benefit ratio	1.09	1.19	1.42

gains of 221.67±7.64 g in T_1, 240.67±6.66 g in T_2, and 295.00±5.0 g in T_3 (Figure 1). The mean weight gain varied significantly amongst the treatments (Table 1). The Oreochromine cichlids SGR (percentage per day) values were 3.17±0.02 in T_1, 3.25±0.05 in T_2, and 3.40±0.10 in T_3 (Figure 2). and there was a significant difference ($P<0.05$) among the treatments. The average feed conversion ratio was 1.41±0.01, 1.29±0.01, and 1.06±0.02 for T_1, T_2, and T_3 respectively (Figure 2). The mean survival rates varied between 95.99 and 97.33.8 percent in different treatments. This range is higher than that reported by Azad *et al.* (2004); Siraj *et al.* (1988) but somewhat similar to the findings of Ali *et al.* (2005). The comparatively bigger size of fingerlings stocked may be the cause of the improved survival rate. This number and findings are essentially comparable with Hossain *et al.* (2004) and Nabi *et al.* (2017). There was no discernible difference in the survival rate ($P>0.05$) between the regimens. Fish production in T_3 was higher (2882±62.00 kg/ha/120 days) than in T_2 (2272±75.14) and T_1 (2096±49.50), and the differences were statistically significant ($P<0.05$) (Table 1). A straightforward economic evaluation of the culture operation revealed that T_3 three-fold feeding frequency produced the highest net return and benefit. T_3 had a considerably greater weight growth and percentage of weight gain than T_2 (240.67±6.66g and 4813±133.17%) and T_1 (221.67±7.64g and 4333.33±152.75%). The higher weight gain in T_3 might be attributed to the fish's appropriate use of both natural and supplemental feed as well as the high-water quality conditions that are upheld by feeding the fish three times a day. Food waste has been shown to increase the concentration of nutrients in water, which aids in the growth of plankton and degrades the quality of the water (Khan *et al.*, 2009; Andrews *et al.*, 1975; Lin and Diana, 1995; Lin *et al.*, 1990). The weight increases of Oreochromine cichlids in this study were largely consistent with those found in Azad *et al.* (2004). Following 120 days, T_3 had a greater gross production of fish (2882±62 kg/ha/120 days), followed by T_2 (2272±75.14 kg) and T_1 (2096±49.50 kg). The maximum yield in T_3 may have resulted from efficient use of the feed that was provided. The highest production was observed in T_3, which is somewhat in line with the findings of Hossain *et al.* (2004); Hossain (2007), and Grayton *et al.* (1977).

Water quality parameters

All of the water quality indicators that were tested in ponds with varying treatments were found to be within the permitted range for fish culture and to be very similar. Because the study was done from March to July, which encompassed both the winter and summer seasons, the water temperature fluctuated from 22.4°C to 33.9°C (Table 2). Hossain *et al.* (2017) reported that the suitable water temperature range was 25 to 35°C for fish culture. The months of March through June, when the temperature ranges from 25°C to 33°C, are ideal for tilapia farming (Faruk *et al.*, 2003). The transparency means values in T_1, T_2, and T_3 were, respectively, 24.22± 0.76, 24.50± 1.10, and 24.29± 0.97 cm, with a range of 18 to 29 cm. Comparable levels of transparency were noted by Rahman *et al.* (2020) and Latif *et al.* (1986). The range of the mean DO levels was 3.30 to 5.60 mg/L (Table 2). Fish and other decomposing microorganisms' oxygen consumption and changes in the rate of photosynthesis

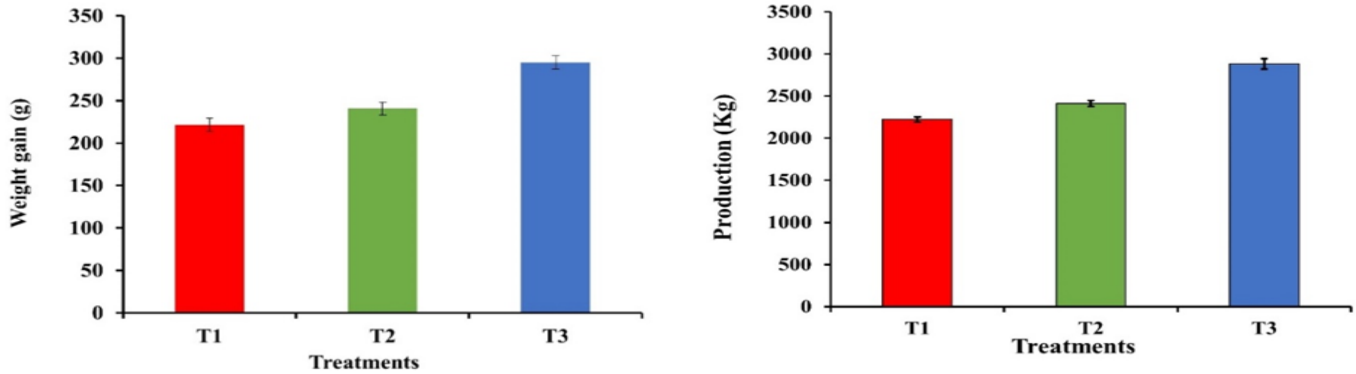

Figure 1. *Weight gain and Production of Oreochromine cichlids under different treatments.*

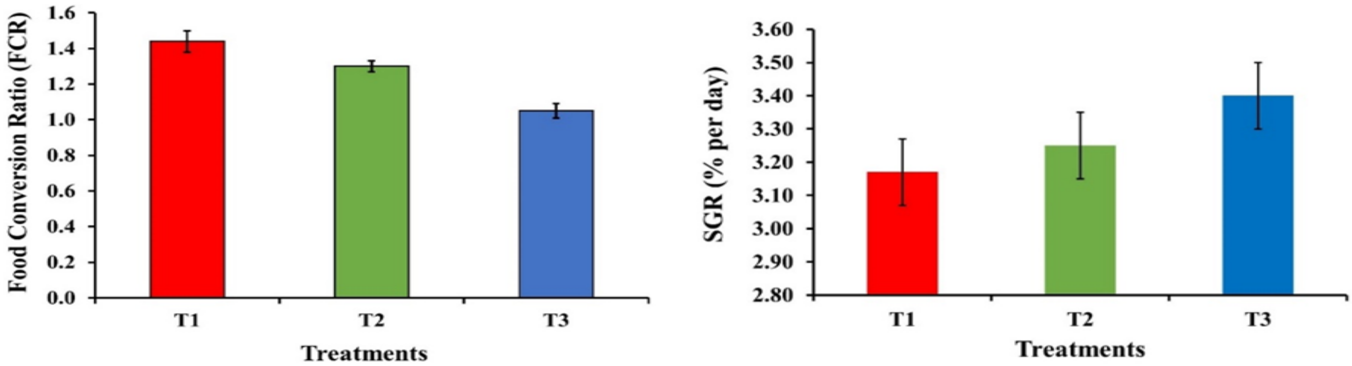

Figure 2. *Food Conversion Ratio (FCR) and Specific Growth Rate (SGR) of Oreochromine cichlids under different treatments.*

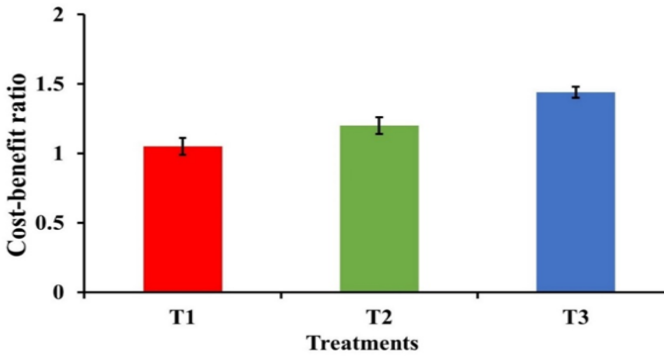

Figure 3. *Cost-benefit analysis of Oreochromine cichlids under different treatments.*

in ponds could cause DO value volatility. T_1 exhibited the lowest average DO value (3.30 mg/L). It could result from more unutilized feeds having a higher organic content. T_3 had the highest average dissolved oxygen concentration (5.60 mg/L), possibly caused by reduced organic feed breakdown. Nasrin *et al.* (2021) found dissolved oxygen content of water in between (4 to 4.5) mg/l of the three treatments. For fish culture, DO levels between 4 and 8 mg/L are ideal (Eknath, 1992; Banerjee *et al.*, 1978). In the ponds of T_1, T_2, and T_3, the mean pH levels were 6.77, 7.07, and 7.30, respectively. These values suggest favorable circumstances for productivity. The natural waters and surrounding soil conditions may have contributed to the cultured pond's pH of neutral to slightly alkaline. Additionally, it's possible that the initial lime treatment during pond preparation contributed to the preservation of the carbon buffer system in the pond water. The experimental ponds water pH ranged from 6.78±0.17 to 7.31±0.16, which is deemed appropriate according to suggestions made by other authors (Michael, 1969; DoF, 1996; Matsha Pakkah Shankalan, 1981).

Economic analysis

According to the economic analysis (Table 3), T_3 was found to have a significantly ($P<0.05$) higher capacity than T_2 (USD 527/ha/120 days and a cost-benefit ratio of 1.19) and T_1 (USD 270/ha/120 days and a cost-benefit ratio of 1.09), with a maximum profit potential of USD 1163/ha/120 days and a cost-benefit ratio of 1.42 (Figure 3). Moniruzzaman *et al.* (2015) found that the highest cost-benefit ratio was 0.759 and the lowest was 0.238. Monocultures of Oreochromine cichlids fed commercial feed produced a net profit of Tk. 31,004/ha/120;70 days, according to research by Nabi *et al.* (2017) and Kader *et al.* (2003). Their profit margin is lower than the present study. Among other things, pond productivity, variations in the rearing season, present fish prices, and cultural periods could have contributed to the higher profit this study found.

Conclusion

Increased fish output, more animal protein sources, the creation of jobs, and increased farm income are all benefits of aquaculture. In light of diminishing capture fisheries production and expanding populations, freshwater aquaculture has been acknowledged as a major means of closing the rising gap between the supply and demand of fishery products in our nation. Therefore, reviewing and developing regulations for the sustainable development of aquaculture is crucial for our nation. The utilization of natural resources, research, inputs and outputs, and price should all be covered by these policies. Ultimately, the profitability of aquaculture hinges on the cost of feeding. Our fishermen will benefit if we lower the feed conversion ratio and feeding expenses for aquaculture.

DECLARATIONS

Authors contribution

Conceptualization, methodology: M.S.R. and M.F.I.; validation: M.M.R. and M.F.A.; Investigation: M.S.R. and M.F.I.; Data curation: M.F.I., M.M.R., and M.F.A.; Writing -original draft preparation: M.S.R., M.F.I., and M.S.H.; Writing-review and editing: M.M.R., M.F.A. and M.S.H.; Supervision: M.S.R. All authors have read and agreed to the published version of the manuscript.

Conflict of interest: The authors declare that there is no conflict of interest.

Ethics approval: Not applicable.

Consent for publication: All co-authors consented to publish this paper in AAES.

Data availability: The data that support the findings of this study are available on request from the corresponding author.

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