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Optimization of Dietary Protein Level for Cage Aquaculture of *Oreochromis niloticus* in River Ecosystem of Northern Bangladesh

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ABSTRACT

Water quality, production and economics of small scale cage aquaculture were studied for a period of four months at the Mahananda river in Chapainawabganj district, Bangladesh under three different treatments of dietary protein level like T_1 (25% dietary protein feed), T_2 (30% dietary protein feed) and T_3 (35% dietary protein feed) of *Oriochromis niloticus* each with three replications. Cage size (1mx1mx1m), stocking density (150 fish/m^3 cage), initial stocking weight of fingerling (15 g) and feed regime (pellet feed, twice daily application at 10% of body weight at the start and 5% of body weight at the end of feeding trial) were same for all the treatments. Water quality parameters (Water temperature, transparency, dissolved oxygen, CO_2, pH, hardness, alkalinity and NH_3-N) were monitored fortnightly and the growth parameters were measured monthly. The mean values of water temperature, secchi disc transparency, dissolved oxygen, pH, free CO_2, alkalinity, total hardness and ammonia- nitrogen (NH_3-N) varied from 26.12±2.12 to 26.20±2.33°C, 32.49±8.04 to 32.78 ±8.13cm, 5.42±0.24 to 5.80± 0.20mg/l, 7.28±0.09 to 7.41±0.08, 5.70±0.20 to 5.97±0.18mg/l, 85.32±1.08 to 89.45±1.07mg/l, 95.35±3.65 to 97.81±3.61mg/l and 0.41±0.06 to 0.59±0.07mg/l, respectively. There were no significant difference into mean values of water quality parameters among the treatments and were found within the suitable range. Treatment T_3 (35% dietary protein feed) varied more significantly ($P<0.05$) than that of others for the mean values of growth parameters (final weight, weight gain, Specific Growth Rate (SGR), survival rate and yield) and Cost Benefit Ratio (CBR). Findings indicated that cage tilapia with 35% protein feed was the suitable technique for small scale cage farming in river. Further research is also recommended to explore the production and economics of tilapia farming in large scale in river ecosystem.

Key words: Cage farming, Dietary protein, Economics, *Oriochromis niloticus*, Production

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1. INTRODUCTION

Growth, health and reproduction of fish and other aquatic animals are primarily dependent upon an adequate supply of nutrient, both in terms of quantity and quality, irrespective of the culture system in which they are grown. Supply of inputs (feeds, fertilizers etc.) has to be ensured so that the nutrients and energy requirements of the species under cultivation are met and the production goals of the system are achieved. Protein requirements for different fish species range from 25 to 56 percent of dry diet (Hasan et al., 1996; De Silva & Anderson, 1995; Akand et al., 1991; Hepher, 1990; Tacon, 1990; Akand et al., 1989).

Apparently, marine and freshwater carnivorous species require 40-55 percent dietary protein, while most freshwater omnivorous and herbivorous species require 30-40 percent of their dry diet to be made up of protein. Like finfish, most crustaceans studied to date have rather high protein requirements, ranging from 30 to 57 percent of the dry diet (Tacon, 1990). Tilapias are considered as the best species for culture because of their high tolerance to adverse environmental conditions, their relatively fast growth and they could be easily breed (El-Sayed, 1999). Tilapia intensive culture would require the formulation of efficient food with optimum potency to meet the protein requirements in fish culture during grow-out period (Kenawy, 1993).

Protein is the main constituent of the fish body thus sufficient dietary supply is needed for optimum growth. Protein is the most expensive macronutrient in fish diet (Pillay, 1990). So, the amount of protein in the diet should be just enough for fish growth where the excess protein in fish diets may be wasteful and cause diets to be unnecessarily expensive (Ahmad, 2000). Reducing feeding costs could be a key factor for successful development of aquaculture.

Protein requirements for optimum growth of the fish seem to be affected by numerous factors such as temperature, salinity, fish age and size, etc. (Cowey, 1976). Most studies are confined to fry and young tilapia, although the supplementary feed is used during grow-out phase. Furthermore, understanding the protein requirement during the grow-out period is an important thing in fish culture management. Realization of the optimum protein level for cultured fish would help reduce the costs and maximize the feed conversion efficiency (Chiu et al., 1987; Charles et al., 1984; Sampath, 1984).

Therefore, the present study aimed at optimizing the dietary protein level for farming of Nile tilapia, *Oreochromis niloticus* in cage in river ecosystem.

The specific objectives of this study were to monitor the water quality parameters; to monitor the fish growth performance in terms of weight gain, SGR, survival rate, final weight and yield; to evaluate the economics of tilapia farming in cage under different treatments of dietary protein level and to recommend suitable protein level feed for small scale cage farming of tilapia in river ecosystem.

2. MATERIALS AND METHODS

2.1. Duration and location of the study

The experiment was conducted for the period of four months from September to December in the Mahananda River in Chapainawabganj district (24° 37′ 48″ N latitude 88° 39′ 13″ E longitude) of Bangladesh. Three different protein levels were tested under three treatments namely T_1, T_2 and T_3 each having three replications. T_1: 25% protein level feed, T_2: 30% protein level feed and T_3: 35% protein level feed. Tilapia stocking density (150 fish/m^3 cage) was same for all the treatments.

2.2. Cage Description

The study was carried out in a river using cages (1m x 1m x 1m) made of knotless, high-density polyethylene netting of 0.5mm mesh size. The submerged volume of each cage was 1m^3. Cage frames were made of bamboo bars. The cages were suspended from a bamboo structure fixed by cotton nylon cords to a walkway from the shore. Plastic bottles were attached along the four corners of each cage to keep them floating.

2.3. Stocking of Fish Fingerlings

The fingerlings of *O. niloticus* (initial stocking weight 15.0 g) were collected from a rearing pond located at Nachole Upazila of Chapainawabganj. Fingerlings were brought to the experimental site through oxygenated polythene bag. Fingerlings were acclimatized by letting the transport bags float in the fish cage for about 30 minutes, after which letting the fingerlings get out freely from the bags. The fishes were randomly released into different replicates of three treatments. Fish were stocked early in the morning when the water was cool**.**

2.4. Feeding

A commercial pellet feed (Quality feed, Dhaka, Bangladesh) with 25%, 30% and 35% crude protein content was used. Fish were hand-fed using feeding trays at 10% of body weight at the start of the feeding trial. Feeding level was reduced to 5% of body weight by the end of the trial. Fish were fed twice a day at 09:00-10:00 hours and at 05:00-06:00 hours with 50% of the ration allocated at each time. Feed quantity was adjusted every month according to fish biomass determined by sub sampling. The cage nets and feeding trays were cleaned in each week.

2.5. Water Quality Monitoring

Some important physico-chemical parameters such as water temperature, transparency, dissolved oxygen (DO), hydrogen ion concentration (pH), free carbon dioxide (CO_2), alkalinity, total hardness and ammonia-nitrogen (NH_3-N) were measured fortnightly between 10 AM to 11 AM for the present study. Water temperature was recorded by the help of a Celsius thermometer (°C) at 20 to 30 cm water depth. Transparency of water was measured by a secchi disc (cm), DO (mg/l), pH, CO_2 (mg/l), alkalinity (mg/l), total hardness (mg/l), NH_3-N (mg/l) were measured with the help of water quality test kit (HACH kit FF-2, USA).

2.6. Growth Monitoring

At least 10% (by number) of the fish in each cage were randomly sampled on a monthly basis by partially lifting the cage and removing fish with a dip net. On each sampling day, individual fish from each cage were weighed and measured. The purpose was to determine fish growth in weight and to adjust the ration. The following parameters were used to monitor the growth-

2.7. Weight Gain (g)

Weight gain (g) = Mean final weight (g) – Mean initial weight (g).

2.8. Specific Growth Rate (SGR, % bwd⁻¹)

SGR was measured according to Brown (1957).

$$\mathrm{SGR} = \frac{\mathrm{L_n(final\ weight)\text{-}\ L_n(initial\ weight)}}{\mathrm{Culture\ Period}} \times 100$$

2.9. Survival Rate (%)

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

2.10. Production/Yield of Fishes

Yield (Kg/cage/cycle) = Fish biomass at harvest–fish biomass at the stock

2.11. Economics

In order to assess the financial viability of cage culture, economic data were collected and a simple economic analysis was conducted to determine economic returns of different treatments based on market prices in Bangladesh for harvested fishes. The total cost (variable cost and fixed cost) was calculated and total return was determined from the current market prices of harvested fish. CBR was also calculated by the following equation:

CBR= Total return / Total cost

2.12. Statistical Analysis

All the data collected during experiment were recorded and preserved on a computer spreadsheet. Data of water quality, growth and economics were analyzed statistically by one-way analysis of variance (ANOVA) using the SPSS (Statistical Package for Social Science, version-15.0). Significance was assigned at the 0.05% level. The mean values were also compared to see the significant difference through DMRT (Duncan Multiple Range Test) (Zar, 1984).

3. RESULTS

3.1. Water Quality Parameters

The mean values of different water quality parameters in different treatments of all fortnights are presented in Table1.

The mean value of water temperature during the study period was found to be ranged from 26.12±2.12 to 26.20±2.33°C. The minimum value was recorded in treatment T_3 whereas the maximum value was recorded in treatment T_1. The mean value of water transparency varied from 32.49±8.04 to 32.78 ±8.13cm. The minimum value was recorded in treatment T_1 whereas the maximum value was recorded in treatment T_3. The mean value of DO varied from 5.42±0.24 to 5.80±0.20mg/l. The minimum value was recorded in treatment T_1 whereas the maximum value was recorded in treatment T_3. The mean value of water pH varied from 7.28±0.09 to 7.41±0.08. The minimum value was recorded in treatment T_1 whereas the maximum value was recorded in treatment T_3. The mean value of free carbon dioxide varied from 5.70±0.20 to 5.97±0.18mg/l. The minimum value was recorded in treatment T_3 whereas the maximum value was recorded in treatment T_1. The mean value of total alkalinity varied from 85.32±1.08 to 89.45±1.07mg/l. The minimum value was recorded in treatment T_1 whereas the maximum value was recorded in treatment T_3. The mean value of water hardness varied from 95.35±3.65 to 97.81±3.61mg/l. The minimum value was recorded in treatment T_1 whereas the maximum value was recorded in treatment T_2. The mean value of ammonia-nitrogen varied from 0.41±0.06 to 0.59±0.07mg/l. The minimum value was recorded in treatment T_3 whereas the maximum value was recorded in treatment T_1. No significant variation was found among the treatments for the mean values of all the water quality parameters.

3.2. Fish Growth

The variations in the mean values of different growth parameters under the different treatments during the study period are presented in Table 2.

3.2.1. Weight Gain (g/month)

The mean weight gain(g/month) of tilapia at different treatments of dietary protein level were found as 21.35±3.20g at treatment T_1, 24.63±3.90g at treatment T_2 and 31.29±3.70g at treatment T_3.

3.2.2. Specific Growth Rate (%, bwd⁻¹)

The mean specific growth rate (%, bwd⁻¹) of tilapia at different treatments of dietary protein level were found as 1.03±0.36 at treatment T_1, 1.11±0.42 at treatment T_2 and 1.26±0.45 at treatment T_3.

3.2.3. Final Weight (g)

The mean final weight of tilapia at different treatments of dietary protein level were found as 120.50±0.29g at treatment T_1, 133.63±0.41g at treatment T_2 and 160.33±0.33g at treatment T_3. All the treatments varied significantly for the mean values of final weight.

3.2.4. Survival Rate (%)

The survival rate (%) of tilapia at different treatments of dietary protein level were found as 93.78±0.22 at treatment T_1, 94.00±0.39 at treatment T_2 and 94.89±0.22 at treatment

Table 1 Variations in the mean values of water quality parameters under different treatments during study period

Parameters \ Treatments	T_1	T_2	T_3	*F*-value	*P*-value
Water temperature (°C)	26.20±2.33[a]	26.18±1.93[a]	26.12±.2.12[a]	0.003	1.000
Transparency (cm)	32.49±8.04[a]	32.69±8.09[a]	32.78±8.13[a]	0.005	1.000
DO (mg/l)	5.42±0.24[a]	5.65±0.22[a]	5.80±0.20[a]	0.750	0.485
pH	7.28±0.09[a]	7.35±0.08[a]	7.41±0.08[a]	0.627	0.544
CO_2 (mg/l)	5.97±0.18[a]	5.84±0.19[a]	5.70±0.20[a]	0.352	0.707
Alkalinity (mg/l)	85.32±1.08[a]	87.38±1.08[a]	89.45±1.07[a]	0.004	0.996
Hardness (mg/l)	95.35±3.65[a]	97.81±3.61[a]	96.39±3.57[a]	0.021	0.979
NH_3-N (mg/l)	0.59±0.07[a]	0.50±0.07[a]	0.41±0.06[a]	1.250	0.307

Mean values with different superscript letters in the same row indicate significant difference ($p<0.05$).

Table 2 Variations in the mean values of growth parameters under different treatments during the study period

Parameters \ Treatments	T_1	T_2	T_3	*F*-value	*P*-value
Weight gain (g/month)	21.35±3.20[a]	24.63±3.90[a]	31.29±3.70[a]	1.964	0.196
SGR (%, bwd^{-1})	1.03±0.36[a]	1.11±0.42[a]	1.26±0.45[a]	0.083	0.921
Final weight (g)	120.50±0.29[c]	133.63±0.41[b]	160.33±0.33[a]	403.766	0.000
Survival rate (%)	93.78±0.22[b]	94.00±0.39[ab]	94.89±0.22[a]	1.654	0.268
Yield (kg/cage/cycle)	16.95±0.08[c]	18.84±0.13[b]	22.82±0.05[a]	19.100	0.003
Yield (kg/cage/yr)	50.85±0.23[c]	56.52±0.40[b]	68.46±0.15[a]	69.686	0.000

Mean values with different superscript letters in the same row indicate significant difference ($p<0.05$).

Table 3 Variations in the mean values of different parameters of economics under different treatments

Parameters \ Treatments	T_1	T_2	T_3
Fixed/common cost (Tk.)			
Net	500±0.00[a]	500±0.00[a]	500±0.00[a]
Bamboo	30±0.00[a]	30±0.00[a]	30±0.00[a]
Rope	10±0.00[a]	10±0.00[a]	10±0.00[a]
Labour	60±0.00[a]	60±0.00[a]	60±0.00[a]
Fish seed	375±0.00[a]	375±0.00[a]	375±0.00[a]
Subtotal (TK.)	975±0.00[a]	975±0.00[a]	975±0.00[a]
Cost/cycle (TK.)	162.5±0.00[a]	162.5±0.00[a]	162.5±0.00[a]
Variable cost (Tk.)			
Feed	700.00±0.00[c]	875.00±0.00[b]	1050±0.00[a]
Total cost (Tk.)	862.50±0.00[c]	1037.50±0.00[b]	1212.50±0.00[a]
Return/cage/cycle (Tk.)	1708.28±7.73[c]	2056.88±14.59[b]	2875.32±6.34[a]
Return/cage/year (Tk.)	6101.00±27.62[c]	7346.00±52.12[b]	10269.00±22.65[a]
CBR	1.98±0.01[b]	1.98±0.01[b]	2.37±0.01[a]

Mean values with different superscript letters in the same row indicate significant difference ($p<0.05$).

T_3. No significant difference was found among the treatments for the mean values of survival rate (%).

3.2.5. Yield (kg/cage/cycle)

The mean yield (kg/cage/cycle) of tilapia at different treatments of dietary protein level were found as 16.95±0.08 at treatment T_1, 18.84±0.13 at treatment T_2 and 22.82±0.05 at treatment T_3. All the treatments varied significantly for the mean values of yield (kg/cage/cycle).

3.3. Economics

The economics of different treatments are presented in Table 3. The total cost (Tk/cage/cycle) of tilapia at different treatments of dietary protein level were found as Tk. 862.50±0.00 at treatment T_1, Tk. 1037.50±0.00 at treatment T_2 and Tk. 1212.50±0.00 at treatment T_3. Among the different treatments, the highest cost (Tk/cage/cycle) was found with treatment T_3 whereas the lowest cost was found with treatment T_1. Total cost (Tk/cage/cycle) varied significantly under the different treatments.

The total return (Tk/cage/cycle) of tilapia at different treatments of dietary protein level were found as Tk. 1708.28±7.73 at treatment T_1, Tk. 2056.88±14.59 at treatment T_2 and Tk. 2875.32±6.34 at treatment T_3. Among the different treatments, the highest return (Tk/cage/cycle) was found with treatment T_3 whereas the lowest return was found with treatment T_1. Total return (Tk/cage/cycle) varied significantly under the different treatments.

The CBR of tilapia at different treatments of dietary protein level were found as 1.98±0.01 at treatment T_1, 1.98±0.01 at treatment T_2 and 2.37±0.01 at treatment T_3. Among the different treatments, the highest CBR was found with treatment T_3 whereas the lowest was found with treatment T_1 and treatment T_2. CBR varied significantly under the different treatments.

4. DISCUSSION

4.1. Water Quality Parameters

In the present study, the mean value of water temperature varied from 26.12±2.12 to 26.20±2.33°C. Temperature of 27.5°C was recorded for tilapia culture by Abo-State et al. (2009). The average water temperature as 27.52°C was found in the Buriganga river by Islam et al. (1974) and as 27.6±6.68°C in Meghna by Ahmed et al. (2005). Shafi et al. (1978) observed average temperature as 25.8°C of the Meghna river near Daudkaudi. Patra & Azadi (1987) found the average temperature as 25°C in Halda river.

The mean value of water transparency in this study varied from 32.49±8.04cm to 32.78±8.13cm. Present finding has similarity with the findings of Ahmed et al. (2005) who found the transparency value of 34.2 ±1.18cm in Meghna river. Wahab et al. (1995) suggested that the transparency of productive water should be 40 cm or less. However, Boyd (1998) reported the secchi disc reading between 30 to 45cm as suitable for fish farming.

The mean value of dissolved oxygen varied from 5.42±0.24 to 5.80±0.20mg/l. This value is more or less similar to the findings of Ahmed et al. (2005) who got the mean DO value of 6.7±0.8mg/l. According to Boyd (1982) dissolved oxygen can be crucial in the tropics and sub tropics where fish growth and survival in aquatic environment is frequently oxygen limited. Banerjee (1967) & Bhuyan (1970) reported with 5.0 to 7.0mg/l of DO content of water was fair or good in respect of productivity and water having DO less than 5mg/l to be unproductive.

The mean value of pH varied from 7.28 ±0.09 to 7.41±0.08. pH of 7.6 was recorded by Abo-State et al. (2009) for tilapia culture. Ahmed et al. (2005) recorded the mean value of Meghna river water pH as 7.8±0.18 which was similar to the present study. In the present study the alkaline pH range in all treatments indicate good pH condition for biological production and fish culture.

Result from the study indicate that the value of free CO_2 that varied from 5.70±0.20 to 5.97±0.18mg/l has more or less similarity with the findings of Ahmed et al. (2005) who obtaining the CO_2 value of 4.8±0.74 mg/l in Meghna river.

The recorded mean total alkalinity varied from 85.32±1.08 to 89.45±1.07mg/l, which has similarity with Ahmed et al. (2005) and Ashfaque (2004) obtaining the alkalinity value of 76.3±8.94mg/l in Meghna river and 80.3±6.78 mg/l in Padma river, respectively.

The recorded mean total hardness varied from 95.35±3.65 to 97.81±3.61mg/l. This value is more or less similar to the findings of Ahmed et al. (2005), Ali et al. (2011) and Ali et al. (2019) who got the mean hardness value 72.5±6.21mg/l and 83.29±3.44 to 84.13±3.47 mg/l respectively.

The recorded mean value of ammonia-nitrogen varied from 0.41±0.06 to 0.59±0.07mg/l. This value is more or less similar to the findings of Ahmed et al. (2005) who got the mean ammonia-nitrogen value of 0.35±0.08mg/l in Meghna river. Ali et al. (2011) and Asaduzzaman et al. (2006) recorded ammonia nitrogen value ranged from 0.2 to 0.4, 0.29 to 0.38, and 0.203 to 0.569mg/l, respectively.

4.2. Growth of Fish

Dietary protein is always considered to be of primary importance in fish feeding (Jauncey & Ross, 1982), thus sufficient supply of dietary protein is needed for rapid growth (Lovell, 1989). In the present study, the results show that growth performance in terms of weight gain, specific growth rate, final weight, survival rate and total yield of *O. niloticus* were significantly affected by the experimental diets. Results of the present research suggest that 35% protein contain feed (Treatment T_3) is a suitable feed option for cage culture of *O. niloticus*. These results are in agreement with Ahmad (2000), Chowdhury et al. (2007) and Ng & Hanim (2007) they stating that significant growth performances were found in 35% protein content meal for *O. niloticus*. Tacon (1987) reported that dietary protein level varies from 42% for fry to 35% for growing adult of omnivorous fish. The dietary protein requirement for fish fry is high and ranges from 35% to 56% (Jauncy & Ross, 1982). Furthermore, Wilson (1989), Pillay (1990) and El-

Sayed & Teshima (1991) found that dietary protein requirements decreased with increasing fish size and age. Based on various studies, Balarin & Halfer (1982) made a general conclusion that fry of tilapia <1g requires diet with 35-50% protein, 1-5g fish requires diet with 30-40% protein and 5-25g fish requires diet with 25-35% protein. These results may be due to the fact that each fish size has a certain protein limit after which excess protein level could not be utilized efficiently. Many authors obtained conflicting results from their studies on the effect of dietary protein level on the growth of Nile tilapia, *O. niloticus*. The dietary protein requirements of several species of tilapia have been estimated to range between 20% and 56% (El-Sayed & Teshima, 1991). De Silva & Perera (1985), Siddiqui et al. (1988) and Abdelghany (2000) reported that the optimum dietary protein level for growth of *O. niloticus* fry was 30% crude protein.

4.3. Economics

In the present study, higher return and CBR were found in treatment T_3 (35% protein feed) and lowest were recorded in treatment T_1 (25% protein feed). The economics in the present study clearly indicated that the 35% protein level feed (treatment T_3) was more profitable than the other treatments (T_1 and T_2). These findings support those of Ahmad (2000), Chowdhury et al. (2007), Ng & Hanim (2007), Ogunji et al. (2008) and Tavares et al. (2008), whose reported higher positive returns in 35% protein level feed. However, data from the present study indicated that all treatments T_1, T_2 and T_3 were profitable above total costs because of increased yields of tilapia in response to protein %. In contrast, tilapia in T_3 had the highest margin between the current market price.

These results demonstrated that 35% protein level feed could be an effective means to optimize economic returns in the production of *O. niloticus* in a cage culture system. However, as the market size of fish is sometimes an important concern, low protein level feed may not always be suitable because individual growth rates of fish are reduced due to protein deficiencies.

5. CONCLUSION

Water quality parameters were found more or less within the suitable range with treatments. Treatment T_3 varied more significantly for almost all the growth parameters favorable for aquaculture farming in cages. Higher fish production was obtained in treatment T_3 (22.82±0.05kg/cage/cycle) where protein level was 35%. The higher economic return and CBR (cost-benefit ratios) was also found in treatment T_3. Considering water quality, growth and economics, treatment T_3 i.e. 35% protein level diet was found suitable for tilapia cage farming in river ecosystem. The findings of this study will provide improved knowledge on the potential for cage fish farming in river ecosystem. Based on the present findings, it is recommended to conduct future research on river based tilapia farming in large scale.

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