Growth and Production Performance of Stinging Catfish (*Heteropneustes fossilis*) in Different Cage Conditions

A DISSERTATION SUBMITTED TO THE DEPARTMENT OF FISHERIES, UNIVERSITY OF DHAKA IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE DEGREE OF MASTER OF SICENCE IN FISHERIES

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TO

MY BELOVED PARENTS

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Abstract

Stinging catfish (*Heteropneustes fossilis*) is very popular in Bangladesh. It has high market value. A number of attempts have been taken in different study to develop culture systems of this fishes in cages but the survivability and growth rate was not satisfactory which ultimately decreased production. In the present study, attempt has been taken to develop sustainable cage culture technique providing natural environment for the species inside cage to increase survival rate as well as production. For this purpose, mud with hanging plastic pipe substrate was provided inside the cages since the fish naturally dwell in the mud and prefer to hide inside substrate. Survival and growth of fish inside such modified cage were compared with the fishes reared in ordinary cage. The experiment was conducted for a period of 150 days. Fish fries with a mean weight and length ranged from 2.02 to 2.72 g and 6.30 to 7.28 cm respectively were stocked at 100 and 150 fish per m^3 floating cage with eight treatments and two replicates each in a large earthen pond at Sher-e-Bangla Agricultural University (SAU) campus, Dhaka. Commercial pelleted feed was supplied to caged fish twice daily at a rate of 50% body weight initially per day and later feeding rate was adjusted based on body weight by sampling. Important water quality parameters (temperature, DO, pH, transparency, ammonia, phosphate and nitrate) were recorded weekly throughout the culture period. Survival was 82.50% and 73.67% in the modified square shaped cages and 43.0% and 54.67% in modified rectangular shaped cages for the density of 100 and 150 fish per m^3 respectively. Mean final weight were 24.34g and 32.32g in the modified square shaped cages and 24.84g and 24.55 in the modified rectangular shaped cages for the stocking density of 100 and 150 fish per m^3 respectively. In case of ordinary cages, survival was only 57.0% and 52.33% in the square shaped cages and 40.0% and 34.67% in the rectangular shaped cages for the density of 100 and 150 fish per m^3 respectively. The mean final weights were 17.63g and 18.66g in the square shaped cages, and 15.16g and 16.40g in the rectangular shaped cages for those stocking density respectively. Results showed that net yield was relatively higher in modified square shaped cages than that of ordinary and rectangular shaped cages. This experiment demonstrated the potential of *H. fossilis* production through new technique of cage culture system. However, more research is needed using local feed ingredients with higher stocking density, and also setting mud and substrate separately inside cage to increase profitability and efficiency of the culture system.

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Chapter I
Introduction

Bangladesh is uniquely fortunate having huge water resources scattered all over the country in the form of small ponds, beels, jheels, lakes, canals, estuaries, rivers etc. Both open water and closed water covering an area of about 4.76 million hectares (DoF, 2013). At present the Fisheries sector in Bangladesh represents as one of the most productive and dynamic sectors in the country. This sector plays a significant role in employment, nutrition and foreign exchange earnings in the economy of Bangladesh. In our country more than11% of peoples are directly or indirectly earn their livelihoods from fisheries related activities (DoF, 2013). The Fisheries sector contributes about 4.39% of GDP, 22.76% of gross agricultural product and 2.46% of export earnings (DoF, 2013). From both capture and culture fisheries provide about 60% of the population's total animal protein intake of the country (DoF, 2013). Fisheries is being an important source of essential minerals, vitamins and fatty acids, which are vital factors in child development and adult health. In our country the annual fish intake is18.94 kg per person and the demand is 20.44 kg per person (DoF, 2013).

In our country the number of fresh water fish species is 260 (DoF, 2013). The stinging catfish (*Heteropneustes fossilis*) is very popular air-breathing fresh water fish species and high priced among other air-breathing catfish. This fish is locally known as Shing. It is considered as highly palatable and tasty and well preferred because of its less spine, less fat. It can survive for a very long time when kept in captivity even in a small quantity of water, because it has massive paired sac-like pharyngeal lungs as accessory respiratory organs (Das, 1927). Due to accessory respiratory organs it can thrive well in water in low oxygen levels. The stinging catfish belongs to the phylum chordata, class Actinopterygii, order siluriformes, family heteropneustidae, genus *Heteropneustes*, species *H. fossilis* (Bloch, 1794).

1.1 General Background

Cage culture of fish and in some cases prawns has developed successfully elsewhere in Asia, Europe and America (Bardach *et al.,* 1972). Water bodies in Bangladesh including rivers, irrigation canals, oxbow lakes and haors offer potential sites for cage culture

(Golder *et al.,* 1996). The caged fish are fed with high protein diets and the open pond fish solely depend on the natural foods generated from cage waters (Yang and Lin, 2000).

Earlier studies on stinging catfish include general remarks on the fish (Deraniyagala, 1930), seasonal histology of gonads (Ghosh and Kar, 1952), seasonal morphology of gonads in relation to the pituitary (Sunderaraj, 1959), biology (Bhatt, 1968, Sufi and Bakeya, 1985, Azadi and Siddique, 1986, kuddus *et al.,* 1997). Induced breeding for fry production was reported by Pal and Khan (1969), Sundararaj and Goswami (1969), Khan (1972a and 1972b), Thakur *et al.* (1974 and 1977), Saha *et al.* (1998). The other research was done on food and feeding habits (Kuddus *et al.,* 1995) and nutrition (Molla *et al.,* 1973, Asadur Rahman *et al.,* 1982, Sufi and Begum, 1986, Akand *et al.,* 1989 and 1991, Hossain *et al.,* 1993, Anwar and Jafri, 1995). Haque *et al.* (1988) reported on cultural prospects of Shingi in floating cages.

In cage culture selection of species, fish size and culture cycle is important factors. Catfish can be grown more successfully in cages and these are more desirable species for cage culture (Collins, 1971). The modern cage culture with high stocking density and artificial feed becomes increasingly popular because of its high production and economic return. Lin *et al.* (1997) reported that the wastes from intensive fish (e.g. cage culture) culture are potential fertilizer, which can be reused to generate natural foods for filter feeding species like different carp species. Talukder *et al.* (1998) reported that fish in fixed cages exhibit poorer growth and high mortality rates compared to fish in floating cages with rigid cage frames.

1.2 Rationale

The demand of fish has been increased than the rate of increase of fish production in Bangladesh. Fish production is declining gradually due to unplanned construction of flood control dikes, use of insecticides, improper withdrawal of water for irrigation purpose, over fishing, use of current nets, use of over doses of pesticides in agricultural land. At present, increase of fish production through practicing modern techniques in ponds and other inland waters is the best option. The cage culture technique is one of them. The scope of increasing fish production in inland waters through cage culture is highly expected in Bangladesh. Cage culture is a technique of farmir in a particular type of rearing facility. The cage culture in ponds refers to the system in which high valued species are stocked in suspended cages and fed them with high protein diets. The culture method is very easy because it utilizes publicly owned resources, requires small amount of capital investment and has a rapid return of investment.

In traditional pond aquaculture a common problem is multiple ownership. This is the cause of conflicts when determining the ownership of the fish produced, utilizing the water resources. In cage aquaculture the ownership issue is simple, in that the owners of the cages are the owners of the fish within. The advantages of using cages are the use of existing ponds that are currently not utilize, ease of feeding, ease of stocking and harvesting, less expense associated with treating or preventing disease, technical simplicity with which farms can be established or expanded, lower capital cost compared with land-based farms, easier stocking management and monitoring compared with pond culture. The modern cage culture with high stocking density and artificial feed becomes increasingly popular because of its high production and economic return. As caged fish are generally fed with high protein diets, wastes derived from feed are either directly or indirectly released to the surrounding environment, causing accelerated eutrophication in that water and provide food for outside fish species (Beveridge, 1984, Ackefors, 1986 and Lin, 1990).

Stinging catfish is very high content of iron (226 mg per 100g) and fairly high content of calcium compared to many other freshwater fishes. Due to high nutritive value the fish is recommended in the diet of sick and convalescents. Considering its high market value (500-800 Tk/kg; 3-4 times higher than carp fishes) and high consumer demand, culture of *H. fossilis* in ponds has been started in many parts of the country for last few years. Culture of stinging catfish relatively in deeper and larger ponds is not practiced since the ponds are needed drying for harvesting due to its dwelling in bottom mud. The species could not be caught easily by netting. Therefore, farmers culture this species in small ponds. In addition, the culture ponds of *H. fossilis* are fenced by nylon net with bamboo poles since the fish tend to escape from ponds especially in rainy days. Arrangement and maintenance of fencing is somewhat difficult and cost involving. Rural pond aquaculture practiced in Bangladesh is mainly the semi-intensive carp polyculture of both Indian major and Chinese carps with low production (e.g. 2.8 tha^{-1}, DoF, 2 ponds are perennial and large in size especially in the middle and southern region of the country. Small-scale poor farmers get low return on investment from these ponds due to requirement of external feed and/or fertilizers to apply during culture. Such a system often discourages poor farmers to fish culture. On the other hand, such poor farmers have limited financial resources to turn their whole ponds to culture high valued species using expensive artificial feed. In these circumstances, the cage culture of high valued fish like *H. fossilis* in pond culture system may provide an opportunity for small-scale farmers to use their limited resources to generate more income and improve their livelihood.

1.3 Research gap and need of that research for Bangladesh

Few attempts (Haque et al. 1988 and Wahab et al. 2004) have been taken to develop culture systems of stinging catfish in cages but the results were not very satisfactory due to low survivability. Therefore, more research has been suggested to conduct for improving survivability and production of the species. As for example, Wahab et al. (2004) stocked at 50, 100, 150, and 200 fish per 0.85 m^3 cage placed in carp ponds in his study. The fish were reared 237 days. Survival of caged *H. fossilis* was low, ranging only from 39.33% to 60.67% in different treatments. Caged fish in all treatments grew slowly. Net yields were 0.10 to 0.18 kg m^{-3} $crop^{-1}$ in some treatments, while the other treatments gave negative net yields. Considering this fact, our attempt in the proposed study is to develop an effective cage culture technology of *H. fossilis* through increasing survivability and growth rate. If it becomes successful, the developed culture system not only will be useful for the ponds but also for open water like river, floodplain, beel etc.

1.4 Objectives

The present research was aimed to study comparative production of stinging catfish in different types of cages. However, the specific objectives of the research were-

- To assess comparative growth and production of stinging catfish in square and rectangular shaped cages
- To assess growth and production of stinging catfish in ordinary cage, and modified cage which includes mud and substrate inside
- To determine appropriate stocking density of the fish in cage

- To identify the problem in cage culture of stinging catfish for further improvement of culture technology using cages
- To evaluate the economic benefits of different cage

Chapter II
Materials and Methods

2.1 Study area and pond facilities

The experiment was conducted in an open pond situated in Sher-e-Bangla Agricultural University, Dhaka. The area of pond was about 3 acres with an average depth of 2m. The pond was rectangular in shape, exposed to available sunlight and free from aquatic vegetation. The main source of the pond was rainfall. The embankments of pond were well protected, covered with grass and few trees.

2.2 Study period

The study period of the trial was 150 days from 30 July to 30 December, 2013.

2.3 Construction of cages

Sixteen cages of $1m^3$ were constructed to conduct this experiment. Eight cages were square shaped and rest eight cages were rectangular. The frame of some cages was made of iron sheet and some were made by using bamboo pole which were covered by black nylon net with the help of nylon twine. The shape (width x length x depth) of square and rectangular cages were 1m x1m x 1m and 1m x 1.25m x 0.80m respectively. The mesh size of the net was 1cm which did not allow the experimental fish fry to escape but allowed water to pass easily through the cage. One edge of the upper side was kept an opening of each cage for supplying feed and handling of the fishes when necessary. A floating feeding frame was set inside cages where feed was given regularly. This feeding frame prevented the passing out of feed outside cages (i.e. misuse of feeds). In the experiment two different groups of cages were prepared for both square and rectangular cages. Each group contained 8 square and 8 rectangular cages. First group belonged to ordinary cages made in traditional way using only frame and net. In another group, clay mud collected from pond bottom was placed on the bottom of the cages using polythene paper sheet. These type of cages were designated as “modified cages” in the present study. The depth of mud layer was around 2-3 cm. In these cages some pieces of PVC pipe were horizontally tied with the cage frame on the side wall inside cages. The purpose of introducing mud and pipes were to create a feeling of natural environment for stinging catfish inside those cages.

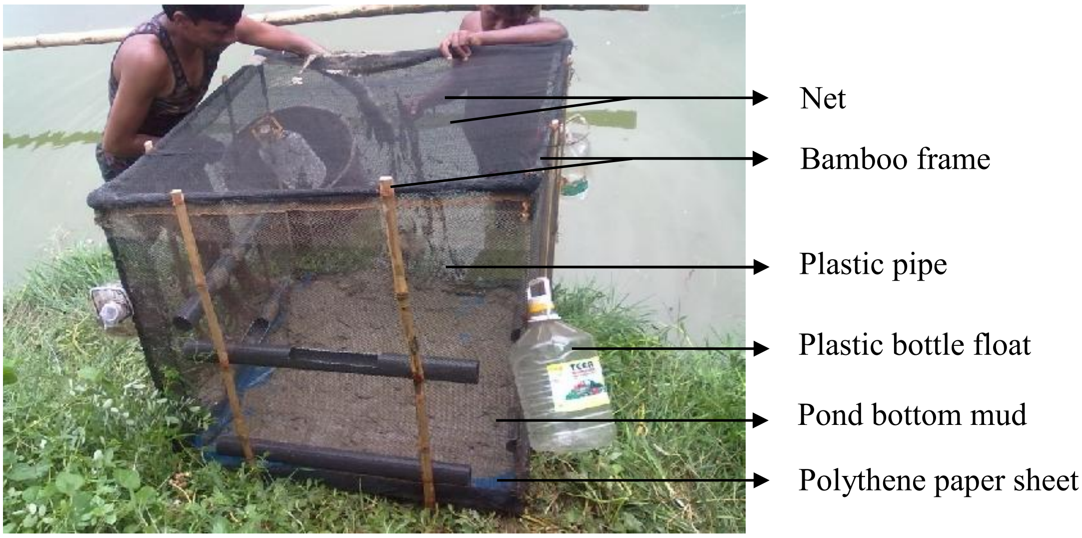

Plate 2.1: Pond bottom mud was provided inside the modified cage

Plate 2.2: Modified rectangular cage with bamboo frame

Plate 2.3: Ordinary square cage with iron frame

2.4 Design of the experiment

The experiment was designed with 8 treatments and 2 replications for each. The experiment design has presented in table 1.

Table 2.1: Design of the experiment

Treatment No.	Type of treatment	Treatment No.	Type of treatment
T1	Ordinary square shaped cage with 100 fish	T5	Ordinary rectangular shaped cage with 100 fish
T2	Ordinary square shaped cage with 150 fish	T6	Ordinary rectangular shaped cage with 150 fish
T3	Modified square shaped cage with 100 fish	T7	Modified rectangular shaped cage with 100 fish
T4	Modified square shaped cage with 150 fish	T8	Modified rectangular shaped cage with 150 fish

2.5 Suspension of cages

The cages were tied using nylon rope to the bamboo platform so that the cages remain fixed near to the platform. This platform was used to supply feed easily and observing the fish of the cages. Plastic bottle floats were used for suspension of the cages.

Plate 2.4: Cages were set up in the pond with the help of bamboo platform

2.6 Fry collection and stocking of fish

Fries of stinging cat fish were collected from Mr. Shahin, a nursery farmer in Shomvuganj upazilla under Mymensingh district. The fish fries were carried by oxygenated polythene bag during bringing to the experiment place. Transportation was done carefully as possible in order to minimize mortality. Then the fries were kept into hapa for one day for conditioning. The average initial length and weight of fries were measured before releasing into the cage. The fish were stocked in the cages at various densities among treatments according to experiment design (Table 2.1).

2.7 Feeding

In each cage, a floating feeding frame was tied from the upper portion of the cages with the help of nylon rope to keep the frame fix near middle portion of the side walls. Fish were fed twice in a day at 7 AM and 6 PM with commercial pellet feed (Mega Feed Ltd.). Feeding rates and protein contain of feeds were adjusted after measuring mean body weight by sampling. The feeding regime has been given in Table 2.2.

Table 2.2: Feeding rates adjusted on the basis of percentage of body weight

Fish weight (gm)	Types of feed supplied	Protein content of feed (%)	Amount of feed supplied (% fish body weight)
0.2-3	Nursery	35	50
3-10	Starter (Crumble)	30	20
10-30	Starter	30	10
31-60	Grower	30	5

2.8 Cage management

The cages were lifted and checked every 15 days interval to clean the nets for good water exchange and aeration. If there found any dead fish was also removed at that time. The cages were also checked whether the nets had any damage.

2.9 Sampling of fish

The fish were sampled fortnightly using a scoop net. The purpose of sampling was to observe the health condition and to adjust the feeding rate with increased body weight. Total length and body weights of fishes were recorded. The lengths were measured using a centimeter scale and the body weight by an electric balance.

Plate 2.5: Weight and length were measured by using an electric balance and a centimeter scale

2.10 Study of water quality parameters

Water quality parameters are the most important factors which influence the aquatic production directly. The suitable water quality parameters are prerequisite for sound aquatic atmosphere. In fish culture, water quality is usually defined as the suitability of water for the survival and growth of fish. Water quality parameters such as temperature (°C), transparency (cm), pH, dissolved oxygen (mg/l), Phosphate-phosphorus (mg/l), nitrate nitrogen (mg/l) and ammonia nitrogen (mg/l) were measured biweekly in the morning time at 8 am. Temperature, transparency, dissolved oxygen and pH was measured on the spot. Other analyses were accomplis

Department of Fisheries, SAU, Dhaka.

Plate 2.6: Water quality parameters were measured beside the pond

2.11 Collection of water sample

Water samples were collected by using white plastic bottles having a volume of 250ml each and marked with treatment number. Then the water samples were carried to the laboratory for chemical analysis.

2.12 Measurement of physical parameters

The physical factors were recorded by the following methods:

Temperature (°C)

Water temperature (°C) was recorded using Celsius thermometer (digi-thermo WT-2) at the pond site

Transparency (cm)

Water transparency was measured with a standard Secchi disc of 30 cm diameter and measuring tape. At first the secchi disc was pierced into water upto the view point of naked eye. Then the length of secchi disc depth was measured in cm.

2.13 Methods used for chemical analysis

The chemical factors of water were determined by the following methods:

Dissolved Oxygen (mg/l)

A portable digital DO meter (Lutron, DO-5509) was to determine the dissolved oxygen of water.

Hydrogen ion concentration (pH)

Hydrogen ion concentration (pH) of pond water was measured by using a digital pH meter (Eco Test r pH2).

Nitrate-Nitrogen (mg/l)

Nitrate-Nitrogen (mg/l) was determined by nitrate measuring kit (HANNA instrument Test Kit).

Ammonia-Nitrogen (mg/l)

Ammonia-Nitrogen (mg/l) was determined by ammonia measuring kit (HANNA instrument Test Kit).

Phosphate-Phosphorus (mg/l)

Phosphate-Phosphorus (mg/l) was determined by phosphate measuring kit (HANNA instrument Test Kit).

2.14 Study of growth and production of fish

At the end of the culture period fishes were picked up and measured length and weight. To evaluate the growth and production of fishes following parameters were used:

Weight gained

Weight gained refers to as the difference between final weight and initial weight.

The formula:

Weight gained =Mean final fish weight – Mean initial fish weight

Percentage of weight gained

The formula for measuring Percentage of weight gained was as follows:

Percentage of weight gained = $\frac{\text{Mean final fish weight} - \text{Mea}}{\text{Mean initial fish weight}} \times 100$

Analysis of specific growth rate

The specific growth rate was measured by the following formula:

$$\text{Specific Growth Rate (\% day)} = \frac{\log_e w2 - \log_e w1}{T2 - T1} \times 100$$

Where,

W1 = Initial live body weight (g) at time T1 (day)

W2 = Final live body weight (g) at time T2 (day)

T_2-T_1 = No. of days of the experiment

Food conversion ratio (FCR)

The food conversion ratio is defined as a ratio expressing the weight of dry feed required to produce a unit live weight gain of an animal. It is a measure of degree of gross utilization of feed. The FCR value always will be more than 1. The lower the FCR value, the better the quality of supplied feed. The food conversion ratio for fishes was determined by the following formula:

$$\text{FCR} = \frac{\text{Food fed (Dry matter)}}{\text{Live weight gain}}$$ (Castell and Tiews, 1980)

Survival rate

The formula used for determining survival rate as below:

$$\text{Survival rate} = \frac{\text{No.of fishes harvested}}{\text{No.of fishes stocked}} \times 100$$

Yield of fishes

1. Gross Yield = No. of fish caught x Average final weight
2. Net Yield = No. of fish caught x Average weight gained

2.15 Statistical analysis

During experimental period all the data collected, record
spreadsheet. The data obtained in the experiment were analyzed statistically one-way ANOVA and linear regression (Steele and Torrie, 1980) using statistical software (SPSS, version 16.0, SPSS Inc., Chicago, USA). Means were given with ± standard error (SE).

2.16 Economic analysis

Economic analysis was conducted to determine economic returns of different treatments based on market prices of stinging catfish in Bangladesh. The fish fries and pelleted feed were purchased at the rate of 2 TK/piece and 40 TK/Kg respectively. The market price of adult stinging cat fish was considered as 600 TK/Kg in this analysis.

Chapter-III
RESULTS

3.1 Water quality parameters

To observe any appreciable change a large number of samples were analyzed for water quality parameters that might have occurred on response to case-pond aquaculture. Different physico-chemical parameters such as temperature (°C), dissolved oxygen (mg/l), hydrogen ion concentration (pH), transparency (cm), nitrate-nitrogen (mg/l), ammonia-nitrogen (mg/l) and phosphate-phosphorus (mg/l) were recorded throughout the experimental period. The mean values (±SEM) of water quality parameters of different treatments have been presented in tables 3.1 and 3.2.

Table 3.1: Water quality parameters (Mean±SEM) were recorded weekly from different treatments of experimental pond. Values are means of 21 sampling dates (N=21)

Parameters	Pond	Treatments		Level of significance (ANOVA)
		Ordinary cage	Modified cage	
Temperature (°C)	27.7±0.734 (20.10-32.20)	27.7±0.734 (20.10-32.20)	27.7±0.734 (20.10-32.20)	NS
Dissolved oxygen (mg/l)	6.86 ± 0.140^{c} (5.80-8.10)	6.21 ± 0.080^{b} (5.40-6.90)	5.31 ± 0.110^{a} (4.40-6.20)	*
Hydrogen ion concentration (pH)	7.66 ± 0.034^{b} (7.30-7.90)	7.57 ± 0.025^{b} (7.40-7.80)	7.43 ± 0.029^{a} (7.20-7.70)	*
Transparency (cm)	39.81±1.030 (31.0-49.0)			NS

NS – Not significant ($P>0.05$)

* Significant ($P<0.05$)

Mean values with different superscript letters in each row indicate significantly difference (*P<0.05*). Figures in the parenthesis indicate low values.

Table 3.2: Water quality parameters (Mean±SEM) were recorded weekly from different treatments of experimental pond. Values are means of 21 sampling dates (N=21)

Parameters	Pond	Treatments		Level of significance (ANOVA)
		Ordinary cage	Modified cage	
Nitrate-nitrogen (mg/l)	0.13 ± 0.011^a (0.05-0.24)	0.15 ± 0.009^a (0.06-0.22)	0.19 ± 0.009^b (0.08-0.25)	*
Ammonia-nitrogen (mg/l)	0.61 ± 0.051^a (0.20-1.0)	0.81 ± 0.046^b (0.30-1.20)	1.24 ± 0.063^c (0.30-1.70)	*
Phosphate-phosphorus (mg/l)	2.50 ± 0.135^a (1.50-3.70)	2.98 ± 0.136^a (2.10-4.10)	3.68 ± 0.205^b (2.10-5.10)	*

NS – Not significant (*P>0.05*)

* Significant (*P<0.05*)

Mean values with different superscript letters in each row indicate significantly difference (*P<0.05*). Figures in the parenthesis indicate lowest and highest values.

3.1.1 Temperature

The water temperature of experimental ponds varied from 20.10 to 32.20°C during the study period. The mean values (±SEM) of water temperature in each treatment were exactly same (27.7 ± 0.734 ºC) and hence no significant difference (*P>0.05*) among the treatments. Average weekly variations of water temperature in pond under different treatments are shown in Figure 3.1.

3.1.2 Dissolved oxygen (DO)

Dissolved oxygen was recorded at 7.30 to 8.30 am. The range of dissolved oxygen was recorded from 4.40 to 8.10 mg/l. The mean values of dissolved oxygen concentration were 6.86±0.140, 6.21±0.080 and 5.31±0.110 mg/l in pond water, ordinary cage and modified cage respectively. There was significant difference ($p<0.05$) of mean values of dissolved oxygen concentration among different treatments. Average w of dissolved oxygen concentration under different treatments are shown in figure 3.2.

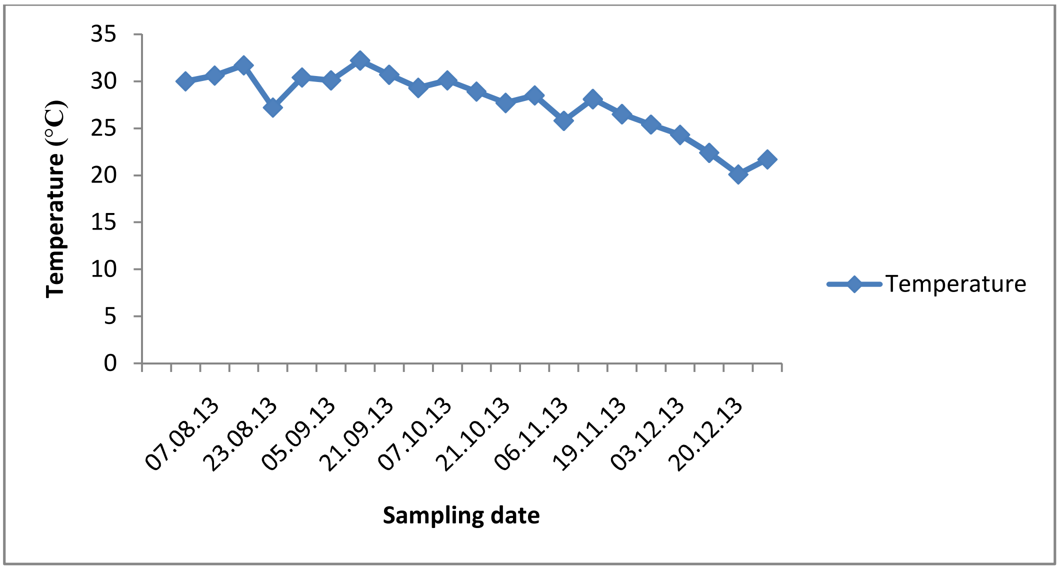

Figure 3.1: Average weekly variations of temperature in different treatments throughout the experimental period

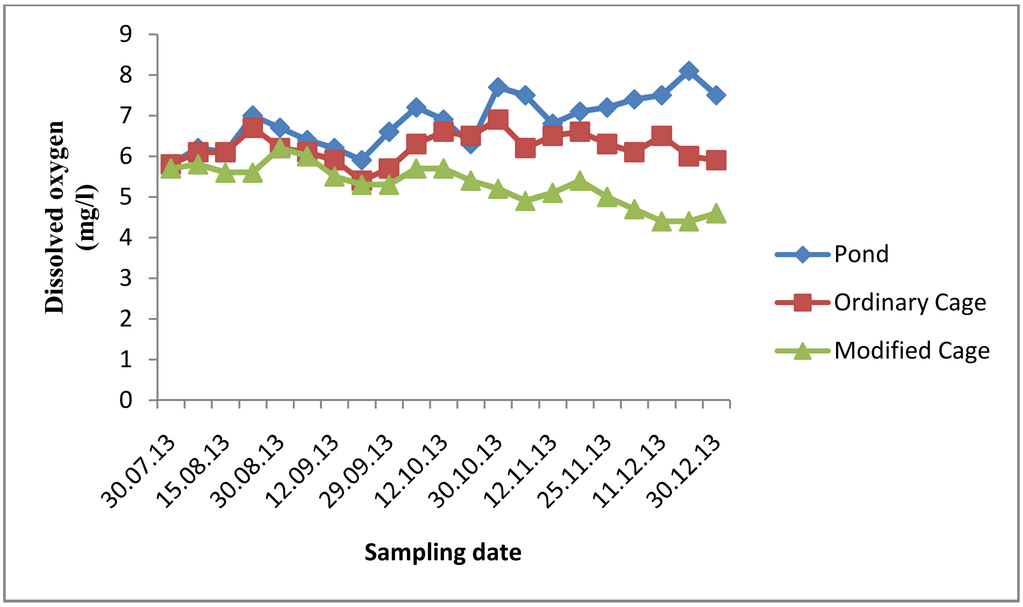

Figure 3.2: Average weekly variations of dissolved oxygen in different treatments throughout the experimental period

3.1.3 Hydrogen ion concentration

The pH values of different treatments were found to be slightly alkaline ranging from 7.20 to 7.90. The mean values of pH were 7.66±0.034, 7.57±0.025 and 7.43±0.029 in pond water, ordinary cage and modified cage respectively. There was significant difference ($p<0.05$) among different treatments when compared using ANOVA. Average weekly variations of pH under different treatments are shown in figure 3.3.

3.1.4 Transparency

The mean value of water transparency was 39.81±1.030cm. The highest value of water transparency was recorded 49cm. There was no significant difference ($p>0.05$) of mean values of dissolved oxygen concentration among different treatments. The average weekly variations of Secchi disc reading are shown in figure 3.4.

3.1.5 Nitrate-nitrogen

Some variations of the overall mean values of nitrate-nitrogen were found in treatments. The range of nitrate-nitrogen was recorded from 0.05 to 0.25 mg/l. The mean values of nitrate-nitrogen were 0.13±0.011, 0.15±0.009 and 0.19±0.009 mg/l in pond water, ordinary cage and modified cage respectively. There was significant difference ($p<0.05$) of mean values of nitrate-nitrogen among different treatments. Average weekly variations of nitrate-nitrogen under different treatments are shown in figure 3.5.

3.1.6 Ammonia-nitrogen

The range of the value ammonia-nitrogen was recorded from 0.20 to 1.70 mg/l. The mean values of ammonia-nitrogen were 0.61±0.051, 0.81±0.046 and 1.24±0.063 in pond water, ordinary cage and modified cage respectively. There was significant difference ($p<0.05$) among different treatments when compared using ANOVA. Average weekly variations of ammonia-nitrogen under different treatments are shown in figure 3.6.

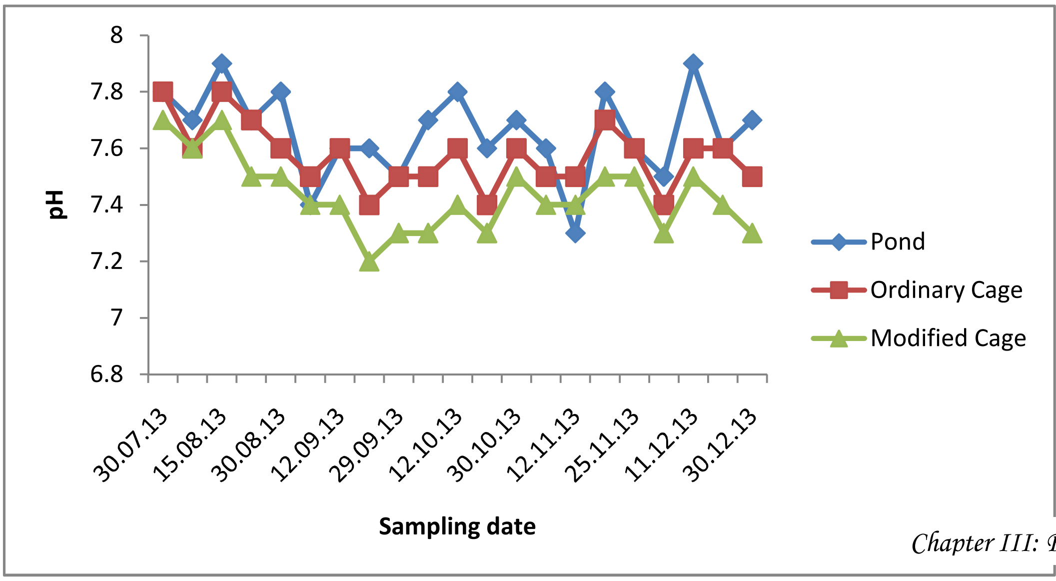

Figure 3.3: Average weekly variations of pH in different treatments throughout the experimental period

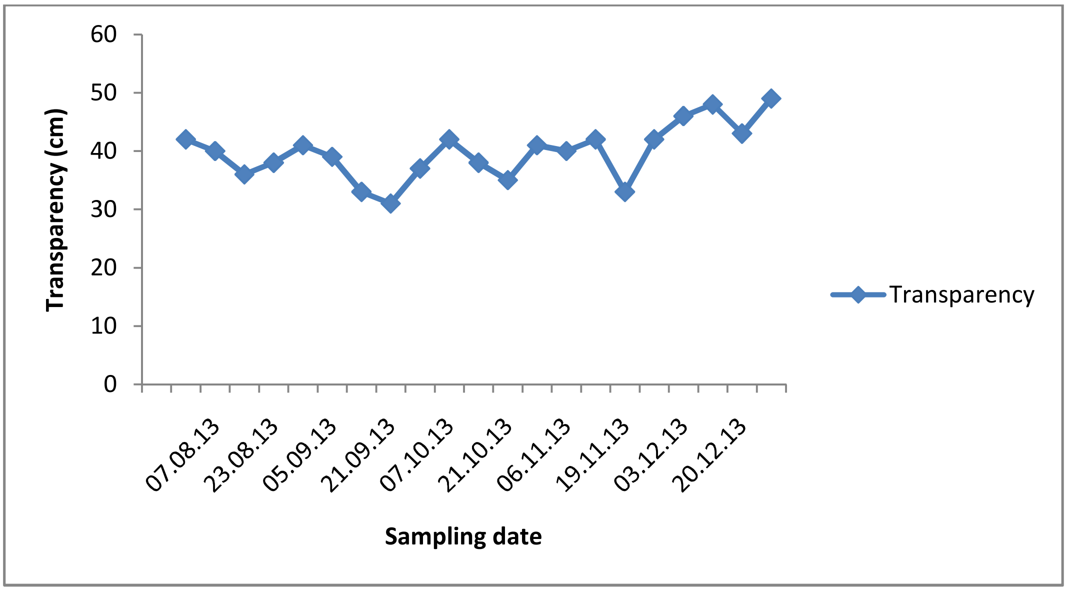

Figure 3.4: Average weekly variations of transparency in different treatments throughout the experimental period

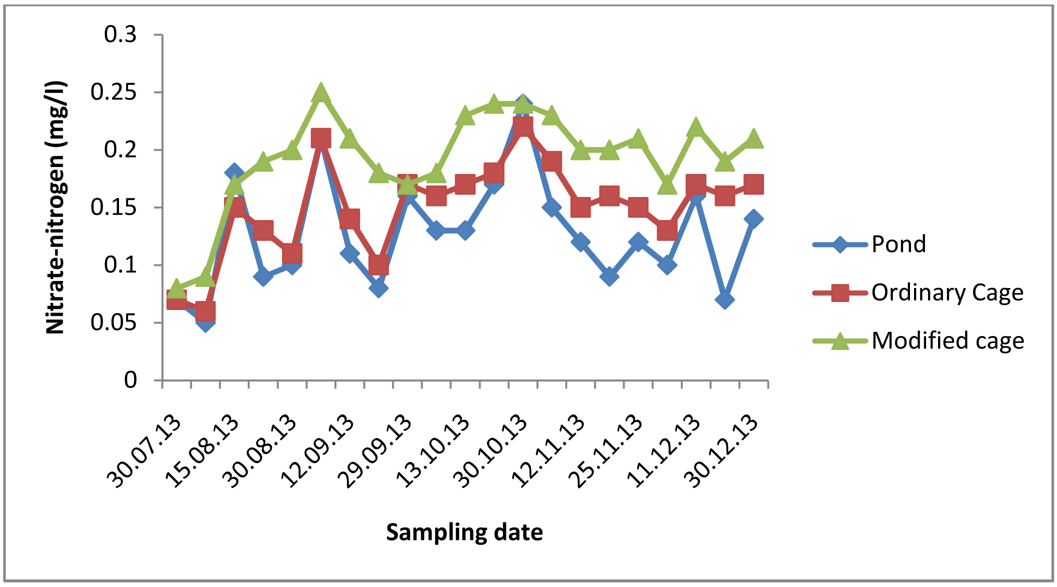

Figure 3.5: Average weekly variations of nitrate-nitrogen in different treatments throughout the experimental period

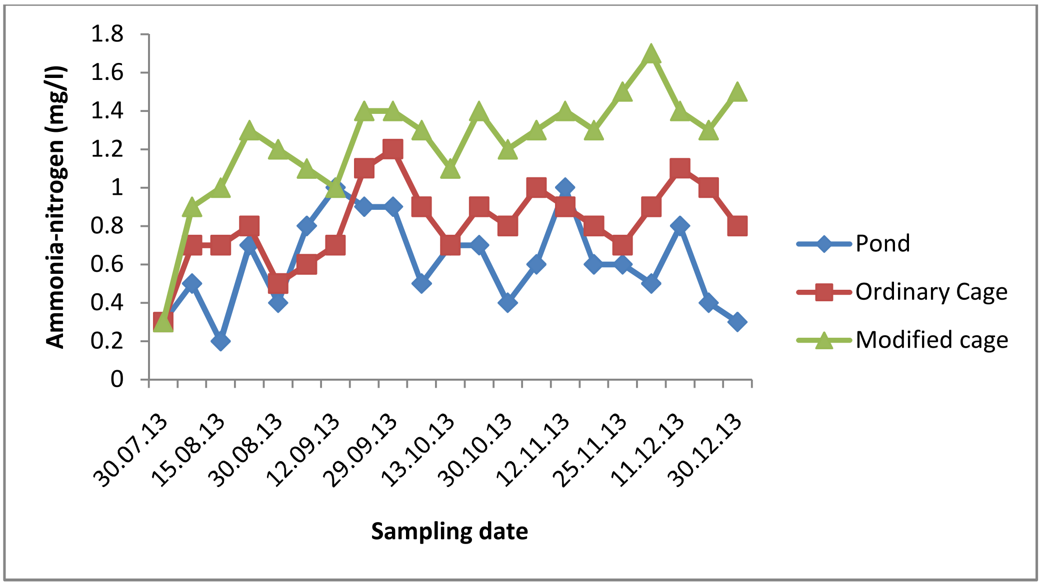

Figure 3.6: Average weekly variations of ammonia-nitrogen in different treatments throughout the experimental period

3.1.7 Phosphate-phosphorus

The value of phosphate-phosphorus ranged from 1.50 to 5.10 mg/l during the experimental period. The mean values of phosphate-phosphorus were found 2.50±0.135, 2.98±0.136 and3.68±0.205 mg/l in pond water, ordinary cage and modified cage respectively. There was significant difference (*p<0.05*) among different treatments when compared using ANOVA. Average weekly variations of phosphate-phosphorus under different treatments are shown in figure 3.7.

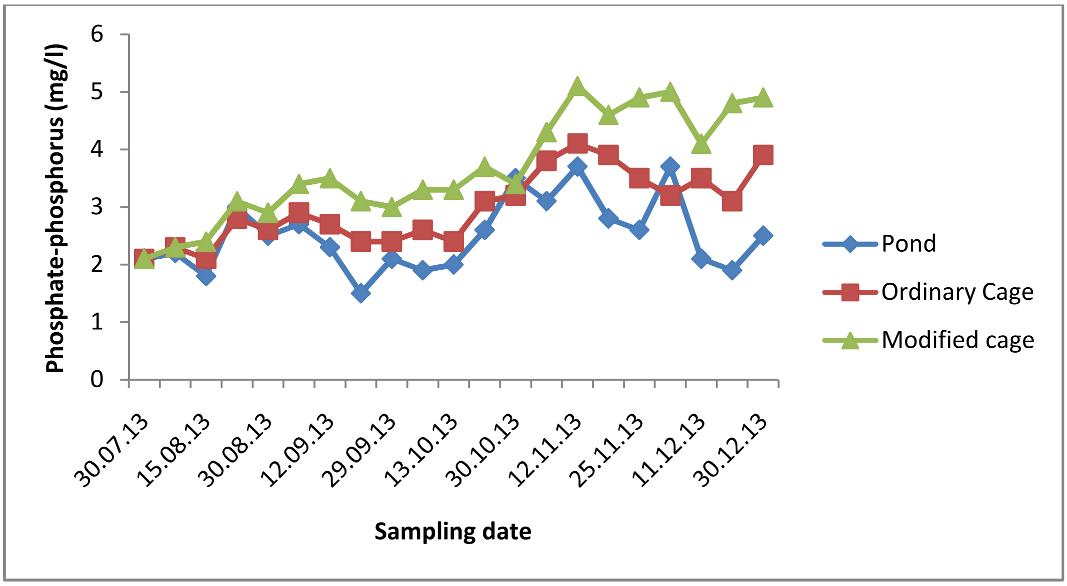

Figure 3.7: Average weekly variations of phosphate-phosphorus in different treatments throughout the experimental period

3.2 Growth and production performance of fish

The growth and production performance of stinging catfish in terms of initial weight, final weight, weight gain, average daily gain, specific growth rate (SGR%), food conversion ratio, survival and gross yield among the treatments are presented in Table 3.3 and 3.4.

Table 3.3: Growth and production parameters (Mean±SEM) of stinging catfish in different treatments of square shaped cages

Growth and production performance parameters	Treatments				Level of significance (ANOVA)
	Ordinary cage		Modified cage		
	T1	T2	T3	T4	
Initial length	6.30±0.12^{a}	6.79±0.16^{a}	6.86±0.23^{a}	6.92±0.24^{a}	NS
Final length	14.45±0.56^{a}	14.78±0.38^{a}	15.77±0.65^{a}	17.84±0.51^{b}	*
Length gain (cm)	8.15±0.63^{a}	7.99±0.36^{a}	8.91±1.24^{a}	10.92±0.11^{a}	NS
Initial weight	2.04±0.13^{a}	2.22±0.16^{a}	2.34±0.20^{a}	2.35±0.25^{a}	NS
Final weight	17.63±1.94^{a}	18.66±1.35^{a}	24.34±2.72^{ab}	32.32±2.78^{b}	*
Weight gain (g)	15.59±2.28^{a}	16.44±0.88^{a}	22.0±3.20^{ab}	29.97±0.82^{b}	*
Specific growth rate (SGR% /day)	1.44±0.14^{a}	1.43±0.05^{a}	1.55±0.09^{a}	1.76±0.08^{a}	NS
FCR	14.80±0.32^{b}	18.10±0.06^{c}	10.98±0.12^{a}	15.46±0.40^{b}	*
Survival (%)	57.0±7.00^{a}	52.33±4.34^{a}	82.50±0.50^{b}	73.67±0.34^{ab}	*
Gross yield (kg/m^3)	0.775±0.03^{a}	1.0±0.05^{ab}	1.35±0.05^{bc}	1.70±0.10^{c}	*

NS – Not significant (*P>0.05*)

* Significant (*P<0.05*)

Mean values with different superscript letters in each row indicate significantly difference (*P<0.05*)

Table 3.4: Growth and production parameters (Mean±SEM) of stinging catfish in different treatments of rectangular shaped cages

Growth and production performance parameters	Treatments				Level of significance (ANOVA)
	Ordinary cage		Modified cage		
	T5	T6	T7	T8	
Initial length	6.62±0.32[a]	7.14±0.15[a]	6.96±0.43[a]	7.28±0.21[a]	NS
Final length	13.87±0.56[a]	14.08±0.60[a]	16.11±0.84[a]	16.13±1.06[a]	NS
Length gain (cm)	7.25±0.13[a]	6.94±0.07[a]	9.15±0.03[a]	8.85±1.26[a]	NS
Initial weight	2.02±0.19[a]	2.46±0.19[a]	2.72±0.39[a]	2.60±0.22[a]	NS
Final weight	15.16±1.49[a]	16.40±1.62[a]	24.84±3.22[a]	24.55±4.17[a]	*
Weight gain (g)	13.14±0.37[a]	13.94±0.43[a]	22.12±0.81[a]	21.85±3.01[a]	*
Specific growth rate (SGR% /day)	1.35±0.05[a]	1.28±0.13[a]	1.48±0.01[a]	1.50±0.08[a]	NS
FCR	18.04±0.18[b]	19.71±0.28[b]	11.89±0.16[a]	13.83±0.90[a]	*
Survival (%)	40.0±6.0[a]	34.67±6.0[a]	43.0±2.0[a]	54.67±8.0[a]	NS
Gross yield (kg/m³)	0.45±0.06[a]	0.60±0.04[a]	0.51±0.02[a]	1.47±0.19[b]	*

NS – Not significant (*P>0.05*)

* Significant (*P<0.05*)

Mean values with different superscript letters in each row indicate significantly difference (*P<0.05*)

3.2.1 Initial length

The initial lengths of stinging catfish were more or less similar among treatments. The range of mean value of initial lengths of stinging catfish was recorded from 6.30±0.12 to 6.92±0.24 cm in square shaped cages and 6.62±0.32 to 7.28±0.21 cm in rectangular shaped cages. There was no significant difference (*p>0.05*) among different treatments when compared using ANOVA.

3.2.2 Final length

The range of mean value of final lengths of stinging catfish was recorded from 14.45±0.56 to 17.84±0.51 cm in square shaped cages and 13.87±0.56 to 16.13±1.06 cm in rectangular shaped cages. The mean values of final length of stinging catfish showed that there was significant difference (*p<0.05*) among treatments of square shaped cages and no significant difference (*p>0.05*) among treatments of rectangular shaped cages.

3.2.3 Length gain

The range of mean value of length gain was 6.94±0.07 to 8.15±0.63 cm in ordinary cages and 8.85±1.26 to 10.92±0.11 cm in modified cages (Table 3.3 and 3.4). In square shaped cages and rectangular shaped cages the range of mean value of length gain was 7.99±0.36 to 10.92±0.11cm and 6.94±0.07 to 9.15±0.03 cm respectively. The mean values of length gain of stinging catfish showed that there was no significant difference (*p>0.05*) among different treatments. The highest and lowest length gain was found in T4 and T6 treatment respectively.

3.2.4 Initial weight

The initial weights of stinging catfish were more or less similar among treatments. The range of mean value of initial weights of stinging catfish was recorded from 2.04±0.13 to 2.35±0.25 g in square shaped cages and 2.02±0.19 to 2.72±0.39 g in rectangular shaped cages. There was no significant difference (*p>0.05*) among different treatments when compared using ANOVA.

3.2.5 Final weight

The range of mean value of final lengths of stinging catfish was recorded from 17.63±1.94 to 32.32±2.78 g in square shaped cages and 15.16±1.49 to 24.84±3.22 g in rectangular shaped cages. The highest and lowest mean final weight was found in treatment T4 (modified square cage) and T5 (ordinary rectangular cage) respectively. The mean values of final length of stinging catfish showed that there was significant difference (*$p<0.05$*) among treatments of both square and rectangular shaped cages.

3.2.6 Weight gain

Among the treatments, the mean weight gain of stinging catfish different (*$p<0.05$*) when compared using ANOVA. The weight gain was highest in T4 treatment (modified square cage with 150fish/m^3 stocking density) and lowest in T5 treatment (ordinary rectangular cage with 100 fish). The range of mean value of weight gain was 13.14±0.37 to 16.44±0.88 g in ordinary cages and 21.85±3.01 to 29.97±0.82 g in modified cages (Table 3.3 and 3.4). Considering only the shape of cages, the ranges of mean value of weight gain in square shaped cages and in rectangular shaped cages were 15.59±2.28 to 29.97±0.82 g and 13.14±0.37 to 22.12±0.81 g respectively.

3.2.7 Specific growth rate (SGR)

The specific growth rate of fish ranged from 1.43±0.05 to 1.76±0.08 (% per day) in square shaped cages and 1.28±0.13 to 1.50±0.08 (% per day) in rectangular shaped cages. There was no significant difference (*$p>0.05$*) among different treatments. The range of mean value of specific growth rate was 1.28±0.13 to 1.44±0.14 (% per day) in ordinary cages and 1.48±0.01 to 1.76±0.08 (% per day) in modified cages. The highest and lowest specific growth rate was found in T4 and T6 respectively.

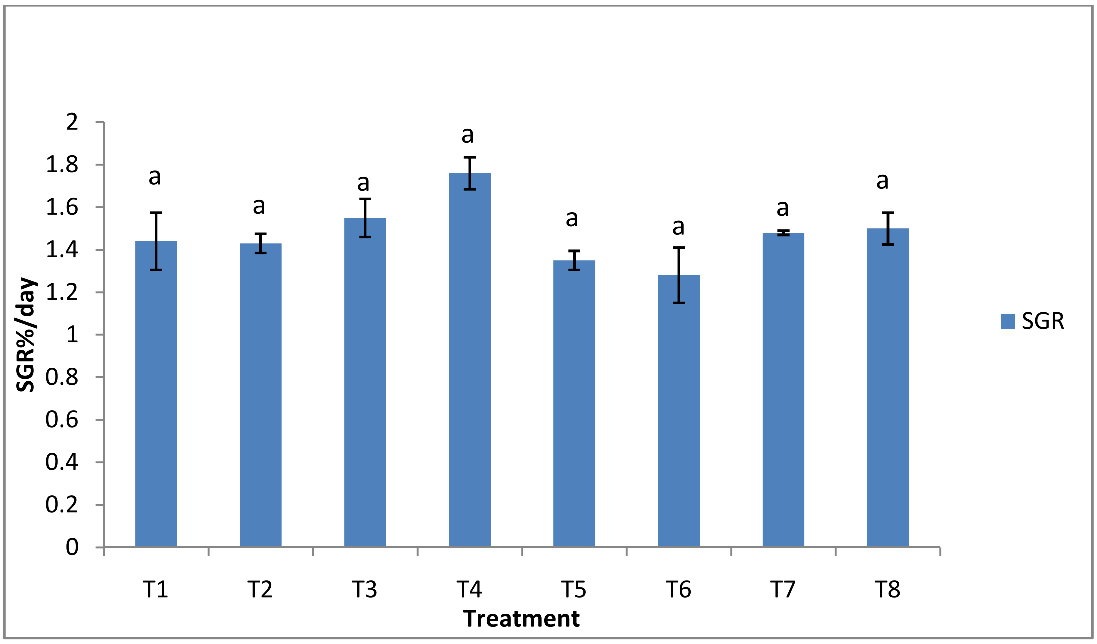

Figure 3.8: Comparative Specific Growth Rate of stinging catfish in different treatments

3.2.8 Food conversion ratio (FCR)

Artificial commercial feed was supplied in the study which contained 30-35 % protein. The values of FCR were varied from 10.98±0.12 to 19.71±0.28 throughout the study. The range of mean values of FCR was 14.80±0.32 to 19.71±0.28 in ordinary cages and 10.98±0.12 to 15.46±0.40 in modified cages. The mean value of FCR was significantly difference (*$p<0.05$*) among treatments.

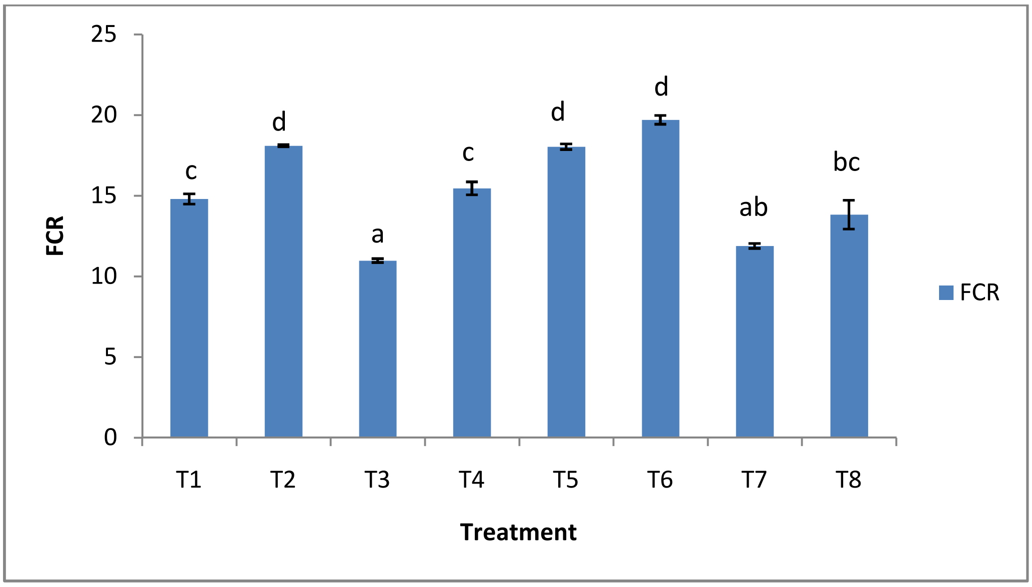

Figure 3.9: Comparative Food conversion ratio (FCR) of stinging catfish in different treatments

3.2.9 Survival rate (%)

If the cage shape is considered, square shaped cages (treatment T1 to T4) showed higher survival rate (range of mean values 52.33±4.34 to 82.50±0.50 %) than those of rectangular cages (34.67±6.0 to 54.67±8.0 %) (Table 3.3 and 3.4). On the other hand, considering inclusion of mud and substrate inside cage, the survival rate was found higher in modified cages (mean values 43.0±2.0 to 82.50±0.50 %.) than ordinary cages (34.67±6.0 to 57.0±7.00 %). Among the modified cages, the survival rate was found higher in square shaped cages (T3 and T4) than rectangular shaped cages (T7 and T8). The mean value of survival rate in square shaped modified cages wa whereas in rectangular modified cages the survival rate was below 50% (Figure 3.10). There was significant difference (*p<0.05*) in the treatments of square shaped cages and no significant difference (*p>0.05*) in the treatments of rectangular shaped cages. In square shaped modified cages, higher survival rate (84%) was found in the cage with lower stocking density (100 fish per m³; T3). On the contrary, the modified cage with higher stocking density of 150 fish/m³ (T4), the survival rate was found lower which was around 74%.

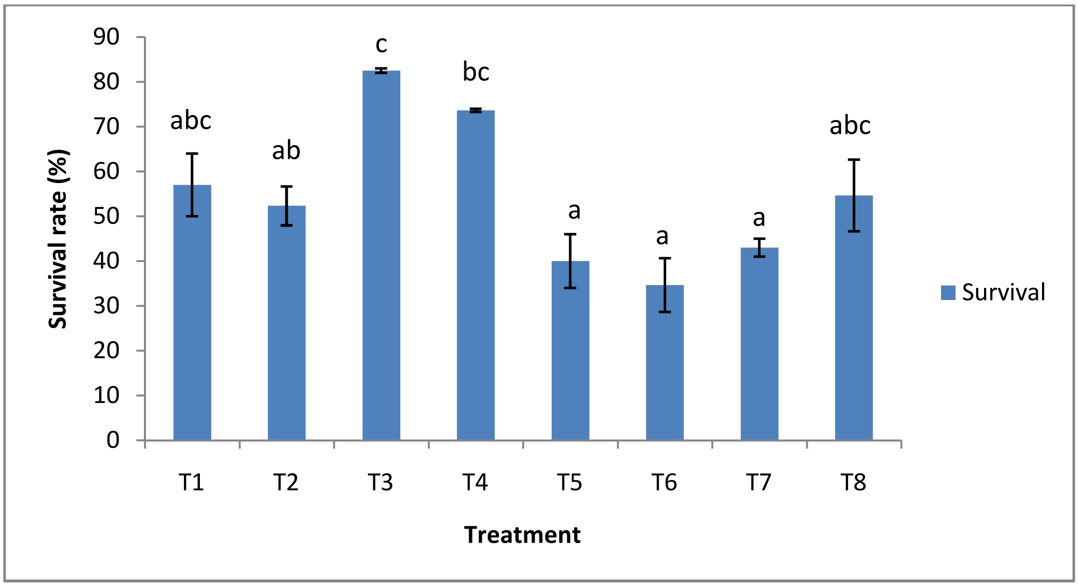

Figure 3.10: Comparative survival rate (%) of stinging catfish in different treatments

3.2.10 Gross yield

At the end of the experiment the gross yield of fish was estimated. The gross yield of fish was calculated on per cage basis over 150 days culture period. The gross production of stinging catfish ranged from 0.45±0.06 to 1.0±0.05 kg/cage in ordinary cages and 0.51±0.02 to 1.70±0.10 kg/cage in modified cages (Table 3.3 and 3.4). The highest value was found from T4 treatment that was modified square shaped cage with 150 fish (Figure 3.11). The lowest value was found from T5 treatment that was ordinary rectangular shaped cage with 100 fish. Irrespective of the presence of mud and substrate inside cage, the range of mean value of gross yield was 0.775±0.03 to 1.70±0.10 kg/cage in square shaped cages and 0.45±0.06 to 1.47±0.19 kg/cage in rectangular shaped cages. There was significant difference ($p<0.05$) among treatments of both square and rectangular shaped cages.

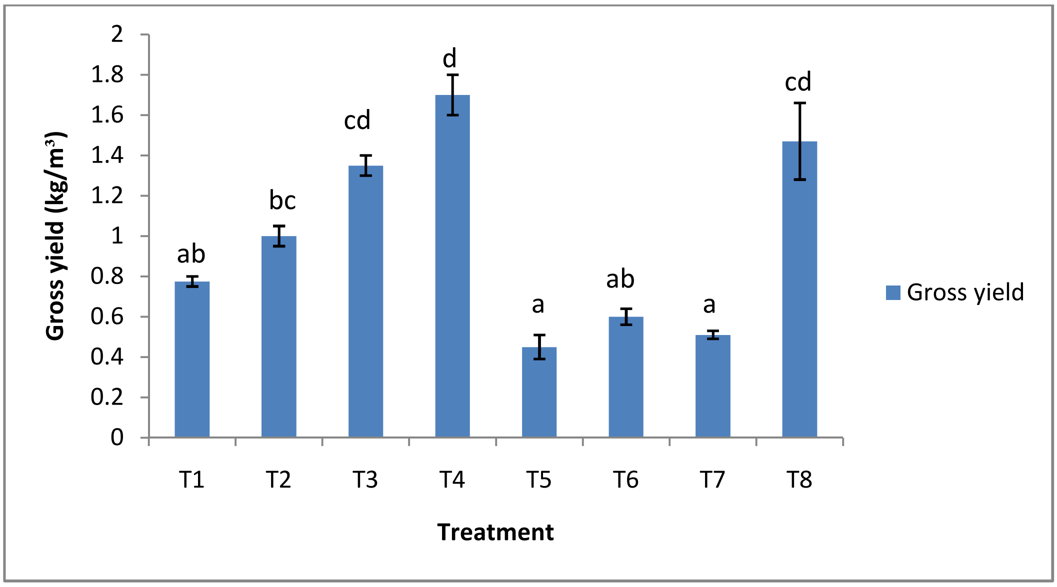

Figure 3.11: Comparative gross yield of stinging catfish in different treatments

3.3 Economic analysis

The economic analysis of stinging catfish production of each treatment per cage (m^3) has been shown in table 3.5 and 3.6. The results (Tk/cage) have been discussed under the following subheadings:

Table 3.5: Comparison of gross and net income with cost-benefit analysis in each treatment of square shaped cages (Tk/cage)

Parameters	Treatments				Level of significance (ANOVA)
	Ordinary cage		Modified cage		
	100T1	150T2	100T3	150T4	
GROSS REVENUE					
Stinging catfish	$465±15^{a}$	$600±30^{ab}$	$810±30^{bc}$	$1020±60^{c}$	*
Total	$465±15^{a}$	$600±30^{ab}$	$810±30^{bc}$	$1020±60^{c}$	*
OPERATIONAL COST					
Catfish fry	200±0	300±0	200±0	300±0	NS
Cage	160±0	160±0	170±0	170±0	NS
Bamboo platform	10±0	10±0	10±0	10±0	NS
Pelleted feed	$303±5^{a}$	$514±28^{b}$	$392±15^{a}$	$604±19^{b}$	*
Total cost	$673±5^{a}$	$984±28^{b}$	$772±15^{a}$	$1084±19^{b}$	*
NET RETURN (TK/m^3)	$-208±10^{b}$	$-384±1^{a}$	$37±14^{c}$	$-64±40^{c}$	*

NS – Not significant (*P>0.05*)

* Significant (*P<0.05*)

Mean values with different superscript letters in each row indicate significantly difference (*P<0.05*)

Price: Stinging catfish selling price 600Tk/kg was considered

Table 3.6: Comparison of gross and net income with cost-benefit analysis in each treatment of rectangular shaped cages (Tk/cage)

Parameters	Treatments				Level of significance (ANOVA)
	Ordinary cage		Modified cage		
	100T5	150T6	100T7	150T8	
GROSS REVENUE					
Stinging catfish	$270{\pm}36^{a}$	$360{\pm}24^{a}$	$306{\pm}12^{a}$	$882{\pm}114^{b}$	*
Total	$270{\pm}36^{a}$	$360{\pm}24^{a}$	$306{\pm}12^{a}$	$882{\pm}114^{b}$	*
OPERATIONAL COST					
Catfish fry	200±0	300±0	200±0	300±0	NS
Cage	160±0	160±0	170±0	170±0	NS
Bamboo platform	10±0	10±0	10±0	10±0	NS
Pelleted feed	$206{\pm}5^{a}$	$402{\pm}10^{c}$	$291{\pm}8^{b}$	$500{\pm}13^{d}$	*
Total cost	$576{\pm}5^{a}$	$872{\pm}10^{c}$	$671{\pm}8^{b}$	$980{\pm}13^{d}$	*
NET RETURN (TK/m^3)	$-306{\pm}31^{ab}$	$-512{\pm}13^{a}$	$-365{\pm}3^{ab}$	$-98{\pm}100^{b}$	*

NS – Not significant (*P>0.05*)

* Significant (*P<0.05*)

Mean values with different superscript letters in each row indicate significantly difference (*P<0.05*)

Price: Stinging catfish selling price 600Tk/kg was considered

3.3.1 Gross revenue

The range of mean value of gross revenue was 465±15 to 1020±60 Tk/cage in square shaped cages and 270±36 to 882±114 Tk/cage in rectangular shaped cages. The ANOVA showed that there was significant difference (*P<0.05*) of gross revenue among treatments. The highest revenue was observed in T4 treatment and the lowest in T5 treatment. In ordinary cages and modified cages the range of mean value of gross revenue was 270±36 to 600±30 Tk/cage and 306±12 to 1020±60 Tk/cage respectively.

3.3.2 Operational cost

To calculate operational cost bamboo frame cages was considered. The operational cost ranged from 576±5 to 984±28 Tk/cage in ordinary cages and 671±8 to 1084±19 Tk/cage in modified cages. The highest and lowest operational cost was found in T4 and T5 treatment respectively. The range of mean value of operational cost was 673±5 Tk to 1084±19 Tk per cage for square shaped cages and 576±5 Tk to 980±13 Tk per cage for rectangular shaped cages. There was significant difference ($P<0.05$) of operational cost among treatments of square shaped cages and rectangular shaped cages.

3.3.3 Net return

The net profit was observed only from T3 treatment. The mean value of net return of treatment T3 was 37±14 Tk/cage. In other treatments there were no net profits. Except T3 the mean values of net return were negative. There was significant difference ($P<0.05$) of net return among different treatments.

Chapter IV
Discussion

Aquaculture aims to maximize the yield of useful aquatic organisms from the aquatic environment. Trial of cage culture technology of *H. fossilis* in the present study also has the similar aim. The general goal of the study was to develop sustainable cage culture system for ensuring food security. The modern cage culture with high stocking density and artificial feed becomes increasingly popular. It is also becoming popular day by day due to the scarcity of water, land and labour resources. Results of the present research suggest that the cage culture of stinging catfish is technically feasible and can be readily incorporated into a wide range of existing farming. Indeed cage culture is an aspect of farming that all family members can participate. For the cage culture of fish and other aquatic organisms, environmental parameters play an important role. All the results of water quality parameters, and growth and production performance of fish of the present experiment are discussed below:

4.1 Water quality parameters

Water quality is one of the important factors determining growth and survival of fish in cage culture. Measurement of water quality parameters is pre-requisite for a maintaining a healthy aquatic environment and better production for aquatic organisms. Some of the measured water quality parameters varied significantly and some were not in the study, which indicates that apart from natural factors the stocking density of stinging catfish and ration of feed might have influenced on the pond water. In some other studies on cage culture, it was observed that wastes derived from supplied feed caused variation of water quality parameters inside cage other than outside environment (Shahidul, 2005).

Fish is poikilothermous animal. It has no means of controlling body temperature to change with that of the environment. Water temperature is one of the most important factors for aquatic organisms because it influences other physical and chemical factors especially dissolved oxygen content. It influences all forms of life and opinion differs markedly with regard to the optimum temperature. With increase of water temperature food intake, metabolism and growth rate of fish increase. The temperature of the water available to caged fish depends upon geographic location, water sup the system. In the present study, water temperature in the pond water ranged from 20.10 to 32.20°C during the investigation period from July 2013 to December 2013 where the mean temperature was 27.7±0.734°C which was within the suitable range for growth. Even considering December as the beginning of winter the water temperature was within the acceptable range. Boyd (1982) showed that the range of water temperature of 26.06 to 31.97°C is suitable for fish culture.

Among the dissolved gases, oxygen is most important and critical one in the natural water. Dissolved oxygen is required by all the aquatic organisms except anaerobic bacteria. Prolonged exposure to low concentrations of dissolved oxygen is harmful to fish. Continued exposure to low dissolved oxygen is also considered a precursor to bacterial infection in fish. The minimum concentration of dissolved oxygen tolerated by fish is obviously a function of the exposure time. A fish might survive in 0.5 mg/l dissolved oxygen concentration for a few hours but not for several days. Concentrations reflect the momentary balance between oxygen supply from atmosphere and photosynthesis on one hand, and the metabolic process that consume on the other. In the present study, the concentrations of dissolved oxygen in the experimental ponds were fluctuated and having the range from 4.4–8.1 mg/l, which is more or less similar to the study of Zafar (1964), Banerjee (1967), Azim *et al.* (1995) and Dewan (1973). Most suitable range of dissolved oxygen in a water body for fish culture was suggested from 5.0–8.0 mg/l (DoF, 1996). So, concentrations of dissolved oxygen were found quite suitable for fish culture throughout the experimental period. The lowest DO concentrations were recorded in modified cages. Since the bottom of those cages was closed by mud and plastic sheet the feed residues accumulated on the bottom and decomposed which might have caused the lowest DO concentration. Moreover, DO concentration decreased to below 5.0 mg/l (i.e. 4.4 mg/l) only in December which was not lethal for fish. In ordinary cages, the DO concentration was found always higher than minimum suitable limit (i.e. > 5 mg/l) due to lack of organic load from feed unlike modified cages.

The pH of water has profound effect on the productivity of the water body. According to Swingle (1967) the pH 6.5 to 9.0 is suitable for pond fish culture and pH more than 9.5 is unsuitable. Boyd (1992) stated that the suitable range of pH is 6.5 to 8.5 for pond fish culture. DoF (1996) reported that the suitable range of pH of a culture should be 6.5 to 8.5. During the study period, pH values were slightly alkaline. In the present study, pH values inside cages varied from 7.20–7.80 which maintained the suitable range. The mean values of pH were measured 7.66±0.034, 7.57±0.025 and 7.43±0.029 in pond water, ordinary cage and modified cage respectively. The measured pH was found significant different (*P<0.05*) among treatments. The lowest pH values in modified cages might have occurred due to decomposition of feed residues in the cage bottom. However, the pH values in modified cages never exit the limit of suitable range.

Water transparency is very important factor considered for fish culture. It has an inverse relationship with the plankton abundance. It is generally expressed as the level of pond productivity and indicates the presence or absence of fish food particles. Transparency of a water body varies with soil type, season, amount of surface runoff, amount of decomposition, intensity of entering light and others. Secchi disk visibility about 20 to 30 cm means the water body is productive, if it is not newly constructed or turbid due to rainfall or borrowing by fish or other organisms (Boyd, 1990). In this study the water transparency values ranged from 31.0 to 49.0 cm and the mean transparency of experimental pond during experiment was measured 39.81±1.030 cm which indicates the experiment pond had less natural fish food particle (i.e. less productive) though it was a very old pond. However, the mean transparency value was not out of suitable range of fish culture since Boyd (1982) suggested a water transparency between 15.0 to 40.0 cm is good for fish culture. Though the pond was not productive it should not hamper the growth and production of the stinging cat fish during experiment because the experiment was designed totally based on artificial commercial feed. The transparency values found in the present study is not unusual in other experiments. Such as, Wahab *et al.* (1995) found transparency depth even ranging from 15–74 cm in polyculture pond where the fish were partially dependent on natural food beside supplementary feed.

Nitrate (NO3) is extremely important as a nutrient in supplying nitrogen for protein synthesis. NO3 is contributed to the ecosystem as a byproduct of nitrification. NO3 is removed from solutions through utilization by green plants and through bacterial de-nitrification to uncombined nitrogen and reduction to NH3-N. Bhuiyan (1970) reported that the range of NO3-N from 0.06 to 0.1 mg/l is suitable range for fish culture. The range of NO3-N measured in the present study was found 0.05 to 0.25 mg/l. There was significant difference (*$p<0.05$*) of nitrate-nitrogen among different tr

values of nitrate-nitrogen were 0.13±0.011, 0.15±0.009 and 0.19±0.009 mg/l in pond water, ordinary cage and modified cage respectively. So, the highest NO3-N found in modified cages might be due to the organic load of artificial feed wastes. In ordinary cages the NO3-N is less than modified cages due to no chance of accumulation of feed on the cage bottom. The pond water showed the lowest NO3-N value during study which might be due to the less productivity of water. Due to regular supply of feed might caused the water inside cages more productive, thus higher NO3-N values.

Unionized ammonia (NH3) is highly toxic to fish, but ammonium ion (NH4+) is relatively nontoxic. In culture condition, the lower the value of total ammonia, the better quality of water for fish. The major source of ammonia in pond water is the direct excretion of ammonia by fish (Tucker and Boyd, 1979). Meade (1985) noted that the maximum safe concentration of ammonia was unknown but he concluded that the permissible level was higher than the value of 0.012 mg/l commonly accepted by fish culturists. Chen (1988) found that lower than 1 mg/l of ammonia gas content in pond water was good for fish culture. In the present study, the lowest and the highest concentration of total ammonia were 0.20 and 1.70 mg/l respectively. Azim *et al.* (1995), Nirod (1997), Kohinoor *et al.* (1998), Paul (1998), Kohinoor (2000) and Wahid *et al.* (1997) recorded of total ammonia 0.01 to 0.99 mg/l in their experiment on fish culture at BAU campus, Mymensingh. In the current experiment there was significant variance of ammonia-nitrogen among the treatments. The highest mean value of ammonia-nitrogen was found 1.24 mg/L in modified cages in the experiment which is little higher compared to above mentioned values of different studies on fish culture. Such higher values in modified cages might be occurred due to the organic load of feed wastes. In ordinary cages the ammonia-nitrogen was lower than modified cages, but more than pond water. Accumulation of faeces and urine of fish in the bottom mud might have caused the higher ammonia content in modified cages than ordinary. To minimize this problem of more ammonia-nitrogen concentration in modified cages the cage bottom mud could be changed fortnightly or monthly inside cage.

Phosphate-phosphorus (PO4-P) concentration in the water has been considered very important in aquatic productivity. The nutrient phosphorus is a limiting factor for plant growth. Islam and Shaha (1975) observed that phosphate-phosphorus range from 0.2 to 2.8 mg/l is favourable for growth of blue green algae and diatc reported PO4-P ranged from 0.11 to 2.0 mg/l in different earthen ponds at his study. In present study PO4-P ranged was found 1.50 to 5.10 mg/l. The highest concentration of PO4-P was recorded from modified cages due to the organic load of feed wastes. Since the experiment was not dependent on primary production (natural food- plankton), we think PO4-P load in water did not affect the fish growth in the experiment.

4.2 Growth, production performance and return

In the experiment, square shaped cages showed higher survivability of stinging catfish than rectangular shaped cages irrespective of the presence of mud and substrate inside cage. The mean survival rate of square shaped cages was over 70 % whereas it was below 50% in case of rectangular sized cages (Figure 3.10). The variation in the performance might be the consequence of the difference of depth between two types of cages. In square shaped cages, the height of the cage was kept 1 meter but the rectangular shaped cages were made with the height of 0.8 m. So, the depth of the water inside cage was also higher inside rectangular cages than square cages during experiment. Stinging catfish generally tend to live on the bottom of the pond or cages. The temperature was maintained higher in the bottom of rectangular shaped cage than square cages due to lower height which might affect and caused lower survival rate in rectangular shaped cages. Not only for survival rate but also the SGR (%/day) was also found higher in square shaped cages than rectangular cages. In the ordinary (T1 and T2) and modified (T3 and T4) square shaped cages the mean SGR were 1.43 and 1.65 %/day respectively irrespective of stocking densities (Table 3.3). On the other hand, the mean values of SGR were 1.31% and 1.49% per day in ordinary (T5 and T6) and modified (T7 and T8) rectangular shaped cages (Table 3.4). Temperature variation between square and rectangular shaped cages due to difference of water depth also caused such variation in SGR like survival rate.

When ordinary and modified cages are compared irrespective of shape, overall higher survival rate and SGR were found in modified cages. Figure 3.10 and 3.8 clearly present that scenario where the treatments T3, T4 (modified square cages) and T7, T8 (modified rectangular cages) shows higher survival rate and SGR than T1, T2 (ordinary square cages) and T5, T6 (ordinary rectangular cages) respectively. Now the question is why the survivability is lower in ordinary cages. We think that the fish did n environment inside cage in ordinary cage. *H. fossilis* usually inhabit in the bottom mud of waterbody. They also prefer to stay inside hole, and beneath or in the crack of submerged plant timber. Inclusion of mud on the cage bottom and hanging plastic pipe as substrate inside cage provided a natural environment for the fish which might have caused higher survivability and growth rate in modified cages. During the time of the study when cages were lifted for sampling purpose, it was observed that stinging catfish stayed inside plastic pipe were dropping out on the cage bottom which proves that the fish used plastic pipe as substrate inside cages.

Comparing between two types of shape within modified cages, square shaped cages showed higher mean survival rate than rectangular cages which were 78.08% and 48.83% respectively. Water depth inside cage might have played role for this variation in survival rate as already mentioned above. In modified square shaped cages, the highest survival rate was found in T3 treatment i.e. modified square shaped cages with $100/m^3$ stocking density. However, SGR was not found highest in this treatment. The highest SGR was found in T4 treatment i.e. modified square shaped cages with $150/m^3$ stocking density. After ending of the experiment, survival rate was counted as 82.50% for T3 treatment and 73.67% for T4 treatment, and the SGR were found 1.55% and 1.76% per day for T3 and T4 treatment respectively. From survival rate and growth, the highest gross yield was calculated in T4 treatment which was 1.70 ± 0.10 kg/m^3 cage. In the treatment of T3, gross yield was calculated as 1.35 ± 0.05 kg/m^3 cage.

Finally when the cost-benefit analysis was made, net return was found positive only for T3 treatment considering gross revenue and operational cost among all the treatments set in the present research study (Table 3.5 and 3.6). The cost-benefit analysis was done only for one culture cycle. However, the bamboo made cages used in the present study can be used for several culture cycles if maintained and preserved properly during and after culture. In that case construction cost of the cage will not be included in operation cost for next culture cycles which will give profit ultimately. In the experiment, commercial pellet feed was used in the experiment which was also costly. Further trial is needed using farm made feed using the ingredients of fish meal, blood meal, rice bran, wheat bran, oil cake, flour etc. which may reduce the feed cost.

Present study showed that the cage culture of stinging catfish is profi sustainable culture system for increasing earning of the fish farmers. At present stinging catfish is cultured in small pond in our country for easy harvesting through dewatering since dewatering is problem and also expensive in large pond. Moreover, the culture pond is fenced by net to protect the fish from escaping which causes cost involvement. Using the developed cage culture technology with higher growth and survival rate from the present study, culture of stinging catfish in a large pond is possible and farmers will not need to dewater for harvesting. The net needed for fencing of pond could be used for cage construction. So, there would be no extra cost for purchasing net. We hope this cage culture technology will be also possible to use in river or haor area of the country and could be a source of good income for fishermen and poor people live in the catchment area.

Chapter V
Conclusion

The present experiment was conducted in an earthen pond situated in the Sher-e-Bangla Agricultural University, Dhaka. The size of the pond was almost 3 acre and average depth 2.0 m. The duration of the experiment was 150 days from 30 July to 30 December, 2013. The purpose of the study was to identify the suitable cage culture system of stinging catfish and to increase growth, survival rate and production.

There were eight treatments with two replications each in which four treatments were for modified cages and other four treatments were for ordinary cages in both rectangular and square shaped cages. Among four treatments in both rectangular and square shaped cages, two treatments were set in modified cages and other two treatments were set in ordinary cages where the stocking density was variable. The stocking densities 100fish/m^3 and 150fish/m^3 were set in each type of treatment.

Commercial floating pelleted feed was supplied twice in a day. A floating feeding frame was set inside cages where feed was given regularly. Feeding rates was adjusted after measuring mean body weight by sampling.

The water quality parameters such as temperature, DO, pH, transparency, NO_3-N, NH_3-N and PO_4-P were observed weekly throughout the experimental period. Among the water quality parameters DO, pH, NO_3-N, NH_3-N and PO_4-P were shown significant difference *($P<0.05$)* in different treatments and were the suitable range for fish culture.

The growth rate and survival rate of stinging catfish was the highest in modified square shaped cages with 100fish/m^3 stocking density (T3) where the survival rate was found

82.50%. However, the highest SGR was found in T4 treatment i.e. modified square shaped cages with 150fish/m^3 stocking density. From survival rate and growth, the highest gross yield was calculated in T4 treatment which was 1.70±0.10 kg/m^3 cage. In the treatment of T3, gross yield was calculated as 1.35±0.05 kg/m^3 cage. Net return was found positive for T3 treatment considering gross revenue and operational cost among all the treatments set in the present research study. So, modified (i.e. pipe substrate) square shaped cages with 100fish/m^3 stocking density could be the best option for cage culture of stinging catfish. Since the gross yield was found higher in T4 treatment, trial with more stocking density (e.g. 200fish/m^3 or 300fish/m^3) is needed to increase net return (i.e. more profit). Beside this, the cage with only mud, cage with only plastic pipe substrate, cage with both mud and pipe should be assessed and compared regarding survival rate, growth and return.

The stinging catfish is a high valued species and has potential for cage culture system, however further studies are needed to improve the system. Cage culture systems with mud and plastic pipe substrate might open a new horizon of cage culture for further research. Trial should be conducted in rural ponds with participating of the farmers' household. However, availability and quality of catfish seed is a constraint for such system. Other air-breathing fish species such as walking catfish (*Clarius batrachus*) and climbing perch (*Anabas testudineus*) may also be potential candidates for similar system.

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Appendix I

Temperature

Descriptive Statistics

	N	Minimum	Maximum	Mean		Std. Deviation	Variance
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
Temperature	21	20.10	32.20	27.7000	.73446	3.36571	11.328
Valid N (listwise)	21						

DO

ANOVA

DO

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	25.518	2	12.759	48.191	.000
Within Groups	15.886	60	.265		
Total	41.404	62			

Multiple Comparisons

DO
LSD

(I) treatment	(J) treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
pond	Ordtnary cage	.65238*	.15879	.000	.3347	.9700
	Modified cage	1.55238*	.15879	.000	1.2347	1.8700
Ordtnary cage	pond	-.65238*	.15879	.000	-.9700	-.3347
	Modified cage	.90000*	.15879	.000	.5824	1.2176
Modified cage	pond	-1.55238*	.15879	.000	-1.8700	-1.2347
	Ordtnary cage	-.90000*	.15879	.000	-1.2176	-.5824

*. The mean difference is significant at the 0.05 level.

pH

ANOVA

pH

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.536	2	.268	14.863	.000
Within Groups	1.081	60	.018		
Total	1.617	62			

Multiple Comparisons

pH
LSD

(I) treatment	(J) treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Pond	Ordinary cage	.08571*	.04142	.043	.0029	.1686
	Modified cage	.22381*	.04142	.000	.1410	.3067
Ordinary cage	Pond	-.08571*	.04142	.043	-.1686	-.0029
	Modified cage	.13810*	.04142	.001	.0552	.2210
Modified cage	Pond	-.22381*	.04142	.000	-.3067	-.1410
	Ordinary cage	-.13810*	.04142	.001	-.2210	-.0552

*. The mean difference is significant at the 0.05 level.

Transparency

Descriptive Statistics

	N	Minimum	Maximum	Mean		Std. Deviation	Variance
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
Transparency	21	31.00	49.00	39.8095	1.02961	4.71825	22.262
Valid N (listwise)	21						

Nitrate

ANOVA

Nitrate

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.047	2	.024	12.246	.000
Within Groups	.116	60	.002		
Total	.164	62			

Multiple Comparisons

Nitrate
LSD

(I) Treatment	(J) Treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
Pond	Ordinary cage	-.02286	.01359	.098	-.0500	.0043
	Modified cage	-.06619*	.01359	.000	-.0934	-.0390
Ordinary cage	Pond	.02286	.01359	.098	-.0043	.0500
	Modified cage	-.04333*	.01359	.002	-.0705	-.0162
Modified cage	Pond	.06619*	.01359	.000	.0390	.0934
	Ordinary cage	.04333*	.01359	.002	.0162	.0705

*. The mean difference is significant at the 0.05 level.

Ammonia

ANOVA

Ammonia

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	4.317	2	2.158	35.641	.000
Within Groups	3.633	60	.061		
Total	7.950	62			

Multiple Comparisons

Ammonia

LSD

(I) Treatment	(J) Treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Pond	Ordinary cage	-.20476*	.07594	.009	-.3567	-.0529
	Modified cage	-.62857*	.07594	.000	-.7805	-.4767
Ordinary cage	Pond	.20476*	.07594	.009	.0529	.3567
	Modified cage	-.42381*	.07594	.000	-.5757	-.2719
Modified cage	Pond	.62857*	.07594	.000	.4767	.7805
	Ordinary cage	.42381*	.07594	.000	.2719	.5757

*. The mean difference is significant at the 0.05 level.

Phosphate

ANOVA

PO4

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	14.577	2	7.288	13.219	.000
Within Groups	33.080	60	.551		
Total	47.657	62			

Multiple Comparisons

PO4

LSD

(I) Treatment	(J) Treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Pond	Ordinary cage	-.47619*	.22915	.042	-.9346	-.0178
	Modified cage	-1.17143*	.22915	.000	-1.6298	-.7131
Ordinary cage	Pond	.47619*	.22915	.042	.0178	.9346
	Modified cage	-.69524*	.22915	.004	-1.1536	-.2369
Modified cage	Pond	1.17143*	.22915	.000	.7131	1.6298
	Ordinary cage	.69524*	.22915	.004	.2369	1.1536

*. The mean difference is significant at the 0.05 level.

Appendix II

Initial length

ANOVA

Initial length

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.409	3	.803	2.127	.114
Within Groups	13.589	36	.377		
Total	15.998	39			

Multiple Comparisons

Initial length

LSD

(I) Treatment	(J) Treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
T1	T2	-.49000	.27476	.083	-1.0472	.0672
	T3	-.56000*	.27476	.049	-1.1172	-.0028
	T4	-.62000*	.27476	.030	-1.1772	-.0628
T2	T1	.49000	.27476	.083	-.0672	1.0472
	T3	-.07000	.27476	.800	-.6272	.4872
	T4	-.13000	.27476	.639	-.6872	.4272
T3	T1	.56000*	.27476	.049	.0028	1.1172
	T2	.07000	.27476	.800	-.4872	.6272
	T4	-.06000	.27476	.828	-.6172	.4972
T4	T1	.62000*	.27476	.030	.0628	1.1772
	T2	.13000	.27476	.639	-.4272	.6872
	T3	.06000	.27476	.828	-.4972	.6172

Final length

ANOVA

Final length

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	139.423	3	46.474	8.093	.000
Within Groups	436.453	76	5.743		
Total	575.876	79			

Multiple Comparisons

Final length
LSD

(I) Treatment	(J) Treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
T1	T2	-.33000	.75781	.664	-1.8393	1.1793
	T3	-1.31500	.75781	.087	-2.8243	.1943
	T4	-3.38500*	.75781	.000	-4.8943	-1.8757
T2	T1	.33000	.75781	.664	-1.1793	1.8393
	T3	-.98500	.75781	.198	-2.4943	.5243
	T4	-3.05500*	.75781	.000	-4.5643	-1.5457
T3	T1	1.31500	.75781	.087	-.1943	2.8243
	T2	.98500	.75781	.198	-.5243	2.4943
	T4	-2.07000*	.75781	.008	-3.5793	-.5607
T4	T1	3.38500*	.75781	.000	1.8757	4.8943
	T2	3.05500*	.75781	.000	1.5457	4.5643
	T3	2.07000*	.75781	.008	.5607	3.5793

*. The mean difference is significant at the 0.05 level.

Length gain

ANOVA

Length gain

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	10.837	3	3.612	3.502	.129
Within Groups	4.126	4	1.031		
Total	14.962	7			

Multiple Comparisons

Length gain
LSD

(I) Treatment	(J) Treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
T1	T2	.16000	1.01557	.882	-2.6597	2.9797
	T3	-.75500	1.01557	.499	-3.5747	2.0647
	T4	-2.76500	1.01557	.053	-5.5847	.0547
T2	T1	-.16000	1.01557	.882	-2.9797	2.6597
	T3	-.91500	1.01557	.419	-3.7347	1.9047
	T4	-2.92500*	1.01557	.045	-5.7447	-.1053
T3	T1	.75500	1.01557	.499	-2.0647	3.5747
	T2	.91500	1.01557	.419	-1.9047	3.7347
	T4	-2.01000	1.01557	.119	-4.8297	.8097
T4	T1	2.76500	1.01557	.053	-.0547	5.5847
	T2	2.92500*	1.01557	.045	.1053	5.7447
	T3	2.01000	1.01557	.119	-.8097	4.8297

Initial weight

ANOVA

Initial weight

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.649	3	.216	.598	.620
Within Groups	13.022	36	.362		
Total	13.671	39			

Multiple Comparisons

Initial weight
LSD

(I) Treatment	(J) Treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
T1	T2	-.17800	.26897	.512	-.7235	.3675
	T3	-.30700	.26897	.261	-.8525	.2385
	T4	-.31400	.26897	.251	-.8595	.2315
T2	T1	.17800	.26897	.512	-.3675	.7235
	T3	-.12900	.26897	.634	-.6745	.4165
	T4	-.13600	.26897	.616	-.6815	.4095
T3	T1	.30700	.26897	.261	-.2385	.8525
	T2	.12900	.26897	.634	-.4165	.6745
	T4	-.00700	.26897	.979	-.5525	.5385
T4	T1	.31400	.26897	.251	-.2315	.8595
	T2	.13600	.26897	.616	-.4095	.6815
	T3	.00700	.26897	.979	-.5385	.5525

Final weight

ANOVA

Final weight

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2724.467	3	908.156	8.758	.000
Within Groups	7880.907	76	103.696		
Total	10605.374	79			

Multiple Comparisons

Final weight
LSD

(I) Treatment	(J) Treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
T1	T2	-1.02500	3.22019	.751	-7.4386	5.3886
	T3	-6.71000*	3.22019	.041	-13.1236	-.2964
	T4	-14.69400*	3.22019	.000	-21.1076	-8.2804
T2	T1	1.02500	3.22019	.751	-5.3886	7.4386
	T3	-5.68500	3.22019	.082	-12.0986	.7286
	T4	-13.66900*	3.22019	.000	-20.0826	-7.2554
T3	T1	6.71000*	3.22019	.041	.2964	13.1236
	T2	5.68500	3.22019	.082	-.7286	12.0986
	T4	-7.98400*	3.22019	.015	-14.3976	-1.5704
T4	T1	14.69400*	3.22019	.000	8.2804	21.1076
	T2	13.66900*	3.22019	.000	7.2554	20.0826
	T3	7.98400*	3.22019	.015	1.5704	14.3976

*. The mean difference is significant at the 0.05 level.

Weight gain

ANOVA

Weight gain

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	263.116	3	87.705	10.408	.023
Within Groups	33.708	4	8.427		
Total	296.825	7			

Multiple Comparisons

Weight gain
LSD

(I) Treatment	(J) Treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
T1	T2	-.84500	2.90295	.785	-8.9049	7.2149
	T3	-6.40500	2.90295	.092	-14.4649	1.6549
	T4	-14.38000*	2.90295	.008	-22.4399	-6.3201
T2	T1	.84500	2.90295	.785	-7.2149	8.9049
	T3	-5.56000	2.90295	.128	-13.6199	2.4999
	T4	-13.53500*	2.90295	.010	-21.5949	-5.4751
T3	T1	6.40500	2.90295	.092	-1.6549	14.4649
	T2	5.56000	2.90295	.128	-2.4999	13.6199
	T4	-7.97500	2.90295	.052	-16.0349	.0849
T4	T1	14.38000*	2.90295	.008	6.3201	22.4399
	T2	13.53500*	2.90295	.010	5.4751	21.5949
	T3	7.97500	2.90295	.052	-.0849	16.0349

*. The mean difference is significant at the 0.05 level.

SGR

ANOVA

Specific Growth Rate

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.141	3	.047	2.769	.175
Within Groups	.068	4	.017		
Total	.209	7			

Multiple Comparisons

Specific Growth Rate

LSD

(I) Treatment	(J) Treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
T1	T2	.01000	.13034	.943	-.3519	.3719
	T3	-.11500	.13034	.427	-.4769	.2469
	T4	-.32000	.13034	.070	-.6819	.0419
T2	T1	-.01000	.13034	.943	-.3719	.3519
	T3	-.12500	.13034	.392	-.4869	.2369
	T4	-.33000	.13034	.065	-.6919	.0319
T3	T1	.11500	.13034	.427	-.2469	.4769
	T2	.12500	.13034	.392	-.2369	.4869
	T4	-.20500	.13034	.191	-.5669	.1569
T4	T1	.32000	.13034	.070	-.0419	.6819
	T2	.33000	.13034	.065	-.0319	.6919
	T3	.20500	.13034	.191	-.1569	.5669

FCR

ANOVA

FCR

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	51.827	3	17.276	124.633	.000
Within Groups	.554	4	.139		
Total	52.381	7			

Multiple Comparisons

FCR

LSD

(I) Treatment	(J) Treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
T1	T2	-3.30500*	.37231	.001	-4.3387	-2.2713
	T3	3.81500*	.37231	.001	2.7813	4.8487
	T4	-.66500	.37231	.149	-1.6987	.3687
T2	T1	3.30500*	.37231	.001	2.2713	4.3387
	T3	7.12000*	.37231	.000	6.0863	8.1537
	T4	2.64000*	.37231	.002	1.6063	3.6737
T3	T1	-3.81500*	.37231	.001	-4.8487	-2.7813
	T2	-7.12000*	.37231	.000	-8.1537	-6.0863
	T4	-4.48000*	.37231	.000	-5.5137	-3.4463
T4	T1	.66500	.37231	.149	-.3687	1.6987
	T2	-2.64000*	.37231	.002	-3.6737	-1.6063
	T3	4.48000*	.37231	.000	3.4463	5.5137

*. The mean difference is significant at the 0.05 level.

Survival

ANOVA

Survival rate

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1196.344	3	398.781	11.702	.019
Within Groups	136.309	4	34.077		
Total	1332.653	7			

Multiple Comparisons

Survival rate

LSD

(I) Treatment	(J) Treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
T1	T2	4.66500	5.83757	.469	-11.5427	20.8727
	T3	-25.50000*	5.83757	.012	-41.7077	-9.2923
	T4	-16.66500*	5.83757	.046	-32.8727	-.4573
T2	T1	-4.66500	5.83757	.469	-20.8727	11.5427
	T3	-30.16500*	5.83757	.007	-46.3727	-13.9573
	T4	-21.33000*	5.83757	.022	-37.5377	-5.1223
T3	T1	25.50000*	5.83757	.012	9.2923	41.7077
	T2	30.16500*	5.83757	.007	13.9573	46.3727
	T4	8.83500	5.83757	.205	-7.3727	25.0427
T4	T1	16.66500*	5.83757	.046	.4573	32.8727
	T2	21.33000*	5.83757	.022	5.1223	37.5377
	T3	-8.83500	5.83757	.205	-25.0427	7.3727

*. The mean difference is significant at the 0.05 level.

Gross yield

ANOVA

Gross yield

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.986	3	.329	42.067	.002
Within Groups	.031	4	.008		
Total	1.017	7			

Multiple Comparisons

Gross yield
LSD

(I) Treatment	(J) Treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
T1	T2	-.22500	.08839	.064	-.4704	.0204
	T3	-.57500*	.08839	.003	-.8204	-.3296
	T4	-.92500*	.08839	.000	-1.1704	-.6796
T2	T1	.22500	.08839	.064	-.0204	.4704
	T3	-.35000*	.08839	.017	-.5954	-.1046
	T4	-.70000*	.08839	.001	-.9454	-.4546
T3	T1	.57500*	.08839	.003	.3296	.8204
	T2	.35000*	.08839	.017	.1046	.5954
	T4	-.35000*	.08839	.017	-.5954	-.1046
T4	T1	.92500*	.08839	.000	.6796	1.1704
	T2	.70000*	.08839	.001	.4546	.9454
	T3	.35000*	.08839	.017	.1046	.5954

*. The mean difference is significant at the 0.05 level.

Appendix III

Initial length

ANOVA

Initial length

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.220	3	.407	.924	.452
Within Groups	7.040	16	.440		
Total	8.260	19			

Multiple Comparisons

Initial length

LSD

(I) Treatment	(J) Treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
T5	T6	-.52000	.41952	.233	-1.4094	.3694
	T7	-.34000	.41952	.430	-1.2294	.5494
	T8	-.66000	.41952	.135	-1.5494	.2294
T6	T5	.52000	.41952	.233	-.3694	1.4094
	T7	.18000	.41952	.674	-.7094	1.0694
	T8	-.14000	.41952	.743	-1.0294	.7494
T7	T5	.34000	.41952	.430	-.5494	1.2294
	T6	-.18000	.41952	.674	-1.0694	.7094
	T8	-.32000	.41952	.457	-1.2094	.5694
T8	T5	.66000	.41952	.135	-.2294	1.5494
	T6	.14000	.41952	.743	-.7494	1.0294
	T7	.32000	.41952	.457	-.5694	1.2094

Final length

ANOVA

Final length

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	46.233	3	15.411	2.469	.078
Within Groups	224.727	36	6.242		
Total	270.960	39			

Multiple Comparisons

Final length
LSD

(I) Treatment	(J) Treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
T5	T6	-.21000	1.11736	.852	-2.4761	2.0561
	T7	-2.24000	1.11736	.053	-4.5061	.0261
	T8	-2.26000	1.11736	.051	-4.5261	.0061
T6	T5	.21000	1.11736	.852	-2.0561	2.4761
	T7	-2.03000	1.11736	.078	-4.2961	.2361
	T8	-2.05000	1.11736	.075	-4.3161	.2161
T7	T5	2.24000	1.11736	.053	-.0261	4.5061
	T6	2.03000	1.11736	.078	-.2361	4.2961
	T8	-.02000	1.11736	.986	-2.2861	2.2461
T8	T5	2.26000	1.11736	.051	-.0061	4.5261
	T6	2.05000	1.11736	.075	-.2161	4.3161
	T7	.02000	1.11736	.986	-2.2461	2.2861

Length gain

ANOVA

Length gain

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	7.444	3	2.481	3.082	.153
Within Groups	3.221	4	.805		
Total	10.665	7			

Multiple Comparisons

Length gain
LSD

(I) Treatment	(J) Treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
T5	T6	.31000	.89730	.747	-2.1813	2.8013
	T7	-1.90000	.89730	.102	-4.3913	.5913
	T8	-1.60000	.89730	.149	-4.0913	.8913
T6	T5	-.31000	.89730	.747	-2.8013	2.1813
	T7	-2.21000	.89730	.069	-4.7013	.2813
	T8	-1.91000	.89730	.100	-4.4013	.5813
T7	T5	1.90000	.89730	.102	-.5913	4.3913
	T6	2.21000	.89730	.069	-.2813	4.7013
	T8	.30000	.89730	.755	-2.1913	2.7913
T8	T5	1.60000	.89730	.149	-.8913	4.0913
	T6	1.91000	.89730	.100	-.5813	4.4013
	T7	-.30000	.89730	.755	-2.7913	2.1913

Initial weight

ANOVA

Initial weight

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.390	3	.463	1.382	.284
Within Groups	5.362	16	.335		
Total	6.751	19			

Multiple Comparisons

Initial weight
LSD

(I) Treatment	(J) Treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
T5	T6	-.43400	.36612	.253	-1.2101	.3421
	T7	-.70000	.36612	.074	-1.4761	.0761
	T8	-.57200	.36612	.138	-1.3481	.2041
T6	T5	.43400	.36612	.253	-.3421	1.2101
	T7	-.26600	.36612	.478	-1.0421	.5101
	T8	-.13800	.36612	.711	-.9141	.6381
T7	T5	.70000	.36612	.074	-.0761	1.4761
	T6	.26600	.36612	.478	-.5101	1.0421
	T8	.12800	.36612	.731	-.6481	.9041
T8	T5	.57200	.36612	.138	-.2041	1.3481
	T6	.13800	.36612	.711	-.6381	.9141
	T7	-.12800	.36612	.731	-.9041	.6481

Final weight

ANOVA

Final weight

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	802.766	3	267.589	3.283	.032
Within Groups	2934.518	36	81.514		
Total	3737.284	39			

Multiple Comparisons

Final weight

LSD

(I) Treatment	(J) Treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
T5	T6	-1.23700	4.03768	.761	-9.4258	6.9518
	T7	-9.68000*	4.03768	.022	-17.8688	-1.4912
	T8	-9.38600*	4.03768	.026	-17.5748	-1.1972
T6	T5	1.23700	4.03768	.761	-6.9518	9.4258
	T7	-8.44300*	4.03768	.044	-16.6318	-.2542
	T8	-8.14900	4.03768	.051	-16.3378	.0398
T7	T5	9.68000*	4.03768	.022	1.4912	17.8688
	T6	8.44300*	4.03768	.044	.2542	16.6318
	T8	.29400	4.03768	.942	-7.8948	8.4828
T8	T5	9.38600*	4.03768	.026	1.1972	17.5748
	T6	8.14900	4.03768	.051	-.0398	16.3378
	T7	-.29400	4.03768	.942	-8.4828	7.8948

*. The mean difference is significant at the 0.05 level.

Weight gain

ANOVA

Weight gain

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	144.999	3	48.333	9.630	.027
Within Groups	20.076	4	5.019		
Total	165.075	7			

Multiple Comparisons

Weight gain
LSD

(I) Treatment	(J) Treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
T5	T6	-.80000	2.24031	.739	-7.0201	5.4201
	T7	-8.98000*	2.24031	.016	-15.2001	-2.7599
	T8	-8.81000*	2.24031	.017	-15.0301	-2.5899
T6	T5	.80000	2.24031	.739	-5.4201	7.0201
	T7	-8.18000*	2.24031	.022	-14.4001	-1.9599
	T8	-8.01000*	2.24031	.023	-14.2301	-1.7899
T7	T5	8.98000*	2.24031	.016	2.7599	15.2001
	T6	8.18000*	2.24031	.022	1.9599	14.4001
	T8	.17000	2.24031	.943	-6.0501	6.3901
T8	T5	8.81000*	2.24031	.017	2.5899	15.0301
	T6	8.01000*	2.24031	.023	1.7899	14.2301
	T7	-.17000	2.24031	.943	-6.3901	6.0501

*. The mean difference is significant at the 0.05 level.

SGR

ANOVA

Specific Growth Rate

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.066	3	.022	1.777	.291
Within Groups	.049	4	.012		
Total	.115	7			

Multiple Comparisons

Specific Growth Rate

LSD

(I) Treatment	(J) Treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
T5	T6	.06500	.11102	.590	-.2432	.3732
	T7	-.13500	.11102	.291	-.4432	.1732
	T8	-.15000	.11102	.248	-.4582	.1582
T6	T5	-.06500	.11102	.590	-.3732	.2432
	T7	-.20000	.11102	.146	-.5082	.1082
	T8	-.21500	.11102	.125	-.5232	.0932
T7	T5	.13500	.11102	.291	-.1732	.4432
	T6	.20000	.11102	.146	-.1082	.5082
	T8	-.01500	.11102	.899	-.3232	.2932
T8	T5	.15000	.11102	.248	-.1582	.4582
	T6	.21500	.11102	.125	-.0932	.5232
	T7	.01500	.11102	.899	-.2932	.3232

FCR

ANOVA

FCR

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	78.913	3	26.304	56.489	.001
Within Groups	1.863	4	.466		
Total	80.776	7			

Multiple Comparisons

FCR
LSD

(I) Treatment	(J) Treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
T5	T6	-1.67000	.68239	.071	-3.5646	.2246
	T7	6.15000*	.68239	.001	4.2554	8.0446
	T8	4.21000*	.68239	.004	2.3154	6.1046
T6	T5	1.67000	.68239	.071	-.2246	3.5646
	T7	7.82000*	.68239	.000	5.9254	9.7146
	T8	5.88000*	.68239	.001	3.9854	7.7746
T7	T5	-6.15000*	.68239	.001	-8.0446	-4.2554
	T6	-7.82000*	.68239	.000	-9.7146	-5.9254
	T8	-1.94000*	.68239	.047	-3.8346	-.0454
T8	T5	-4.21000*	.68239	.004	-6.1046	-2.3154
	T6	-5.88000*	.68239	.001	-7.7746	-3.9854
	T7	1.94000*	.68239	.047	.0454	3.8346

*. The mean difference is significant at the 0.05 level.

Survival

ANOVA

Survival rate

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	429.098	3	143.033	2.043	.250
Within Groups	280.000	4	70.000		
Total	709.098	7			

Multiple Comparisons

Survival rate
LSD

(I) Treatment	(J) Treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
T5	T6	5.33000	8.36660	.559	-17.8994	28.5594
	T7	-3.00000	8.36660	.738	-26.2294	20.2294
	T8	-14.67000	8.36660	.154	-37.8994	8.5594
T6	T5	-5.33000	8.36660	.559	-28.5594	17.8994
	T7	-8.33000	8.36660	.376	-31.5594	14.8994
	T8	-20.00000	8.36660	.075	-43.2294	3.2294
T7	T5	3.00000	8.36660	.738	-20.2294	26.2294
	T6	8.33000	8.36660	.376	-14.8994	31.5594
	T8	-11.67000	8.36660	.236	-34.8994	11.5594
T8	T5	14.67000	8.36660	.154	-8.5594	37.8994
	T6	20.00000	8.36660	.075	-3.2294	43.2294
	T7	11.67000	8.36660	.236	-11.5594	34.8994

Gross yield

ANOVA

Gross yield

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.377	3	.459	22.007	.006
Within Groups	.083	4	.021		
Total	1.460	7			

Multiple Comparisons

Gross yield
LSD

(I) Treatment	(J) Treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
T5	T6	-.15000	.14440	.358	-.5509	.2509
	T7	-.06000	.14440	.699	-.4609	.3409
	T8	-1.02000*	.14440	.002	-1.4209	-.6191
T6	T5	.15000	.14440	.358	-.2509	.5509
	T7	.09000	.14440	.567	-.3109	.4909
	T8	-.87000*	.14440	.004	-1.2709	-.4691
T7	T5	.06000	.14440	.699	-.3409	.4609
	T6	-.09000	.14440	.567	-.4909	.3109
	T8	-.96000*	.14440	.003	-1.3609	-.5591
T8	T5	1.02000*	.14440	.002	.6191	1.4209
	T6	.87000*	.14440	.004	.4691	1.2709
	T7	.96000*	.14440	.003	.5591	1.3609

*. The mean difference is significant at the 0.05 level.

Appendix IV

Gross revenue

ANOVA

Gross revenue

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	354937.500	3	118312.500	42.067	.002
Within Groups	11250.000	4	2812.500		
Total	366187.500	7			

Multiple Comparisons

Gross revenue
LSD

(I) Treatment	(J) Treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
T1	T2	-135.00000	53.03301	.064	-282.2432	12.2432
	T3	-345.00000*	53.03301	.003	-492.2432	-197.7568
	T4	-555.00000*	53.03301	.000	-702.2432	-407.7568
T2	T1	135.00000	53.03301	.064	-12.2432	282.2432
	T3	-210.00000*	53.03301	.017	-357.2432	-62.7568
	T4	-420.00000*	53.03301	.001	-567.2432	-272.7568
T3	T1	345.00000*	53.03301	.003	197.7568	492.2432
	T2	210.00000*	53.03301	.017	62.7568	357.2432
	T4	-210.00000*	53.03301	.017	-357.2432	-62.7568
T4	T1	555.00000*	53.03301	.000	407.7568	702.2432
	T2	420.00000*	53.03301	.001	272.7568	567.2432
	T3	210.00000*	53.03301	.017	62.7568	357.2432

*. The mean difference is significant at the 0.05 level.

Feed cost

ANOVA

Feed cost

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	105749.840	3	35249.947	48.146	.001
Within Groups	2928.560	4	732.140		
Total	108678.400	7			

Multiple Comparisons

Feed cost

LSD

(I) Treatment	(J) Treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
T1	T2	-211.00000*	27.05809	.001	-286.1253	-135.8747
	T3	-89.40000*	27.05809	.030	-164.5253	-14.2747
	T4	-301.60000*	27.05809	.000	-376.7253	-226.4747
T2	T1	211.00000*	27.05809	.001	135.8747	286.1253
	T3	121.60000*	27.05809	.011	46.4747	196.7253
	T4	-90.60000*	27.05809	.029	-165.7253	-15.4747
T3	T1	89.40000*	27.05809	.030	14.2747	164.5253
	T2	-121.60000*	27.05809	.011	-196.7253	-46.4747
	T4	-212.20000*	27.05809	.001	-287.3253	-137.0747
T4	T1	301.60000*	27.05809	.000	226.4747	376.7253
	T2	90.60000*	27.05809	.029	15.4747	165.7253
	T3	212.20000*	27.05809	.001	137.0747	287.3253

*. The mean difference is significant at the 0.05 level.

Total cost

ANOVA

Total cost

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	214189.840	3	71396.613	97.518	.000
Within Groups	2928.560	4	732.140		
Total	217118.400	7			

Multiple Comparisons

Total cost
LSD

(I) Treatment	(J) Treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
T1	T2	-311.00000*	27.05809	.000	-386.1253	-235.8747
	T3	-99.40000*	27.05809	.021	-174.5253	-24.2747
	T4	-411.60000*	27.05809	.000	-486.7253	-336.4747
T2	T1	311.00000*	27.05809	.000	235.8747	386.1253
	T3	211.60000*	27.05809	.001	136.4747	286.7253
	T4	-100.60000*	27.05809	.021	-175.7253	-25.4747
T3	T1	99.40000*	27.05809	.021	24.2747	174.5253
	T2	-211.60000*	27.05809	.001	-286.7253	-136.4747
	T4	-312.20000*	27.05809	.000	-387.3253	-237.0747
T4	T1	411.60000*	27.05809	.000	336.4747	486.7253
	T2	100.60000*	27.05809	.021	25.4747	175.7253
	T3	312.20000*	27.05809	.000	237.0747	387.3253

*. The mean difference is significant at the 0.05 level.

Net return

ANOVA

Net return

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	201033.340	3	67011.113	68.825	.001
Within Groups	3894.560	4	973.640		
Total	204927.900	7			

Multiple Comparisons

Net return
LSD

(I) Treatment	(J) Treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
T1	T2	176.00000*	31.20320	.005	89.3660	262.6340
	T3	-245.60000*	31.20320	.001	-332.2340	-158.9660
	T4	-143.40000*	31.20320	.010	-230.0340	-56.7660
T2	T1	-176.00000*	31.20320	.005	-262.6340	-89.3660
	T3	-421.60000*	31.20320	.000	-508.2340	-334.9660
	T4	-319.40000*	31.20320	.001	-406.0340	-232.7660
T3	T1	245.60000*	31.20320	.001	158.9660	332.2340
	T2	421.60000*	31.20320	.000	334.9660	508.2340
	T4	102.20000*	31.20320	.031	15.5660	188.8340
T4	T1	143.40000*	31.20320	.010	56.7660	230.0340
	T2	319.40000*	31.20320	.001	232.7660	406.0340
	T3	-102.20000*	31.20320	.031	-188.8340	-15.5660

*. The mean difference is significant at the 0.05 level.

Appendix V

Gross revenue

ANOVA

Gross revenue

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	495558.000	3	165186.000	22.007	.006
Within Groups	30024.000	4	7506.000		
Total	525582.000	7			

Multiple Comparisons

Gross revenue
LSD

(I) Treatment	(J) Treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
T5	T6	-90.00000	86.63717	.358	-330.5434	150.5434
	T7	-36.00000	86.63717	.699	-276.5434	204.5434
	T8	-612.00000*	86.63717	.002	-852.5434	-371.4566
T6	T5	90.00000	86.63717	.358	-150.5434	330.5434
	T7	54.00000	86.63717	.567	-186.5434	294.5434
	T8	-522.00000*	86.63717	.004	-762.5434	-281.4566
T7	T5	36.00000	86.63717	.699	-204.5434	276.5434
	T6	-54.00000	86.63717	.567	-294.5434	186.5434
	T8	-576.00000*	86.63717	.003	-816.5434	-335.4566
T8	T5	612.00000*	86.63717	.002	371.4566	852.5434
	T6	522.00000*	86.63717	.004	281.4566	762.5434
	T7	576.00000*	86.63717	.003	335.4566	816.5434

*. The mean difference is significant at the 0.05 level.

Feed cost

ANOVA

Feed cost

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	98884.625	3	32961.542	169.001	.000
Within Groups	780.150	4	195.037		
Total	99664.775	7			

Multiple Comparisons

Feed cost
LSD

(I) Treatment	(J) Treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
T5	T6	-195.95000*	13.96558	.000	-234.7247	-157.1753
	T7	-84.90000*	13.96558	.004	-123.6747	-46.1253
	T8	-294.05000*	13.96558	.000	-332.8247	-255.2753
T6	T5	195.95000*	13.96558	.000	157.1753	234.7247
	T7	111.05000*	13.96558	.001	72.2753	149.8247
	T8	-98.10000*	13.96558	.002	-136.8747	-59.3253
T7	T5	84.90000*	13.96558	.004	46.1253	123.6747
	T6	-111.05000*	13.96558	.001	-149.8247	-72.2753
	T8	-209.15000*	13.96558	.000	-247.9247	-170.3753
T8	T5	294.05000*	13.96558	.000	255.2753	332.8247
	T6	98.10000*	13.96558	.002	59.3253	136.8747
	T7	209.15000*	13.96558	.000	170.3753	247.9247

*. The mean difference is significant at the 0.05 level.

Total cost

ANOVA

Total cost

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	203764.625	3	67921.542	348.249	.000
Within Groups	780.150	4	195.037		
Total	204544.775	7			

Multiple Comparisons

Total cost
LSD

(I) Treatment	(J) Treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
T5	T6	-295.95000*	13.96558	.000	-334.7247	-257.1753
	T7	-94.90000*	13.96558	.002	-133.6747	-56.1253
	T8	-404.05000*	13.96558	.000	-442.8247	-365.2753
T6	T5	295.95000*	13.96558	.000	257.1753	334.7247
	T7	201.05000*	13.96558	.000	162.2753	239.8247
	T8	-108.10000*	13.96558	.002	-146.8747	-69.3253
T7	T5	94.90000*	13.96558	.002	56.1253	133.6747
	T6	-201.05000*	13.96558	.000	-239.8247	-162.2753
	T8	-309.15000*	13.96558	.000	-347.9247	-270.3753
T8	T5	404.05000*	13.96558	.000	365.2753	442.8247
	T6	108.10000*	13.96558	.002	69.3253	146.8747
	T7	309.15000*	13.96558	.000	270.3753	347.9247

*. The mean difference is significant at the 0.05 level.

Net return

ANOVA

Net return

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	176636.825	3	58878.942	10.387	.023
Within Groups	22674.150	4	5668.537		
Total	199310.975	7			

Multiple Comparisons

Net return
LSD

(I) Treatment	(J) Treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
T5	T6	205.95000	75.28969	.052	-3.0877	414.9877
	T7	58.90000	75.28969	.478	-150.1377	267.9377
	T8	-207.95000	75.28969	.051	-416.9877	1.0877
T6	T5	-205.95000	75.28969	.052	-414.9877	3.0877
	T7	-147.05000	75.28969	.123	-356.0877	61.9877
	T8	-413.90000*	75.28969	.005	-622.9377	-204.8623
T7	T5	-58.90000	75.28969	.478	-267.9377	150.1377
	T6	147.05000	75.28969	.123	-61.9877	356.0877
	T8	-266.85000*	75.28969	.024	-475.8877	-57.8123
T8	T5	207.95000	75.28969	.051	-1.0877	416.9877
	T6	413.90000*	75.28969	.005	204.8623	622.9377
	T7	266.85000*	75.28969	.024	57.8123	475.8877

*. The mean difference is significant at the 0.05 level.