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Homestead mechanized aquaculture in Bangladesh: New concept for enhancement for production and profitability

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Abstract

In Bangladesh, almost all of the homestead ponds are cultured extensively, where there are scopes to enhance productivity through aquaculture mechanization. Five household-sized ponds (60±0.02 decimal) were selected. No mechanization is done on Pond 1. Pond 2, Pond 3, Pond 4 and Pond 5 were equipped with surface aeration; Pond 3 was with Bottom aeration; Pond 4 and Pond 5 were equipped respectively with surface, bottom, combination of both and combination of both aerations along with additional automated feed sprayer. All ponds were stocked at a rate of 250 pcs. /decimal mono-sex Tilapia (*Oreochromis niloticus)* and the stocking size was 0.90±0.15 g. Water Temperature, pH, and dissolved oxygen (DO) were recorded two times daily, whereas Ammonia, Nitrate, Nitrite and Phosphate data were recorded fortnightly during the 124-day culture period. Highest average growth (266.08±12.80 g) and lowest Feed Conversion Ratio (1.10) were found in Pond 5, whereas the lowest average growth (153.70±48.07) and highest FCR (1.70) was found in Pond 1. Production was enhanced by 40%, 28%, 47% and 54% respectively in Pond 2, 3, 4 and 5; compared with the control Pond 1. Economic analysis showed that the profit increased by 13%, 25% and 41% in Pond 2, 4 and 5 respectively compared with control Pond 1. In Pond 3, profit decreased by 25% compared with control Pond 1. In all treatments, FCR is reduced, which is very important to maintain good water quality for homestead ponds. Economically These experiments need to be further developed for polyculture ponds, to find out the appropriate species combination, to serve partial harvest for household consumption and for more viable economic return.

Keywords: Aquaculture mechanization; Homestead pond; Surface Aeration; Bottom Aeration; Feed-sprayer

1. Introduction

Bangladesh being one of the densely populated countries, shows the potential of aquaculture production for which the country has been ranked 5th in world aquaculture production [1]. The fisheries sector contributes 3.50% to the total GDP and 25.72% to the agricultural GDP [2]. Approximately nineteen and a half million people have been involved in this sector, in which the number of fish farmers is around 13.86 million. The total pond area of Bangladesh was 0.397 million ha, and the annual average production was 4.964 MT/ha [2]. Many cultivable lands are drastically converted to houses and yards. For building houses and yards, required soil is collected by digging agricultural land, which ultimately results in an increased number of homestead ponds. So, homestead pond aquaculture is prevalent throughout Bangladesh in more than four million households' ponds in the homestead vicinity, covering an area of 266,259 ha in 2010 [3]. Those homestead ponds are usually used for household purposes and aquaculture extensively. These

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homestead ponds play a crucial role in providing both household income and fish for consumption, contributing between 3 and 15% of total household income and 25–50% of total fish consumption [3]. The transition from an aquatic food system dominated by capture fisheries to one increasingly dominated by aquaculture has been made possible by the simultaneous horizontal expansion of pond area and achievement of progressively higher levels of productivity per unit area of land (intensification). The latter trend has been supported by the widespread adoption of commercially manufactured aquafeeds, similar to the increased use of feed supplements in the aquaculture industry. Therefore, the intensification of aquaculture is likely to be essential but must occur sustainably to avoid environmental impacts that compromise future food production. This intensification culture pond required to increase in the density of cultured species with an artificial feed supply thus many problems like organic pollution, deficiency of oxygen, increased level of free carbon dioxide and a total increase in ammonia-nitrogen, nitrite-nitrogen ratio frequently occurring [4]. However, the problem of oxygen depletion in the rearing of fish species is a major threat and main limiting factor in intensive aquaculture because it leads to hypoxia, which affects fish growth, food conversion levels feeding efficiency, etc. [5] and fish always show high feed efficiency when they are fed at required Dissolved Oxygen (DO) in water [6]. Another major problem in the intensive aquaculture system is the presence of high concentrations of nutrients, especially phosphorus, ammonia, nitrite, and nitrate. High concentrations of these nutrients can lead to excessive phytoplankton growth (phytoplankton bloom) and deterioration of pond water quality [7]. Repeated use of aqua chemicals and medicines used to solve an instant problem may cause a long-term impact on culture and also may not be cost-effective in the long run. Considering the negative impacts of different chemicals in enhancing DO content, reducing excessive phytoplankton growth in pond water, and improving the aquatic environment by keeping different water quality parameters in a suitable range for fish growth. Aeration can be the alternative and efficient way to get rid of deficiency of oxygen and organic pollution in intensive aquaculture systems [8,9] Moreover, emergency aeration is the best technique for preventing fish kills during a DO crisis since aeration is the dissolution of oxygen (O_2) from the atmosphere (21% O_2) into water [10,11,12,13]. Aquaculture mechanization in Bangladesh is a new concept for enhancing aquaculture production and reducing production costs and water quality deterioration. The long-term vision of the Bangladesh Government is to increase the production and supply of rural electricity, which also creates the opportunity for aquaculture mechanization [14,15]. Aquaculture mechanization, especially aeration mechanization for oxygen supplements, is a way to minimize the problem that occurs due to oxygen deficiency in aquaculture ponds. Feeding mechanization, i.e., the use of the auto fish feeder, reduces feed loss and labour costs and increases productivity and income. So, the effect of aquaculture mechanization, especially aeration and feeding mechanization, was carried out to reduce feed cost, labour cost, pond water pollution and increase pond productivity and income.

2. Materials and methods

Mechanization in the fish farm for research and development purposes was done at different household ponds at Araihazar Upazila, Narayanganj, Bangladesh; where mechanization was adopted in four ponds at different levels and also kept a control pond without mechanization. The experiment was conducted from April 2020 to July 2020.

2.1. Pond Selection and Preparation

Each pond was 60±0.02 decimals in size and its depth was 182.88±0.05 cm. Because these were household ponds; draining out of water for bottom preparation, and use of chemicals for eradicating unwanted species, were not allowed by the household user. So, Ponds were prepared initially by draining out approximately two-thirds of its water then netting was done frequently times to eradicate existing and unwanted species. The bottom mud was removed as much as possible with human labour. Liming was done at the rate of 1kg/ decimal at the waterbody along with the vicinity of the dike. After seven days of liming, the water label was uplifted to 5-6 ft. height from the ground water source then fertilization was done by applying CRSP (Collaborative Research Support Program) methods of 28 kg N/ha/week and 7 kg P/ha/week, giving N: P ratio of 4:1.

2.2. Stocking fish and feeding

GIFT Strain of Tilapia (*Oreochromis niloticus*) was selected as a culture species for four (4) months of the experiment. Stocking was done by 250 pieces/ decimal in each pond. The average size of each fry was 0.90±015g. Acclimatization was done for 30 minutes before releasing them into a water body. Fry was initially fed at the rate of 20% of their body weight and reduced gradually to 1.5% during the last week of culture. Locally available formulated floating feed with a protein content of initially 37% to finisher 28% was fed at the prescribed mesh size at different stages of growth of tilapia.

2.3. Mechanization and Maintenance

A single unit of a 04-wheel paddle aerator (motor: 2HP, 1.5kw, 220V, aeration capacity: ≥2.6 kg O_2/hr.) was given in Pond 2 as a surface aerator. Pond 3 was equipped with a Roots Blower (Motor: 2 HP, 1.5kw, 220V, motor speed: 1450 rpm, pressure: 4000mmAq, capacity: 39 m3/hr.) and a diffuser disk for each one and half decimal area i.e., 45 disks (Dimension: 10"x2.3", Flow range: 20~150 L/min, Membrane: Ethylene Propylene Diene Monomer) were used for 60 decimal experimental ponds. Pond 4 was equipped with a combination of both surface aeration and bottom aeration like Pond 2 and Pond 3. Pond 5 was equipped like Pond 4, the only extra inclusion was an Automated feed sprayer (Motor: 120W, power supply: 220V, hopper volume: 120kg, Shooting distance: 3-20 meters, Fan angle: 90°-110° Maximum feeding capacity: 160kg/hr.) In every case, aeration was done for 8 hours per day on average. At the beginning of culture, aeration was given only 02 hours during the early morning and that was extended to 9-10 hours during the night and as well as daytime of gloomy or rainy days; as our culture extends to the beginning of the rainy season.

Figure 1 04 Paddle wheel aerator

Figure 2 Bottom aeration with diffuser disk and roots Blower

Figure 3 Fish Feeder use in fish pond

Figure 4 Root blower

Figure 5 Disc diffuser

Figure 6 Automatic fish feeder

2.4. Fish Sampling

Fish sampling was done every 15 days intervals to adjust the feeding rate and to observe the health condition of fish. A cast net was used to catch fish at four different points of each pond. A sensitive portable electronic balance, Model AK-3000H AFD was used to measure the weight of fish.

2.5. Water quality parameters

A handheld thermometer was used to measure the temperature of the water body. Hanna HI-98108 model pH meter was used to measure the pH, and dissolved oxygen concentration was measured by Lutron Dissolved Oxygen Meter, Model: DO-5509. Ammonia (NH3-N), Nitrite (NO2-N) Nitrate (NO3-N) and Phosphate (PO4) were measured by using the Hanna Colorimetric Digital meter.

3. Results and Discussion

3.1. Fish Growth

The growth parameters of different ponds in terms of Mean weight gain (g); %SGR per day, Survival rate (%), Production (kg/ha/124 days), and FCR were calculated. (Table 1). Growth of Tilapia indicates that there was a significant variation in growth rate at mechanized pond compared to non-mechanized one. The highest growth and production are shown in Pond 5, where %SGR per day is 2.15 and production is more than 16 (sixteen) tons. Pond 4 showed 2nd highest %SGR per day (2.00) and Production (more than Fifteen tons), this pond is equipped with a combination of Surface and Bottom Aerators and lacks of Automated Feed Sprayer, which was the difference between the mechanization intensification between Pond 5 and Pond 4. Pond 1 showed the lowest production and %SGR per day (1.24) due to the lack of mechanization. The intensification of mechanization increases the production capacity of ponds. Pond 3, which was equipped with only bottom aeration showed less growth efficiency than the other three mechanized ponds. That means bottom aeration as a single mechanization tool is less effective than other mechanized ponds. FCR is a vital issue in fish production to minimize feed costs; lower the FCR, then the requirement of feed is also lower. Here lowest to highest FCR was calculated in pond 5 (1.10), pond 4 (1.16), pond 2 (1.21) pond 3 (1.33) and pond 1 (1.70) respectively.

Table 1 Growth parameters of tilapia in five different ponds

Parameters	**Pond 1**	**Pond 2**	**Pond 3**	**Pond 4**	**Pond 5**
Mean initial weight (g)	0.90±0.15	0.90±0.15	0.90±0.15	0.90±0.15	0.90±0.15
Mean final weight (g)	154.6±34.13	128.9±24.04	210.8±25.34	248.5±13.47	266.98±9.20
Mean weight gain (g)	153.70±48.07	228.00±33.79	209.90±35.64	247.60±18.84	266.08±12.80
% SGR per day	1.24±0.39	1.84±0.27	1.69±0.29	2.00±0.15	2.15±0.10
Survival rate (%)	90±0.02	95±0.02	92±0.02	95±0.02	95±0.02
Production (kg/ha/124 days)	10488.93±0.03	14681.96±0.04	13415.34±0.04	15367.64±0.05	16201.39±0.05
Production increase (%)	N/A	40%	28%	47%	54%
FCR	1.7±0.00	1.21±0.00	1.33±0.00	1.16±0.00	1.10±0.00

3.2. Water Quality Parameter

Dissolve oxygen (DO) concentration was found initially at 6.5 mgl^{-1} in every Pond in the early morning. As the biomass increases, the DO concentration gradually decreases in Ponds. Whereas, at the end of the culture period, it was as low as 2.6 mgl^{-1} in Pond 1, In Pond 3 it was 3.8 mgl^{-1}; in Pond 2 and Pond 4, it was 4 and 5.25 mgl^{-1} respectively (Fig. 1). All aerated ponds were maintained at 4.99 to 5.80 mgl^{-1} DO concentration whereas the average DO concentration of non-aerated pond 1 is 4.24. Frobish L. [16] explained that the concentration of DO exhibits a daily cycle. The lowest concentration of DO occurs at dawn. During the daylight, photosynthesis causes DO concentration to increase, and maximum DO concentrations are reached in the afternoon. during the night photosynthesis ceases and respiration by organisms in the ponds consumes oxygen and causes DO concentrations to fall.

In Pond 1, the average NH_4/NH_3 concentration (0.34 mgl^{-1}) was found highest among the other pond, and the lowest (0.01 mgl^{-1}) was found in Pond 5 (Fig. 1). The concentration of NH_4/NH_3 in the other three ponds was within 0.02 to 0.09 mgl^{-1}, which is within the tolerable limit for fish production. During the culture period, NO_3 and NO_2 were found lowest (0 mgl^{-1}) in Pond 1. In Pond 3, NO3 was found highest (0.3 mgl^{-1}) and in Pond 4 NO_2 was found lowest (0.02 mgl^{-1}). Lim et al. [17] stated that, in an Intermittent Aeration system, high DO concentrations during the aeration period enable aerobic nitrifying bacteria to oxidize NH4+-N to NO2−-N and then to NO3−-N. During the subsequent non-aeration period, the DO concentration declines to a sufficiently low enough level so that NO2−-N and NO3−-N species are transformed into nitrogen gas mediated by anoxic denitrification.

PO4 level varied during the experimental period and it was between 0.8 to 0.1 mgl-1. In the experimental pond PO4 concentration was found higher in Pond 1. and the concentration was between 0.03 to 0.1 mgl-1 in Pond 5 which was at the lowest level. (Fig. 1). Boyd [6] stated that the tolerable limit of PO4 is 0.005-0.2 mgl-1 which is good for pond aquaculture. This variation in the phosphate concentration might be the cause of hampered and made difference in fish production.

pH level was between 7-9 (Fig. 2), where the highest range is found in Pond 1 (7-9) and the lowest range is found in Pond 5 (7.5-8.5). Rebouças et al. [18] assessed the optimum range of water pH for Nile tilapia culture. The fish (1.37 g) were reared at a water pH ranging from 4.5 to 9.5 for 8 weeks. The results revealed that a pH of 5.5–9.0 is suitable for rearing these fish.

The temperature of water during the experimental period was production was between 29-35°C. The average daily water temperature in April May June and July was 35.7°C, 34.85°C, 34.23°C and 32.9°C. Bezault E et al. [19] reported that, in the wild, Nile tilapia may encounter a wide range of temperatures with strong seasonal thermal variations, ranging from warm (28–34°C) to "cold" (22–26°C) seasons or extreme environments such as altitude lakes with constant "cold" temperatures (17–24°C). Though DeLong *et al. [20]* found that at a temperature range of 27 to 29 °C, tilapia grow at optimal rates.

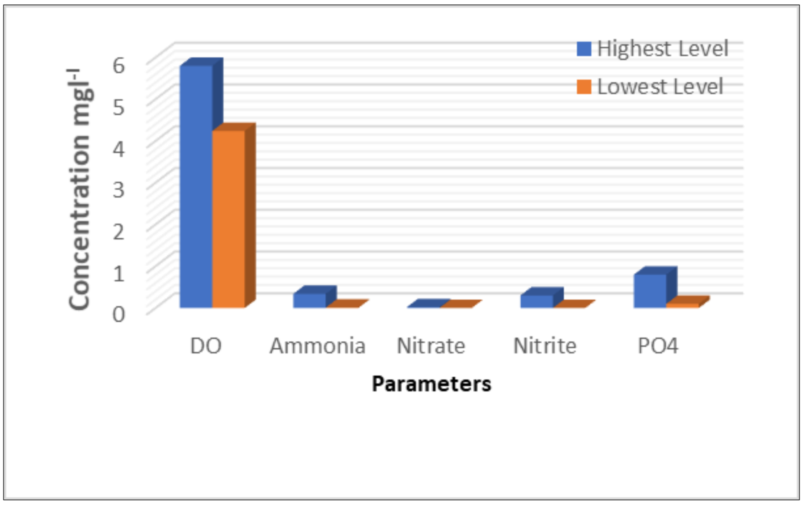

Figure 1 Concentration range of DO, Ammonia, Nitrite, Nitrate and PO_4 in different ponds

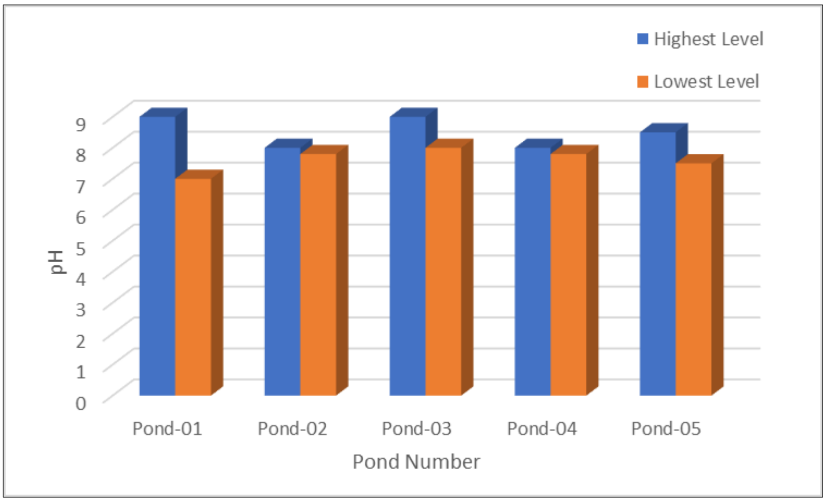

Figure 2 Concentration range of pH in different ponds

3.3. Cost-benefit analysis of mechanized aquaculture

The fixed cost of mechanization for Ponds 2, 3, 4 and 5 is BDT 55000.00, 140000.00, 195000 and 230000 respectively. Though these machineries are fixed assets here depreciation cost (20% of cost) is counted to calculate the overall increase in profit margin. In a mechanized culture system, the production cost is increased only for adding types of machinery and electricity consumption cost to operate those machinery. In an extensive culture procedure in a homestead pond with the addition of formulated floating feed and other auxiliary costs (seed, lime, fertilizer, labour etc.), the other variable cost was calculated; where the cost was decreased in mechanized Ponds than in non-mechanized one, mainly due to lowering the FCR. By considering the BDT 11.00 per unit cost of electricity and depreciation cost of fixed machinery, Table 2 showed that the production cost increased by BDT 27368.00, 44368.00, 71736.00 and 78954.24 for Ponds 2, 3, 4 and 5 respectively. The overall increase in profit was highest in Pond 5, which is equipped with a combination of bottom and surface aerators and with automated feed sprayer, and that is more than BDT 0.6 million. The decrease in profit margin was found in Pond 3, which is only equipped with bottom aeration, and that is almost 25% decreased than control Pond 1. A 13% increase in profit margin was found in Pond 2, which is equipped with only a surface aerator.

Table 2 Profit Analysis of Mechanization in a 124 days culture period of Tilapia

Sl	Particulars	Pond 1	Pond 2	Pond 3	Pond 4	Pond 5
1	Mechanization Techniques	Control	Surface Aeration	Bottom Aeration	Surface Aeration + Bottom Aeration	Surface Aeration + Bottom Aeration + Feed Sprayer
2	Mechanization Tools	N/A	04-wheel Paddle	Roots Blower & diffuser disk	Combination of Pond 1 & pond 2	Combination of pond 1 & 2 + Auto Feed Sprayer
3	Duration of Operation (hrs/day)	N/A	8	8	8	8 + 1
4	Electricity Used (Kw/124 Days)	N/A	1488.00	1488.00	2976.00	2995.84
5	Fixed cost of Mechanization (tk.)	N/A	55000.00	140000.00	195000.00	230000.00
6	Operational Cost (tk.) of mechanization	N/A	16368.00	16368.00	32736.00	32954.24
9	*Increase of Production Cost (tk.)	N/A	27368.00	44368.00	71736.00	78954.24
7	**Other Variable Cost (tk.)	566827	414002.00	451428.00	382209.00	379695.00
8	Decrease in Variable Cost (tk.)	N/A	152825.00	115399.00	184618.00	187132.00
10	Selling Price/kg. (tk.)	100±2	100±2	100±2	100±2	100±2
11	Total Sale (tk.)	1048897.66±299.97	1468202.51±419.69	1341539.37±383.57	1536770.02±439.24	1620145.71±463.07
12	Increase in Sales (tk.)	N/A	419304.86±84.65	292641.71±59.11	487872.36±98.48	571248.05±115.33
13	***Overall increase in Profit (tk.)	482070.66±299.97	544761.86±84.65	363672.71±59.11	600754.36±98.48	679425.81±115.33
14	Increase in Profit (%)	N/A	13%	-25%	25%	41%

*Depreciation cost of machinery (20%) + electricity consumption cost (11.00 tk./ Unit); ** Include Seed cost (1.36 tk./pcs.), Feed cost (average 76.41 tk./kg), Lime, fertilizer and labour cost.; **Increase in Sales (10)-Increase of Production Cost (7) +Decrease in variable cost (8); Note: 1 tk. = 0.0118 USD

4. Conclusion

The present study is conducted to assess the possibility of enhancing the production and profitability of homestead ponds through mechanized aquaculture. It showed that at different stages of mechanization, production and profit increase proportionately. Again, aquaculture mechanization reduces the use of chemicals and medicines and increases farm productivity and income. Mechanization eases the culture system and reduces labour dependency, so women can participate easily in the aquaculture production system. The mechanization of homestead ponds can bring a drastic change in the economy of rural households. The involvement of women in homestead-intensive pond culture opens the way to enhance their contribution to the household economy as well as the national economy. This study needs to be further developed to enhance the production capacity of the homestead ponds through proper calculation of scheduled aeration and Internet of Things (IoT) based mechanization.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

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