Aquatic Resource Sciences

Journal homepage: www.journal.inrrd.com/ars

Original article

Effect of Different Formulated Feeds on the Growth and Production of *Heteropneustes fossilis* (Bloch, 1794) in Bottom Clean Culture Method

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ARTICLE INFO

Article history

Received 07 December 2023

Revised 23 January 2024

Accepted 29 January 2024

Available online 31 January 2024

Keywords

Heteropneustes fossilis

Bottom clean fish farming

Tank culture

Formulated feed

Dietary protein

ABSTRACT

An attempt was made to develop a bottom clean fish farming system in tank for Stinging catfish (*Heteropneustes fossilis*). The experiment was conducted for 150 days (April - August, 2022) three tanks each of 42.48m^3 in size. Fish fries with a mean weight of about 1.6±0.07g was stocked in each treatment. Stocking density was 3500 individuals/tank. Formulated feeds with three different protein levels (28%, 30% and 32%) were supplied as treatments (T_1, T_2 and T_3). The highest mean weight gains of *H. fossilis* were obtained in the T_3 treatment (65.30±0.36g). The SGR (% per day) achieved in T_3 treatment was also higher than other two. At the end of the experiment, treatment T_3 with the highest dietary protein resulted in the highest fish production (230.44kg/tank) followed by T_2 (206.73kg/tank) and T_1 (189.32kg/tank) respectively. Data on economics also indicated that the treatment T_3 was more profitable than treatments T_2 and T_1. The findings revealed that the higher dietary protein level has a significant impact for better aquaculture production. This experiment might be used as a baseline for the culture of stinging catfish through new technique of bottom clean fish farming in tank for the farmers.

Introduction

The demand for edible fish is increasing, which is causing Bangladesh's aquaculture business to intensify quickly. Due to the rapid horizontal and vertical expansion of this thriving industry, the culture patterns have evolved from traditional to semi-intensive or intensive culture, or from minimum to maximum stocking density, resulting in an unprecedented increase in the demand for fish feed (Kader et al. 2007).

Heteropneustes fossilis in addition to its delicious flavor and commercial value, is highly respected for its nutritional and medicinal properties (Chakraborty and Nur 2012). This species became endangered in our country as a result of overexploitation and ecological changes in its natural habitats (IUCN Bangladesh 2000). Nonetheless, this fish's population in this area has recently increased again. It is currently a least concern species globally (Fernado et al. 2019). Unfortunately, there is a dearth of knowledge regarding the precise population state and ecological needs of *H. fossilis*, necessitating further study. In recent years, fish farmers have increasingly used *H. fossilis* as a commercially viable species, however one of its biggest drawbacks is that it is strongly dependent on commercial feed, which is costly for fish farmers. Furthermore, when farmers go from making their own feeds to buying feeds created in factories, they could be deceived into accepting commercial feeds without being aware of their nutritional qualities because there is no strong government law regulating feed quality and pricing.

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Also, there hasn't been any research done to evaluate the viability and potential of bottom clean farming of *H. fossilis* in tanks in our nation.

Fish farming and fishing are both quite diverse industries. While fisheries and aquaculture are still mainly run in the same way they were more than a century ago in certain locations, these are highly developed sectors in others (Roy et al. 2019). Over the past few years, it has been increasingly obvious that fish farming will become more and more important. Technology will play a significant role in determining how successfully fish farming develops as it enters its industrial phase. Hence, it is vital that experts from academia and business come together to talk about the state of fish farming technology now and prospective future advancements for different fish species.

The majority of Bangladesh's aquaculture production practices is extensive and extended extensive, with a small number of semi-intensive and infrequently intensive systems (Nushy et al. 2020). Nonetheless, a variety of recently developed aquaculture technologies have been discovered in Bangladesh, including the In Pond Raceway System (IPRS), Bio floc fish farming, Bottom Clean fish farming, and Recirculating Aquaculture System (RAS). As opposed to flow through systems, which dispose of used water, recirculating systems filter and recycle water (DeLong et al. 2009). Bottom clean fish farming is a comparatively easy and efficient technique among various culture methods. The wastages, which are either unwanted inputs or byproducts, are eliminated from the system using the bottom clean method, which is a type of flow through system. To determine the viability and potential of bottom clean fish farming in tanks in different parts of our nation, more research is required.

Bottom clean fish farming is a relatively new culture practice in our country but it is a widely practiced culture technique in our neighboring countries like India, Philippines, China, Thailand and Vietnam. Culture systems that discard water after use are called flow through systems; while those that filter and recycle water are referred to as recirculating systems (Rakocy et al. 2004). Tank culture of high valued *H. fossilis* can be a good alternative to pond culture if sufficient water or land is not available and the economics are favorable. *H. fossilis* grows well at high densities in the confinement of tanks when good water quality is maintained. This is accomplished by aeration and frequent or continuous water exchange to renew dissolved oxygen (DO) supplies and remove wastes (Roy et al. 2019).

Feeding rate controls the growth and feed utilization efficiency of the cultured species, two factors that affect the economic viability of aquaculture (Nushy et al. 2020). Nutritional components are crucial for the survival and wellbeing of fish species (NRC 1993). Protein is recognized as the most expensive and important dietary component in fish diets for the best growth and quality health (Wang et al. 2006). Knowledge about optimum feeding rates is important not only for promoting good growth and feed efficiency, but also for preventing water quality deterioration as the result of excess feeding (Ng et al. 2000).

Thus, a sufficient intake of protein in the diet is essential for the greatest development and upkeep of healthy farming conditions (Guo et al. 2012). There are no studies in the literature or elsewhere that address the optimization of protein-based formulated diet for *H. fossilis* in a tank utilizing the bottom clean approach. Nonetheless, numerous investigations on various *H. fossilis* cultivation techniques have been conducted (Chakraborty and Nur 2012; Kohinoor et al. 2012; Monir and Rahman 2015; Khan and Maqbool 2017; Roy et al.2019). The goal of the current study was to investigate and evaluate the growth performance of shing (*H. fossilis*) fed formulated meals as well as to create a workable and financially feasible bottom clean system for farming *H. fossilis* in tanks.

Materials and Methods

Experimental design

The experiment was conducted over the course of 5 months (April - August, 2022) in rectangular tanks at the hatchery complex of the Department of Fisheries, Natore District, Bangladesh. The experiment was conducted in cemented tanks with three treatments of different dietary protein level to evaluate the production in a culture period of 150 days. The stocking density in each tank was the same and that was 3500 fries/tank.

Tank preparation

The cemented tanks, each measuring 7.62m by 4.57m by 1.22m (42.48m^3), were utilized as test tanks. The interior of the tanks was created smooth to reduce flow resistance, prevent abrasion harm to fish, and prevent cleaning hassles. Each tank has a central drain at the bottom to allow water to discharge and remove waste through a pipeline. In order to achieve this, a 15-inch slope of the bottom was maintained toward the primary drain. The inlet was situated 20 cm beneath the tank's top. The tank wall was parallel to the intake pipe enabling a straight inlet. The surfaces of the tanks were covered using nylon nets to protect cultured fish from predators or any other kinds of danger. Each tank was fitted with rows of 1 inch L-shape PVC pipes lay on the bottom to maintain the lift aeration system. A 0.50 horsepower (HP) aerator is connected with water hose pipes and air stones for each tank to ensure continuous aeration and optimum water quality parameters for fish.

Stocking

In this experiment, shing (*H. fossilis*) fry were used as culture species. The fries of *H. fossilis* were supplied stocked at the rate of 3500 piece/tank for each treatment. All of the fish were of the same age group and had a mean weight of 1.6±0.07g. The fish were transferred to plastic buckets and released into the experimental tanks in accordance with the experimental design. The length and weight of approximately 10% of all fish in each tank were measured and recorded in order to estimate initial stocking biomass and adjust initial feeding rate for fish. The fish were strong and moved naturally when they were released into the tanks.

Water quality monitoring

Environmental parameters influencing water quality: Temperature (°C), transparency (cm), pH, dissolved oxygen (mg/l), alkalinity (mg/l), and ammonia-nitrogen (mg/l) were monitored weekly. Throughout the sample period, a set sampling hour of 10:00–11:00 a.m. was followed to ensure that water quality parameters were measured consistently throughout space and time to assess the tank's physico-chemical condition. A centigrade thermometer within the range of 0 °C to 120 °C was used to record the water temperature. The pH of pond water was measured by using a pH indicator paper (LOGAK, Korea) at the pond site. The dissolved oxygen, total alkalinity and ammonia-nitrogen concentration of water were determined by the Winkler's titration method (APHA, 1976) and expressed in milligram per liter (mg/l) of water. The Alkalinity of water was measured by the use of a water testing kit (HACK Kit, Model~FF2, Made by USA). NH_3-N was measured by a water testing kit.

Preparation of feed and feeding

Fishes were fed formulated feed. Feeds were formulated using five locally available ingredients namely- fishmeal, soybean meal, rice bran, wheat bran, maize bran. Vitamins and minerals were added at a pre-determined amount during formulation. The inclusion levels of different ingredients were different in three treatments in accordance with required protein level (Table 1). The inclusion level of various ingredients according to target protein level was calculated using 'Pearson Square Method'.

The feeding rate and feeding frequency were adjusted according to body weight. Feed requirements were calculated and adjusted after sampling of fish. In the first two months, feed of 10% of body weight is fed; in the third, 8%; in the fourth, 6%, and in the fifth, 4%. In the first 30 days of culture, feeds were given four to five times a day, and then gradually it was reduced to thrice a day. Feeds were applied manually. Half of the required feed for a day was supplied in the morning to noon and the rest half in the afternoon.

Table 1. Inclusion level of various ingredients

Ingredients (% Protein level)	Inclusion level (%)		
	T_1 (28%)	T_2 (30%)	T_3 (32%)
Fishmeal (55)	22.38	25.70	28.60
Soybean meal (40)	22.38	25.70	28.60
Rice bran (14)	17.75	15.80	13.90
Wheat bran (12)	17.75	15.80	13.90
Maize bran (12)	17.75	15.80	13.90
Vitamins and minerals	2.00	2.00	2.00

Water treatment and management

Liming was done after stocking once a month at a dose of 200gm. The next day after liming, 200 g salt (NaCl) was applied each time. About 20% to 40% water of each tank containing various kinds of wastages produced daily during fish culture was removed through the bottom outlet once daily and equal amount of new fresh water was added in the tank through the inlet.

Monitoring of fish growth

To evaluate the growth performance of fish, 10% of the supplied fish from each tank were captured each month using a cast net. A measuring scale and an electronic digital balance were used to determine the length and weight of the fish samples. The fish were gently handled while sampling to reduce stress. The following metrics were used to assess how well fish grew under various conditions.

Weight gain= final weight (g) - initial weight of fish (g)

Average daily gain, ADG (g) = (Mean final body weight-Mean initial body weight)/Time (T_2-T_1). (De Silva 1989)

Specific growth rate, SGR (% bwd^{-1}) = (In W_2- lnW_1)/ (T_2-T_1)×100 (Ricker, 1979)

Where,

W_2= Final live body weight (g) at time T_2

W_1=Initial live body weight (g) at time T_1)

Food Conversion Ratio, FCR= $\frac{\text{Feed fed in dry weight(g)}}{\text{Live weight gain (g)}}$

After five months, the fish were harvested by repeated netting and the tanks were dried. The sample were counted and weighed. Fish survival and production were then calculated and compared across treatments.

Survival rate (%) = No. of actual fish survived /No. of actual fish stocked (De Silva 1989).

Production (Kg/tank) = No. of fish harvested × final weight of fish.

Economic analysis

To study the economics of *H. fossilis* culture under three treatments for the current experiment, a straightforward cost-benefit ratio (CBR) was used. The total cost (BDT/tank/5 months) was calculated using data on both fixed and variable costs at the end of the experiment. The total return calculated using the fish market price was expressed as BDT/tank/5 months. Net benefit was determined as BDT/tank/5 months by subtracting entire return from total cost. CBR was calculated as follows:

$$\text{CBR}=\frac{\text{Benefit}}{\text{total cost}}$$

Statistical analysis

To ascertain whether there was a significant difference in the different treatments, the data were analyzed using one-way analysis of variance (ANOVA) in GraphPad Prism (ver. 6.00) and descriptive statistics through Microsoft Excel.

Results

Physico-chemical properties of water

The physico-chemical parameters measured in different treatments throughout the experimental period were found within the acceptable range for fish culture. The results of physico-chemicals parameters in three treatments are presented in Table 2. In the present study, the mean water temperature was measured 29.45±0.796, 29.44±0.773 and 29.58±0.820 ^{o}C in T_1, T_2 and T_3, respectively and there was no significant variation among the treatments. (p=0.9087).

The average dissolved oxygen (DO) content in the experimental tanks throughout the culture period were 6.14±0.236, 6.17±0.188 and 6.43±0.176 mg/l in T_1, T_2 and T_3, respectively and significant differences were found between the treatments T_2 and T_3 and also between treatments T_1 and T_3 (p=0.0060). In present experiment, pH values were found to fluctuate from 7.16±0.250 (T_1) to 7.21±0.152 (T_3). In all the treatment the pH values found were slightly alkaline. No significant difference was found among the treatments (p=0.8440).

Table 2. Variation in the physico-chemicals parameters of water

Parameters	T_1	T_2	T_3
Temperature (^{0}C)	29.45±0.796^a	29.44±0.773^a	29.58±0.820^a
pH	7.21±0.152^a	7.19±0.159^a	7.16±0.250^a
Dissolved oxygen (mg/l)	6.14±0.236^a	6.17±0.188^a	6.43±0.176^b
Total alkalinity (mg/l)	112.7±3.772^a	112.6±3.912^a	114.9±4.094^a
Ammonia-nitrogen (mg/l)	0.039±.014^a	0.032±0.015^a	0.019±0.0087^b

Values with the same superscript are not significantly different at p>0.05

The mean water total alkalinity was measured 112.7±3.772, 112.6±3.912 and 114.9±4.094 mg/l in T_1, T_2 and T_3, treatments respectively in the present experiment and there was no significant variation among the treatments (p = 0.3). The mean values of ammonia-nitrogen (NH_3-N) contents in the present study were highest in T_1 (0.039±.014 mg/l) followed by T_2 (0.032±0.015 mg/l) and T_3 (0.019±0.0087 mg/l) and there was significant variation among the treatments (p= 0.0064).

Growth and production performances

The growth parameters, survival rate and production and of Shing (*H. fossilis*) in three treatments have been reported in Table 3.

Table 3. Variation in the growth parameters of *Heteropneustes fossilis*

Parameter	T_1	T_2	T_3
Initial weight (g)	1.6±0.07^a	1.6±0.07^a	1.6±0.07^a
Final weight (g)	57.13±0.32^a	62.25±0.66^b	66.90±0.36^c
Weight gain (g)	55.53±0.32^a	60.65±0.66^b	65.3±0.36^c
SGR (% bwd^{-1})	2.40±0.02^a	2.42±0.01^a	2.48±0.02^b
Survival rate (%)	92.55±0.62^a	94.00±0.32^a	96.75±1.16^b
ADG(g)	0.34±0.03^a	0.45±0.05^b	0.47±0.04^b
FCR	1.96±0.02^a	1.74±0.01^b	1.56±0.02^c
Production (kg/42.48m^3)	189.32±1.46^a	206.73±0.90^b	230.44±1.21^c

Values with the same superscript are not significantly different at p>0.05

The mean stocking weight of shing was equal in T_1, T_2 and T_3 treatments which weighed about 1.6±0.07g (Figure 1a). The mean harvesting weight of shing were 57.13±0.32, 62.25±0.66 and 66.90±0.36g in T_1, T_2 and T_3 treatments, respectively (Figure 1a). The highest mean final weight was obtained in T_3 (66.90) followed by T_2 (62.25) and T_1 (57.13) which was significantly different (p< 0.0001) from each other (Figure 1b). The findings indicated that the mean weight gains of *H. fossilis* in the T_1, T_2 and T_3 treatments were 55.53±0.32 g, 60.65±0.66 g and 65.30±0.36g, respectively, at the end of the experiment. The highest weight gain was obtained in T_3, which is 65.30±0.36g which is significantly (p>0.05) higher than both T_1 (60.65±0.66g) and T_2 (55.53±0.32g) (Figure 1c).

In the current study, the average daily gains for the T_1, T_2 and T_3 treatments were 0.34±0.03, 0.45±0.05 and 0.47±0.04g, respectively (Figure 1d). However, there was significant variation of the treatments T_2 and T_3 from the treatment T_1 (p= 0.0174), although there was no significant difference between T_2 and T_3. The highest average daily gain was obtained in T_3 (0.47g) where fish were treated with feed containing highest protein level (32%).

The mean FCR values as recorded in the present study of T_1, T_2 and T_3 treatments were obtained 1.96±0.02, 1.74±0.01 and 1.56±0.02, respectively (Table 3 and Figure 2a). The FCR value of T_3 was found to be significantly (p< 0.0001) lowest highest was found in T_1.

At the end of the experiment, the SGR (% bwd-1) attained under T_1, T_2 and T_3 treatments were 2.40±0.02, 2.42±0.01 and 2.48±0.02 %, respectively (Figure 2b). The result of the experiment revealed that the highest SGR value (2.48±0.02 % bwd-1) was recorded in T_3. However, there was no significant difference between T_1 and T_2, but there was significant variation (p< 0.0001) between T_2 and T_3 and also between T_1 and T_3, as far as specific growth rate is concerned.

The percentage of survival as recorded in the present study was 92.55±0.62, 94.00±0.32 and 96.75±1.16% in T_1, T_2 and T_3 treatments, respectively (Figure 2c). The highest survival rate was observed in T_3 (96.75) and the lowest in T_1 (92.55). No significant difference was found between treatments T_1 and T_2. But the differences in survival rates between the treatments T_2 and T_3 and between T_1 and T_3 were found to be significant (p= 0.0001). During the whole culture period, slightly slower growth was observed in the earlier months in the younger fish. Growth in the month of June-August increased greatly (Figure 3).

Economic analysis

The mean productions of *H. fossilis* were 189.32±1.46, 206.73±0.90 and 230.44±1.21 kg/tank in T_1, T_2 and T_3 treatments, respectively (Figure 4). The highest fish production was obtained in treatment T_3 (230.44kg/tank) followed by treatments T_2 (206.73kg/tank) and T_1 (189.32kg/tank).

In the present experiment, the total cost of production (BDT/tank) was lower in T_1 (43880±257.23) than those in T_2 (44200±246.23) and T_3 (44500±357.54) (Table 4). The net benefits generated from 150 days culture period was obtained as 31848±732.34, 42492±743.54 and 53437±823.25 BDT/tank for T_1, T_2 and T_3, respectively. However, the highest net benefit of BDT 53437±823.25 was found from T_3. For T_1, T_2 and T_3 treatments, the cost-benefit ratio (CBR) was 0.73±0.02, 0.96±0.01 and 1.20±0.02, respectively.

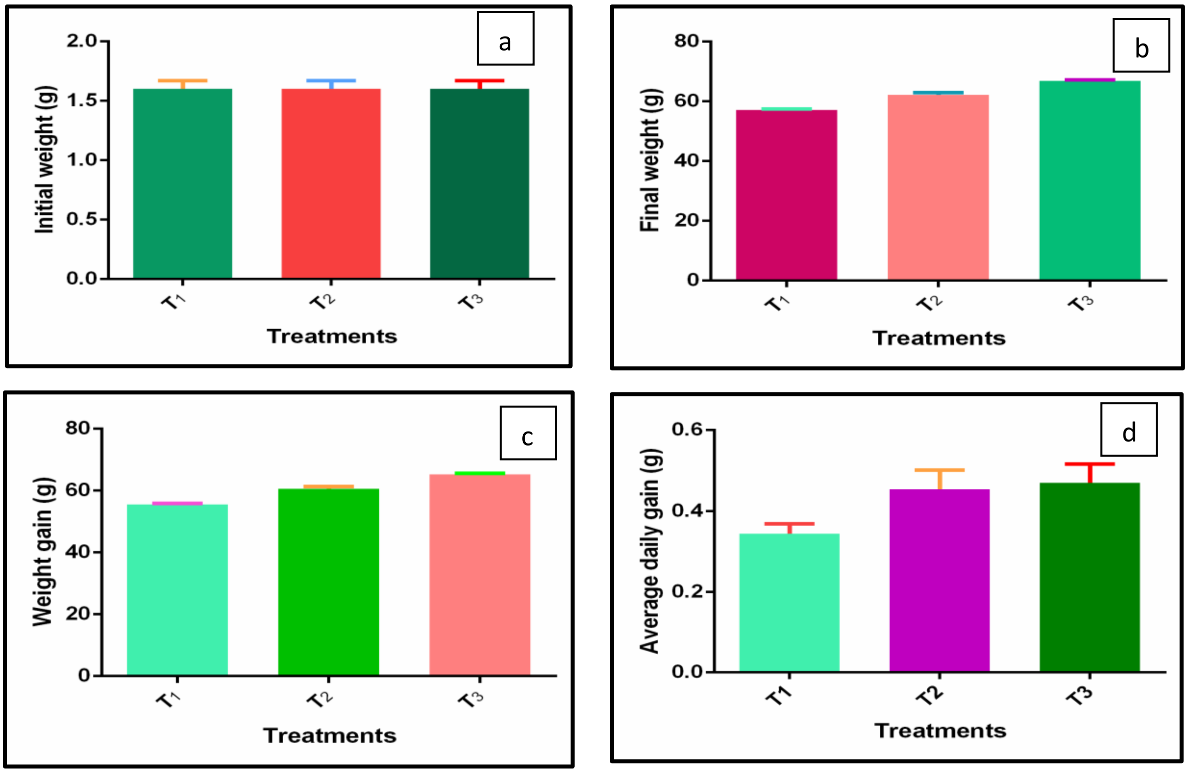

Fig. 1. Variations in mean values of Initial weight, final weight, mean weight gain and average daily gain among three different treatments during the study period.

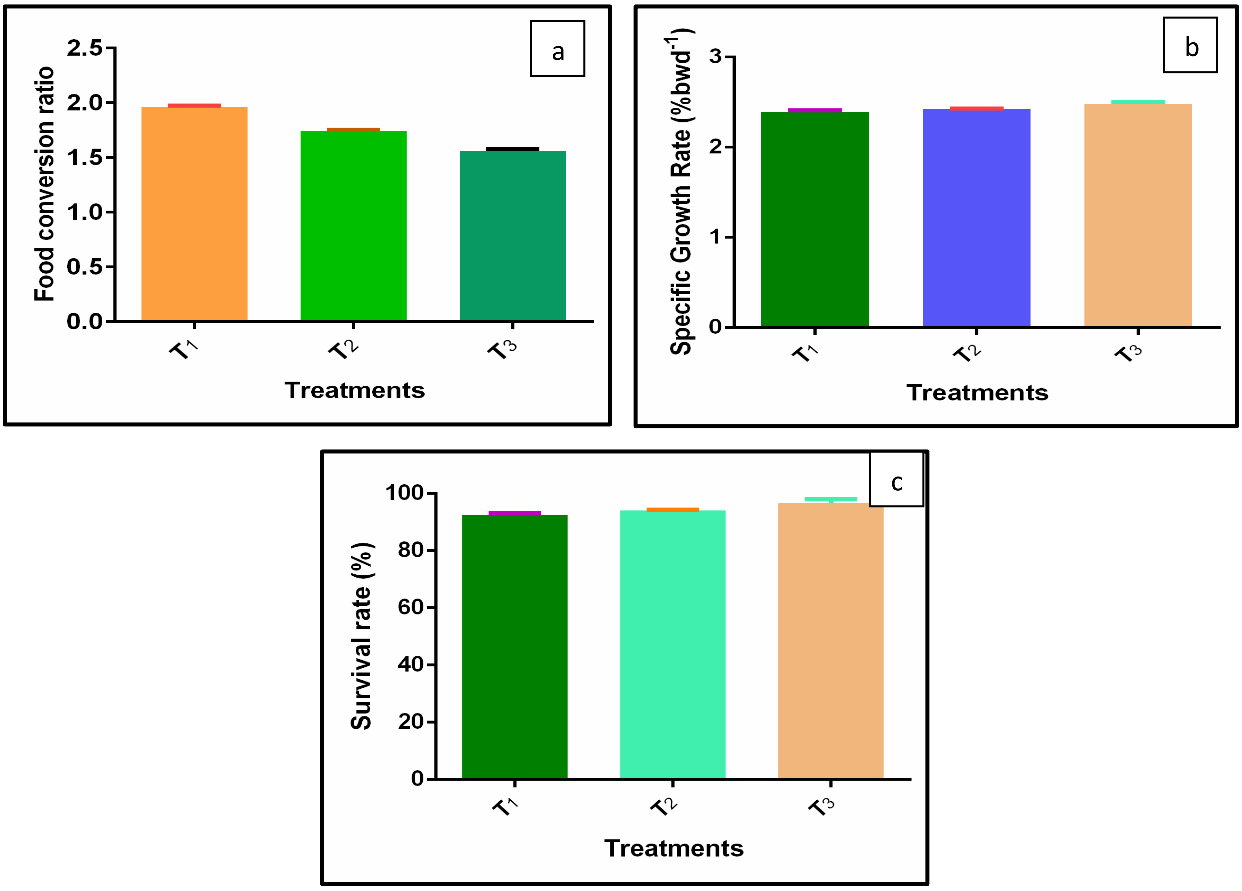

Fig. 2. Variations in mean values of FCR, SGR and Survival rate among three different treatments during the study period.

Table 4. Costs and benefits of *Heteropneustes fossilis* production in tanks for a culture period of 5 months

Treatments/Economics	T_1	T_2	T_3
Tank construction	15000±0.00 [a]	15000±0.00[a]	15000±0.00[a]
Liming and Salting	265±0.00[a]	265±0.00[a]	265±0.00 [a]
Cost of Fry (with transportation)	4700±0.00[a]	4700±0.00[a]	4700±0.00 [a]
Feeding cost	13915±0.05[a]	14235±0.06[b]	14535±0.04[c]
Aerator + Electricity cost	3500±0.00[a]	3500±0.00[a]	3500±0.00[a]
Harvesting cost	1000±0.00[a]	1000±0.00[a]	1000±0.00 [a]
Labor cost	4800±0.00[a]	4800±0.00[a]	4800±0.00 [a]
Marketing cost	700±0.00[a]	700±0.00[a]	700±0.00[a]
Total Cost	43880±257.23[a]	44200±246.23[b]	44500±357.54[c]
Total Income	75728±397.45[a]	86692±467.57[b]	97937±483.76[c]
Benefit	31848±732.34[a]	42492±743.54[b]	53437±823.25[c]
CBR	0.73±0.02[a]	0.96±0.01[b]	1.20±0.02[c]

Liming =BDT 40.00/kg and Salting=BDT 40.00/kg; fishmeal=BDT 90/kg; soybean meal= BDT 60/kg; rice bran= BDT 30/kg; wheat bran= BDT 32/kg; maize bran= BDT 35/kg; vitamins and minerals= BDT 2000/100 kg feed; Cost of Fry=BDT 1.20/pcs

Discussion

Physico-chemical properties

Water quality is one of the most neglected parts of pond management, until it has an impact on fish production. Environmental factors have a significant impact on the maintenance of a healthy aquatic environment and the generation of food organisms. Fish growth, feed efficiency, and feed consumption are often influenced by a few environmental conditions (Brett 1979). All of the water quality metrics measured in the three treatments was found to be more or less close to each other, and nearly all of them fell within the desirable range for fish culture.

Water loses oxygen as the temperature rises. Furthermore, due to increasing respiration rates, plants and animals consume more oxygen. During the summer and fall months, these variables frequently result in less accessible oxygen for fish (Bhatnagar and Devi 2013). However in tank culture, it is easier to maintain a desired temperature and temperature fluctuation is hardly a problem. In the present study, the mean water temperatures were measured as 29.45±0.796, 29.44±0.773 and 29.58±0.820 ºC in T_1, T_2 and T_3 treatments, respectively. However, there were no significant variations among the treatments. The mean range of temperature in the experimental tanks were within the acceptable range for farming of *Heteropneustes fossilis* that agrees well with the findings of Haque et al. (1984) and Kohinoor et al. (2012). Monir and Rahman (2015) also found the mean range of water temperature 28 to 32 ºC in the nursery ponds for nursing of Shing (*H. fossilis*) which is similar to the present experiment. Samad and Bhuiyan (2017) recorded mean values of temperature of about 28.38±1.91ºC for culture of *H. fossilis* in seasonal ponds of Rajshahi, Bangladesh, that is slightly different from this experiment. This is probably occurred due to seasonal variation of water temperature.

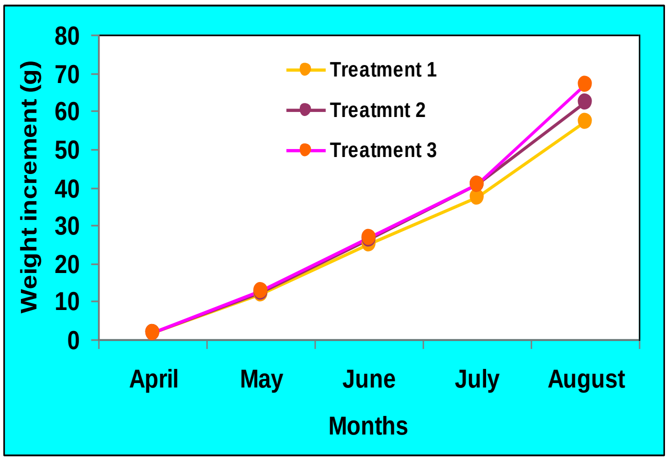

Fig. 3. Variations in growth increment among three different treatments of *Heteropneustes fossilis* during the study period

Most aquatic species including fish rely entirely on dissolved oxygen (DO) for breathing, and it has been noted that in many aquatic bodies, huge fish population deaths have occurred owing to low levels DO (Bhatnagar and Garg 2000). The average DO content in the experimental tanks throughout the culture period were 6.14±0.236, 6.17±0.188 and 6.43±0.176 mg/l in T_1, T_2 and T_3, respectively and are in the suitable range for fish culture which strongly agrees with the findings of Roy *et al.*, (2019). They recorded the range of dissolved oxygen from 6.8 to 8.6 mg/l for culture of *H. fossilis* in cemented tanks. Samad and Bhuiyan (2017) also recorded the DO concentration ranged from 3.95 to 6.25 mg/l for culture of *H. fossilis* in seasonal ponds, which is slightly lower than present study. Rahman et al. (2013) found dissolved oxygen 4.13 to 4.71 mg/l, while Kohinoor et al. (2012) measured dissolved oxygen 4.23 to 5.32 mg/l in *H. fossilis* cultured ponds. These differences might have been aroused from difference in stocking densities. It also reveals that using aerators offered the cultured fish with an adequate level of dissolved oxygen content throughout the culture periods in the present study.

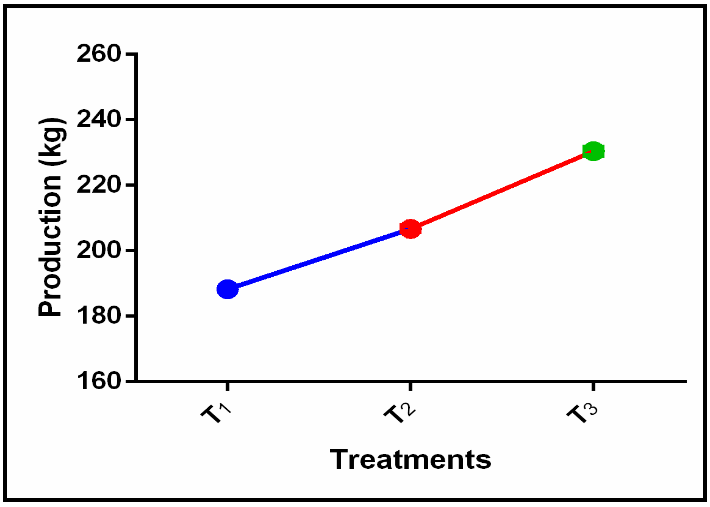

Fig. 4. Variations in mean values of production among three different treatments of *Heteropneustes fossilis* during the study period

The pH of water indicates whether it is acidic or basic. Because fish have an average blood pH of 7.4, pond water with a pH close to this value is ideal. The pH of pond water changes during the day as a result of photosynthesis and respiration by plants and animals. The pH is often highest at twilight and lowest at dawn (Boyd 1979). This is due to increased carbon dioxide concentrations during the night, which interact with water, creating carbonic acid and reducing pH. This can limit the ability of fish blood to carry oxygen. But it is possible to maintain a stable pH content in tank. In present experiment, pH values were found to fluctuate from 7.16±0.250 (T_1) to 7.21±0.152 (T_3). In all the treatment the pH values found were slightly alkaline. (Samad et al. 2017) found the mean value of pH ranged from 7.44 ± 0.06 to 7.52 ±0.06 in culture ponds of *H. fossilis* that is more or less similar to the present study. Present findings also agree with the findings of Haque et al. (2005). Samad and Bhuiyan (2017) obtained the mean values of pH in the ponds of *H. fossilis* as 7.17±0.04, 7.22±0.04 and 7.24±0.03 that goes well with our findings. Roy *et al.*, (2019) also observed the pH values of water to be slightly alkaline ranging from 7.26 ± 0.31 to 7.30 ± 0.28 in culture of *H. fossilis* in cemented tanks that is also similar to the present findings. The pH values in all the three treatments were good for culture of *H. fossilis.*

Alkalinity is a measurement of the overall concentration of bases in pond water, which includes carbonates, bicarbonates, hydroxides, phosphates, and borates. Water with high alkalinity and similar hardness levels has a neutral or slightly basic pH and does not fluctuate widely (Cook et al. 1986). The mean water total alkalinity was measured 112.7±3.772, 112.6±3.912 and 114.9±4.094 mg/l in T_1, T_2 and T_3, treatments respectively in the present experiment. Samad and Bhuiyan (2017) recorded mean values of total alkalinity to be 104.50±2.18 to 109.61±2.06 mg/l which is slightly lower than the present study. Monir and Rahman (2015) observed the highest mean value of total alkalinity as (148.83±0.9.28 mg/l) and the lowest as (135.00±12.65 mg/l) in nursery ponds of *H. fossilis* fingerlings in northern region of Bangladesh, which is more or less close to the present result. Boyd (1998) stated that the natural fertility of pond water increases with increase in total alkalinity more than 100mg/l should be present in high productive water bodies. Thus, the variations of total alkalinity in all the tanks were within the productive range for aquaculture.

The mean values of ammonia-nitrogen (NH_3-N) contents in the present study were highest in T_1 (0.039±.014 mg/l) followed by T_2 (0.032±0.015 mg/l) and T_3 (0.019±0.0087 mg/l). Samad and Bhuiyan (2017) recorded the mean value of ammonia-nitrogen in the range from 0.0108 ± 0.002 to 0.0112 ± 0.001 mg/l which is relatively close to the present value. This is found suitable for fish culture and was supported by Boyd (1998) who suggested to keep the ammonia-nitrogen value in fish pond less than 0.1 mg/l. The mean values of ammonia-nitrogen (NH_3-N) contents in the present study is pretty higher than the finding of Roy et al. (2019) who found the range of the value of ammonia-nitrogen from 0.20 to 1.6 mg/l in culture of *H. fossilis* in cemented tanks. This difference has been achieved probably by using the bottom clean method in present experiment. As the wastage was regularly removed from the system, less ammonia-nitrogen content has been resulted.

Growth and production performances

For establishment of a balanced nutrition, economical, and successful feed for culturing practice, understanding the dietary protein requirement of *H. fossilis* becomes a prerequisite. Growth of *H. fossilis* in tanks was investigated and the results obtained from the experiment indicated that there was no significant variation in initial weight of this species between the treatments but in case of final weight, weight gain, ADG, SGR, survival rate, and production of *H. fossilis* in different tanks varied on different treatments. In the present study different types of dietary protein containing feed had a significant effect on production and growth and economy increased with increasing dietary protein levels from 28% to 32%.

The highest weight gain was obtained in $T_{3,}$ which is 65.30±0.36g which is significantly ($p>0.05$) higher than both T_1 (60.65±0.66g) and T_2 (55.53±0.32g). It clearly indicates that the higher dietary protein level results in higher weight gain. Roy et al. (2019) found the mean final weight gain of *H. fossilis* in different treatment as 39.1 ± 0.97 g to 40.48 ± 2.15 g in culture of *H. fossilis* in cemented tanks with a culture period of three months which is very lower than the present finding. This difference has probably been evolved from difference in culture period. Samad and Bhuiyan (2017) revealed their findings as the mean value of weight gain of *H. fossilis* significantly varying from 34.30 ± 0.62g to 43.90 ± 0.42g in six month culture which was more or less similar to that of Mohammed and Ibrahim (2001). These figures are also markedly poor than the present findings, although they also found the similar trend of differences in weight gains with the difference among dietary protein level that supports the present study. From this, it can be summarized that the weight gain of *H. fossilis* in tanks, using bottom clean method is significantly higher than those were found in many previous studies.

The SGR (% bwd^{-1}) achieved under T_1, T_2, and T_3 treatments were 2.63±0.18, 2.91±0.02 and 3.25±0.03 % bwd^{-1}, respectively, after completing the experiment. The lowest SGR was attained in T_1, in which the least amount of dietary protein level was given. Nushy et al. (2020) found specific growth rate (SGR) of *H. fossilis* as 1.00 % bwd^{-1} to 1.23 % bwd^{-1}, which are lower than the present result. A cause of this deviation may include the difference in the age of the stocked animals in these two cases; as Minot (1908) recognized that, for most animals the specific growth rate is highest early in life and that it typically decreases with increasing age, becoming zero in some animals and his epigram. Samad et al. (2014) obtained the specific growth rate (% bwd^{-1}) as 0.92±0.21, 0.83±0.10 and 0.70±0.025 % bwd^{-1} in three different treatments with different dietary protein level for *Clarias batrachus*. They observed that SGR progressively increased with the increase in protein level that is similar to present finding. So, it can be said from this study that the increasing protein inclusion in diet has a positive impact on the specific growth rate of *H. fossilis.*

In the current study, the average daily gains for the T_1, T_2 and T_3 treatments were 0.34±0.03, 0.45±0.05 and 0.47±0.04g, respectively. The highest average daily gain was obtained in T_3 (0.47g) where fish were treated with feed containing highest protein level (32%). Samad et al. (2020) also found the same trend. They obtained highest ADG (0.21±0.04g) at 35% protein level in case of *Mystus cavasius*. Rahman et al. (2013) obtained the highest result (0.134±0.024g) at 35% protein level in case of *Heteropneustes fossilis* for 60 days experiment and the result was lower than that of present study. Samad and Bhuiyan (2017) found ADG ranging from 0.21±0.003 to 24±0.003g for catfish *H. fossilis* in seasonal ponds of Rajshahi, which is also slightly lower than the present study. This indicates that the average daily gain is higher in bottom clean fish farming in tanks than those were found in many earthen ponds. This is probably due to better water quality in tanks, less accumulation of ammonia-nitrogen and less competition among organism for feeding and space resulting in better feed utilization.

The FCR value of T_3 was found to be significantly ($p< 0.0001$) lowest which indicates that lower amount of feed was needed to produce one unit fish biomass and highest was found in T_1. The result indicates that lower FCR is obtained from higher dietary protein, which is supported by the finding of Samad et al. (2017). They also obtained lowest FCR of *H. fossilis* (2.22 ± 0.05) in the highest dietary protein level (31%). Monir and Rahman (2015) recorded the FCR ranging from 1.47±0.25 to 3.10±0.25, which is different from the present findings. This dissimilarity might have been evolved from the difference in dietary protein and also difference in stocking densities in these two studies. Samad and Bhuiyan (2017) recorded the FCR values ranged between 2.05 to 4.14, which were significantly ($P<0.05$) different among the treatments. The lowest value was recorded in T_1 (2.05) with highest protein containing feed (32%). A low FCR value is an indicator of better food utilization efficiency of formulated feed. So, from the present study and also the findings of other previous studies it is supported that lower FCR is obtained with the higher dietary protein in the culture of *H. fossilis*.

The percentage of survival as recorded in the present study was 92.55±0.62, 94.00±0.32 and 96.75±1.16% in T_1, T_2 and T_3 treatments, respectively. The highest survival rate was observed in T_3 (96.75) and the lowest in T_1 (92.55). Rahman et al. (2013) found 93.33% survival rate at 35% protein level in case of *H. fossilis* which is more or less similar to the findings of the present study. Roy *et al.*, (2019) found the percentage of survival as 84% and 87%; those are quite lower than the present study. This deviation seems to occur as the stocking densities were higher than those of present study. Khan et al. (2003) reported the survival rate of *H. fossilis* in the range of 76.13% to 98.81% which is in the range of our finding. Present finding has similarities with those of Akand et al. (1989) and Samad et al. (2005). The survival rates of the present experiment in all the three treatments were great.

The mean productions of *H. fossilis* were 189.32±1.46, 206.73±0.90 and 230.44±1.21 kg/tank in T_1, T_2 and T_3 treatments, respectively. The highest fish production was obtained in treatment T_3 (230.44kg/tank) followed by treatments T_2 (206.73kg/tank) and T_1 (189.32kg/tank). The better performance of fish in treatment T_3 might be due to the higher protein level and better utilization of the feed. Samad et al. (2017) recorded the same trend of production in the culture of *H. fossilis*, where they attained the highest production (2249.98 ± 10.66 kg/ha) with highest dietary protein level (31%). Similar trend of increase in production with increasing protein level was observed with the Production of *Mystus gulio* (2067 Kg/ha) by Hasan et al. (2023) at 30% protein level. Rahman et al. (2014) found the mean production of *H. fossilis* from 5760.79±450.76 to 9708.16±421.40 kg/ha/210 days with two different stocking densities, which is different from present study possibly due to difference in stocking density and culture period. However, this present study resulted in a fair production of *H. fossilis* in tanks and also revealed that higher dietary protein resulted in significantly (p < 0.0001) higher production.

Economic analysis

In the current experiment, T_1 (BDT 43880±657.23/tank) had a lower total cost of production than T_2 (BDT 44200±546.23/tank) and T_3 (BDT 44500±657.54/tank). The net benefits generated from 150 days culture period was obtained as BDT 75728±897.45, 86692±967.57 and 97937±983.76/tank for T_1, T_2 and T_3 treatments, respectively. For T_1, T_2 and T_3 treatments, the cost-benefit ratio (CBR) was 0.73±0.02, 0.96±0.01 and 1.20±0.02, respectively. Data on economics indicated that the treatment T_3 was more profitable than treatments T_2 and T_1. This finding is supported by Azim and Wahab (2003). The better performance of fish in treatment T_3 might be due to the higher protein level of the feed. Samad et al. (2014) recorded that the CBR of *Clarias batrachus* culture was higher (1:1.24) when feed containing 30% protein was used. Samad et al. (2017) found Cost-benefit ratio (CBR) from monoculture system of indigenous catfish Shingi, *H. fossilis* from 1:1.77 to 1:1.91 which is higher from the present findings. This dissimilarity has been evolved probably due to difference in culture period and stocking density. After completing the present study it is clear that the application of higher dietary protein in the culture of *H. fossilis* is economical to the farmers, as it generates the higher benefit and the CBR was significantly higher than those of lower dietary protein

Conclusion and Recommendations

Shing (*Heteropneustes fossilis*) is an attractive and popular species to the people of Bangladesh due to its delicious and nutritious food value. It was clear after completing this study, that the growth and production of *H. fossilis* is better by feeding higher dietary protein level. The present study concludes that the growth, production and net benefits of *H. fossilis* were inversely related to the dietary protein content in the experimental tanks. From this study, it can be recommended that treatment, 32 % dietary protein might be the best *H. fossilis* culture technology in the tanks for farmers in Bangladesh to get higher production and net return.

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How to cite this article: Sultana MA, Samad MA, Rahman MA, & Reza MS (2024). Effect of Different Formulated Feeds on the Growth and Production of *Heteropneustes fossilis* (Bloch, 1794) in Bottom Clean Culture Method. Aquatic Resource Sciences, 01, 12-23.