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Effect of skip-feeding and re-feeding regimes on compensatory growth, body composition, feed utilization, feeding cost and survival of monosex tilapia (*Oreochromis niloticus*) in pond aquaculture system

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Abstract. Monosex tilapia has great acceptability particularly among the lower income people due to its lower price. However, due to increased feed price the price of tilapia has been increased in recent years. Compensatory growth (CG) of fish that is achieved after a period of feed deprivation can potentially reduce the feed cost. The present study aimed to get CG in tilapia farming so as to reduce the production cost of this popular fish. Tilapia fry of 0.54 g body weight were nursed in hapa for one month and then stocked in earthen ponds where two different restricted feeding regimes were imposed for next two months followed by one month feeding at satiation level. Sampling was done fortnightly to record average weight gain in control and treatment groups. Average individual weight in restricted feeding group (T1) reached to 170.11±4.6 g in a three months experimental period and it did not significantly ($p>0.05$) differ with the weight gained in control group (182.79±5.32 g) where fish were fed on regular basis. The specific growth rate (SGR) also showed no significant difference ($p>0.05$) between T1 (SGR 2.66±0.011 % day^{-1}) and control group (SGR 2.69±0.012 % day^{-1}). Feed Conversion Ratio (FCR) in T1 (1.26) was found significantly ($p<0.05$) lower to that of control group (1.47), hence the per unit production cost was also found significantly lower in T1 (BDT 75 Kg^{-1}) compared to that of control (BDT 88.23 Kg^{-1}). On the other hand no significant difference was evident in biochemical parameters between the control and restricted feeding groups. Thus, this study suggests skip feeding as an appropriate tool to achieving CG in monosex tilapia and to trim down the production cost as well.

Keywords: *Oreochromis niloticus,* Skip feeding, Compensatory Growth (CG), Specific Growth Rate (SGR), Feed Conversion Ratio (FCR)

Introduction

Monosex tilapia (*Oreochromis niloticus*) farming has been playing an important role in the fish farming business throughout the world as it has great demand and value in the local and international market. As a result, monosex tilapia farming is increasing day by day in Bangladesh. Generally tilapia is highly capable of taking natural food from its habitat, has good preference for supplementary feed, surviving capacity in adverse environment and highly resistant to diseases than other cultured species (Anon 2015). Feed is considered as the most expensive component of aquaculture enterprise accounting for 40-60% of total production costs depending on specific culture types and species to be cultured (El-Sayed 1999, Marimuthu 2010). A profitable aquaculture venture, therefore, requires the adequate supply of running cost and best feeding practices to ensure the optimum growth rates and feeding efficiencies (Gao and Lee 2012). Meanwhile, insufficient feeding leads to poor growth and high fish mortalities which make losses in the aquaculture business (Eroldoğan *et al.* 2006). In manipulative feeding experiments, feed available to the animals can be restricted in two different ways: (1) by decreasing daily feed allotment or (2) by decreasing the time for feeding. Under a restricted feeding regime, some fishes convert a greater portion of the feed to body weight without any

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adverse effect on their growth and nutrient utilization than they do under an unrestricted daily feeding regime (Ali *et al.* 2003). Adjusting the best feeding strategy helps to gain maximum fish growth and feed conversion ratio in addition to homogeneous growth of fish and reduction of the production cost (Yan *et al.* 2004).

One potential way of reducing feed cost is to take advantage of the phenomenon of compensatory growth (CG). CG in fish is a phase of fast growth, which occurs after the refeeding of fish following a period of feed deprivation or after abnormal conditions such as low temperature (Dobson and Holmes 1984). It is usually accompanied by hyperphagia (an increase in appetite). This phenomenon has been found in various fish species, such as Cichlids (Wang *et al.* 2000), Cyprinids (Russell and Wootton 1992, Xie *et al.* 2001), Gadoids (Jobling *et al.* 1994), Pleuronectids (Paul *et al.* 1995) and Salmoinids (Johansen *et al.* 2001). The fishes have different responses for CG either complete or partial (Jobling *et al.* 1994). Complete compensatory growth has been observed in relatively few studies Hayward *et al.* 1997, Quinton and Blake 1990, Xie *et al.* 2001). However, partial compensatory growth was observed in Mozambique tilapia *Oreochromis mossambicus* reared in freshwater (Christensen and McLean 1998), hybrid tilapia *O. mossambicus* X *O. nilotocus* reared in seawater (Wang *et al.* 2000) and the same reared in freshwater (Wang *et al.* 2005).

Effect of skip feeding on fish body composition and overall production cost for tilapia is not well studied. Appropriate design of skip feeding during culture period is of utmost necessity to reduce the production cost of aquaculture species without affecting body composition and growth performance of the species. In the present study, two different protocols of skip feeding were followed to evaluate its effect on compensatory growth and body composition, feed utilization, feeding cost and survival of monosex Nile tilapia which is considered as the prime species of animal protein source of the country.

Materials and Methods

***Experimental design*:** The study was continued for four months in the experimental ponds following the biochemical tests in a nutrition laboratory. The experiment was split into two phases to check the growth of tilapia. In the first phase, fry was nursed for one month in hapa set in the experimental ponds, and in the second phase, the nursed fingerlings were directly stocked in the experimental ponds. Feeding restriction was imposed for the first two months (Table I) after stocking in the experimental ponds and then fed to satiation in the last month of the study period. Each group was replicated twice and the amount of feed was adjusted every two weeks after getting new total weights of the stocks.

Table I. Feeding strategy

<table>
<tr><th>Treatments</th><th>Replications</th><th colspan="2">Feeding Strategy</th></tr>
<tr><td rowspan="2">Control</td><td>CR1</td><td rowspan="2" colspan="2">Regular feeding with satiation for three months</td></tr>
<tr><td>CR2</td></tr>
<tr><td rowspan="2">Treatment 1</td><td>T1R1</td><td rowspan="2">Feeding restriction on Saturday, Sunday and Monday of each week for the first two months</td><td rowspan="4">Refeeding with satiation in the last (third) month</td></tr>
<tr><td>T1R2</td></tr>
<tr><td rowspan="2">Treatment 2</td><td>T2R1</td><td rowspan="2">Feeding restriction on the first week and third week of first two months</td></tr>
<tr><td>T2R2</td></tr>
</table>

To study the body composition of different experimental groups, sample fish were taken at the end of each month for proximate analysis. Thus, for first two months proximate composition data were compiled from restricted feeding groups (T1 and T2) and control group. While the data obtained at the end of experiment reflected satiation effects on the biochemical composition of experimental groups.

***Nursing of tilapia and stocking of fry*:** Earthen pond preparation was done according to methods described by Bassey and Ajah (2010). One hapa ($1m^3$) in each and a total of six hapas were fixed in the experimental ponds. Collected tilapia fry from hatchery with an average weight of 0.54g were acclimatized before stocking in the hapa. Two hundred eighty fry were stocked in each hapa and fed with commercial feed at the rate of 30% and 20% of their body weight for the first two weeks and second two weeks respectively.

***Rearing of the fingerlings*:** The fingerlings were stocked in the growout ponds at the stocking density of 6 individuals/ m^2. Commercial feed was used for this experiment. The proximate composition of the feed was analyzed in the Fish Nutrition Lab according to the standard procedures given by the Association of Official Analytical Chemists (AOAC, 1980). 'Size Grade 2' feed was used at the rate of 15% of body weight and the amount was gradually reduced to 12%, 9% and 6% of body weight fortnightly in the first two months of the culture period. However, in the last month feed was used at a rate of 3% of body weight until harvesting. The feeding frequency was 2 times per day (06.00 AM and 06.00 PM).

Determination of growth parameters: Sampling was done fortnightly for growth monitoring. Thirty individuals were collected randomly from each pond. A measuring scale with 1mm accuracy and an electronic balance with 0.001g accuracy were used to get individual sample length and weight respectively. Full harvesting was carried out at end of the experiment to determine the survival rate, FCR and other production performance parameters. The survival rate and growth parameters were determined using the following formulas:

i) Survival rate (%) = $N_t / N_0 \times 100$ (%)

Where N_t is the number of fishes at the end of the experiment and N_0 the initial number of fishes.

ii) Average individual growth (G) = $W_t - W_0$

Where W_t is the final body weight and W_0 the initial body weight (in grams).

iii) Specific growth rate (SGR) = $(\ln(W_t) - \ln(W_0))/t \times 100$

Where 't' is the duration of the experiment in days, W_t is the final average individual body weight and W_0 the initial average individual body weight (in % BW/day)

iv) Feed conversion ratio (FCR) = TFG/ TWG

where TFG = Total feed given (dry matter basis) to *O. niloticus* and TWG =Total weight gained by *O. niloticus*.

v) Protein efficiency ratio (PER) = $(W_t-W_0) / (F \times P_F)$ (in g/g)

where F is the amount of feed given and P_F is the protein content of feed (in %)

***Proximate composition analysis*:** Proximate composition was measured at the end of each month throughout the experimental periods for the content of protein, lipid, ash, and moisture, following the method of the AOAC (1980).

***Statistical analyses*:** One-way analysis of variance (ANOVA) was used after being confirmed the homoscedasticity of variances (Levene's test) and normality of the data distribution (Shapiro-Wilk test) to determine the differences in growth performance, feeding cost, and proximate compositions among the experimental groups. When there were significant differences ($p<0.05$), the HSD-Tukey test was applied. All the statistical analyses were performed using SPSS 25.0.

Results

***Growth performance in nursery condition*:** The fry with an average weight of 0.54 g reached to 3.7±0.72 g after two weeks and 12.68±1.72 g after four weeks of nursing. Thus, at end of nursing, average, minimum and maximum body weight gain were attained 2,248%, 1511% and 2,974% respectively.

***Growth performance in growout phase*:** After hapa nursing the juveniles with average weight of 12.68±1.72 g were stocked in the experimental growout ponds. In the first two months, significant differences ($p<0.05$) were found in growth performances between control and T1, and control and T2. After the last month, no significant difference was observed between the control and T1 ($p=0.116$) However, the growth of tilapia in the control group was significantly higher ($p=0.014$) to that of T2 even after compensatory feeding in the last month of the experiment (Table II).

***Survival rate*:** In the nursing phase, average survival rate was 96%. In the earthen pond survival rate was 97%, 96% and 93% for control, T1 and T2 respectively.

***Individual weight gain*:** Average individual weight was reported 170.11 g in control group which were 159.32 g and 137.36 g for T1 and T2 respectively. The highest individual weight reached to 182.79±5.32 g in the control group (Table 1). No significant difference in average individual weight gain was found between the control and T1 though it was significantly higher ($p<0.05$) between control and T2 (Table II).

***Specific growth rate (SGR)*:** From starting period to the end of the experiment, the highest specific growth rate (2.69±0.012% day^{-1}) was found in the control group followed by the T1 (2.66±0.011% day^{-1}) and T2 (2.56±0.019% day^{-1}) respectively (Table II). The difference of SGR between the control and T1 group was non-significant ($p>0.05$). Interestingly in the last month, that is after refeeding at satiation T1 group achieved the highest SGR (0.58%) followed by T2 (0.51%) and both the values were significantly higher ($p<0.05$) than that of the control (0.41%), but this difference was non-significant ($p>0.05$) between T1 and T2 (Table II).

Feed Conversion Ratio (FCR): Feed conversion ratio (FCR) varied from 1.26 to 1.47. Lowest FCR was found in T1 (1.26) which was very close to the FCR of T2 (1.30). Lowest FCR in T1 indicates the better utilization of feeds mostly after starvation period. The FCR value for T1 group showed a significant difference with the control (1.47) and T2 groups and no significant difference was found between the control and T2 groups (Table II).

Table II. Growth performance and feed utilization of monosex tilapia under regular and restricted feeding

Growth parameters	C	T1	T2
Average Initial weight (g)	12.8±1.76	12.8±1.76	12.8±1.76
Average Final weight (g)	182.79±5.32	172±4.52	150.04±6.58
Average weight gain (g)	170.11	159.32	137.36
Survival rate (%)	97	96	93
Specific growth rate (SGR) (% day^{-1})	2.69±0.012	2.66±0.011	2.56±0.019
Feed conversion ratio (FCR)	1.47±0.048	1.26±0.036	1.30±0.057
Protein efficiency ratio (PER)	2.96±0.12	3.57±0.27	3.17±0.21

***Feeding cost*:** The highest feeding cost (BDT 88.23 for Kg^{-1} fish production) was calculated in the control group. Feeding cost for Kg^{-1} fish production in T2, where feeding skipped in the alternate weeks was found to be BDT 84.78; and the cost for same was found significantly lower ($p<0.05$) in T1 (BDT 75 for Kg^{-1} fish production) where skip feeding was applied for first three days of a week compare to that of control and T2 groups (Table II).

Protein Efficiency Ratio (PER): Highest protein efficiency (3.57±0.27) was found in the T1 group followed by T2 (3.17±0.21) and control (2.96±0.12) groups. This result indicates better utilization of feed in the treatment groups than that of the control and best feed utilization probably happened during the re-feeding regimes after the restriction period of feeding (Table II).

***Water quality parameter monitoring*:** Important water quality parameters—like temperature, dissolved oxygen (DO), pH, salinity, alkalinity, hardness, and ammonia nitrogen were monitored fortnightly (Table III). No significant difference ($p<0.05$) was recorded among the groups regarding important water quality parameters.

Table III. Mean values of water quality parameters (Mean±SD) in the experimental ponds

Water quality parameters	Experimental groups		
	C	T1	T2
Temperature (°C)	26.91±3.53	27.11±3.48	26.84±3.34
DO (mg/L)	4.95.01±0.67	5.22±0.7	5.34±0.67
pH	7.58±0.17	7.62±0.17	7.66±0.18
Salinity (ppt)	0.40±0.32	0.40±0.21	0.42±0.23
Alkalinity ($CaCO_3$ mg/L)	125.22±14.6	128.78±21.43	123.67±9.01
Hardness ($CaCO_3$ mg/L)	175.3±43.7	180.8±34.2	174.4±42.8
Ammonia-N (NH_3-N mg/L)	0.08±0.02	0.05±0.03	0.05±0.02

***Proximate composition analysis*:** Average protein and lipid content in T1 and T2 were found significantly lower compare to control during restriction feeding period, but after refeeding at satiation level in the last month, difference of these components among control and treatments groups were non-significant. On the other hand, ash and moisture content in T1 and T2 were found significantly higher than control group but showed no significant difference among the experimental groups (Table IV).

Table IV. Average value of body compositions under different feeding protocols

Group	Protein%	Lipid%	Ash%	Moisture%
C	16.93±0.18	7.50±0.21	2.86±0.11	73.34±0.13
T1	15.78±0.18	5.83±0.17	3.22±0.18	75.52±0.22
T2	14.81±0.08	5.394±0.22	3.62±0.10	76.46±0.06

Discussion

Up to date, mechanisms for compensatory growth are poorly understood in fish, despite numerous studies. However, various studies suggest that compensatory growth in fish can be a result of low basal metabolism (Fu *et al.* 2005), increased feed intake (Xie *et al.* 2001), or improved feed utilization indices such as FCR and FER (Adakli and Taşbozan 2015) following period of starvation or intermittent feeding. Improved feed utilization parameters have been observed in many fish including hybrid tilapia (*O. niloticus* x *O. aureus*) and Nile tilapia (Abdel-Hakim *et al.* 2009), and even in shellfish such as *Fenneropenaeus chinesis* (Zhang *et al.* 2010) exposed to feed deprivation and refeeding regimes. Increasing of digestive capacity during refeeding after starvation dramatically improved feed efficiency and compensate growth of many fish species (Bolasina *et al.* 2006).

Correct feeding management is essential in an aquaculture venture because underfeeding leads to competition hence reduces growth and overfeeding leads to wastage of feed in opposite (Thorpe and Cho 1995, Talbot *et al.* 1999). Effect of skip feeding in two different ways i.e. first three days of a week and alternate week for the first two months were studied. To evaluate skip feeding's effect a control group with regular feeding was also studied as one of the experimental groups. Results demonstrated that regular feeding had better performance in terms of final weight gain, and SGR compared to that of skip feeding. This finding supports the finding of Shwetanshumala and Dhaker (2017). On the other hand, types of skip feeding (feeding regimes) also have a great impact on different growth parameters and compensatory growth of tilapia. In the present study final weight gain and SGR were significantly higher in the control group during skip feeding compare to that of the treatment groups. However, after one-month regular refeeding at satiation level, no significant difference was found on the pre-mentioned growth parameters between the control group and T1 (skip feeding on first three days of a week) but the same was significantly lower in T2 (skip feeding on alternate weeks) compared to that of the control group. This finding supports the result of Mohanta *et al.* (2017) where they found a significant impact of different restriction feeding regimes on the growth parameters and body composition of Indian major carps. Higher compensatory growth in T1 indicates the most utilization of supplied feed during the refeeding regimes. Variations in the amount of feed (% of body weight) given during refeeding period as well as the duration of the refeeding period could be a part of an additional experiment through which exact feed utilization after starvation and accurate length of refeeding time could be optimized.

The average specific growth rate was varied from 2.56 to 2.69 % day^{-1}. Shwetanshumala and Dhaker (2017) found SGR 1.26 to 1.98, where ration level varied from 4 to 12% of body weight in different treatments throughout the culture period. Therefore, like the findings of many other studies, it was proved here that gradual reduction of feeding amount is more effective than that of constant feeding rate. Begum et al., (2017) found SGR 4.37 to 4.48 which is much higher than the present findings. This is because they averaged SGR for the entire period of culture whereas in the present study, SGR has been averaged after stocking four week's nursed fry in the earthen ponds. On the other hand, Saha and Khatun (2014) found SGR 6.73±0.1% in the brackishwater ponds. Such a high SGR could be possible as they use feeds containing 35% protein, but in the present study, average protein percentage of feed was 30±1.

FCR in the present study varied from 1.30 to 1.47, which was lower than that of 1.71 to1.77 for GIFT as reported by Hossain et al., (2004) and almost similar with Ahmed et al., (2013) who reported FCR 1.40 to 1.51 for monosex tilapia. The minimum deviations of FCR in different studies may be due to the variations in the proximate composition of the feeds applied for the growout of tilapia. PER values were 2.96, 3.57 and 3.17 for the control, T1 and T2 respectively. Highest PER was found in T1 (3.57) followed by T2 (3.17) and the control (2.96) indicates the better utilization of feed due to skip feeding in the treatment groups. PER of T1 showed significant difference ($p < 0.05$) with the control and T2. Thus, PER in the present study indicates shorter period skip feeding and then refeeding is more effective than longer period of starvation and refeeding. However, the present findings also coincided with the findings of Begum *et al.* (2017) who found PER 3.1 to 2.26 for a period of 120 days culture and Saha and Khatun (2014) who found PER 2.81 to 3.97 for a period of 105 days culture of Nile tilapia (*Oriochromis niloticus*). Similar to growth performance and feed utilization parameters, mixed results were obtained for body composition in fish subjected to feed restriction and refeeding regimes. Both protein and lipid contents during skip feeding trial (in T1 and T2) were found to be significantly lower than the control but after refeeding at satiation level in the last month, difference of these parameters among control and treatments groups were not significant. Studies on channel catfish (*Ictalurus punctatus*) (Gabriel et al., 2018), gilbel carp (Xie *et al.* 2001), hybrid striped bass failed to report significant effect of feeding management strategies on body composition. However, Adakli and Tasbozan (2015) reported a significant reduction in total fat in *Decentrarchus labrax* starved for 10 days and refeed for 40 days when compared to the control (fed daily). Comparably, lower body lipid content in fish subjected to starvation regimes were reported in various studies (Oh *et al.* 2007, Peres *et al.* 2011, Tian and Qin 2004). These findings in part concur with the present study, which presented significantly lower muscle lipid and protein in T2 compared to control (daily fed) and T1 during the skip feeding period (Table IV). Similar findings also obtained by Gabriel *et al.* (2018) who indicated that severe or long-term feed deprivation and refeeding cycles can result in less fattening and higher energy consumption in fish. Like many other previous findings, the present study suggests that an appropriate protocol of restricted/ skip feeding and refeeding is effective enough to get the maximum compensatory growth and optimum body compositions which could greatly reduce the overall production cost of an aquaculture venture.

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