

## Aquaponics for Improving High Density Fish Pond Water Quality Through Raft and Rack Vegetable Production

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**Abstract:** The population of Bangladesh is increasing tremendously and to keep pace with the increasing demand of fish protein, farmers intensified fish production from the water bodies which created environmental pollution. To tackle the situation the raft and rack aquaponics experiment was conducted to reduce the water pollution and have vegetable production from high density poly-culture fish ponds. Three ponds were selected each having an area of 3.12 decimal. The bamboo made raft was placed on water surface and rack on the bank of pond 1 which denoted as treatment T<sub>1</sub> and only raft was placed in pond 2 that noted as treatment T<sub>2</sub> and pond 3 was without any raft and rack denoted as control (T<sub>3</sub>). Summer vegetables were planted in both the rafts and rack in two liter plastic water bottles. The vegetable growth and water quality parameters such as NH<sub>4</sub>/NH<sub>3</sub>, NO<sub>3</sub>, NO<sub>2</sub>, PO<sub>4</sub>, DO and pH were measured fortnightly using test kits. Pungasius and tilapia were released as the experimental fishes at the rate of 33,650 and 16,000 fish/ha. Data interpretation showed that % SGR per day of pungasius and tilapia in T<sub>1</sub>, T<sub>2</sub> and T<sub>3</sub> were 2.57 and 0.822, 1.27 and 0.795, 2.36 and 0.438 respectively. The highest growth was found in T<sub>1</sub> treatment for both species. The water quality parameters were within the acceptable limits but were significantly different among the treatments. The water quality in T<sub>1</sub> and T<sub>2</sub> treatments were better than the T<sub>3</sub>. The production of water spinach, pudina and okra from raft and rack were about 997 and 2460; 797 and 1969; 199 and 492 kg/ha/90days respectively in T<sub>1</sub>. In T<sub>2</sub> only okra production was higher than T<sub>1</sub> (215kg/ha/90days) but water spinach and pudina production was lower than T<sub>1</sub> (923 and 763 kg/ha/90days). The pudina production was highly profitable than the other crops and benefit-cost ratio of pudina was about 6.33. So, along with the fish culture, farmers can produce vegetable through raft and rack aquaponics and can improve the pond condition. The technology can be piloted in different agro-ecological zones in the country.

**Key words:** Aquaponics • Vegetable Production • Polyculture • Raft and Rack

### INTRODUCTION

Aquaponics is a combination of aquaculture and hydroponics (growing vegetables in a soilless environment). It is a bio-integrated system that links recirculating aquaculture with hydroponic vegetable, flower and/or herb production [1]. The system delivered effluents as nutrients for the vegetable that contains sufficient level of ammonia, nitrate, nitrite, phosphorus, potassium and other secondary and micro-nutrients to produce hydroponic plants [2]. Recent advancement in

researches has turned aquaponics into a working model of sustainable and environmental friendly fish and vegetable production. The wastes produced in one biological system serve as nutrients for another. The integration of fish and vegetable production increases the diversity and yields multiple products and water is reused through the process [3].

In developed countries concerns about water pollution have raised interest in aquaponics system as a valid option to get rid of aquaculture wastes through production of high value vegetables [4, 5]. While growing

fishes in a system it produces nitrogenous compound mainly ammonia which is hazardous to fish, even in small quantities and toxicity increases in relation to pH and temperature in the water column. On the other hand, Nitrosomonas bacteria break down ammonia to  $\text{NO}_2$  and Nitrobacter convert the nitrite into nitrate which is food for the plants. By contrast,  $\text{NO}_3$  is less harmful to fish. Pungasius and tilapia is the fish species which has been selected in the present study because they are very hardy, can tolerate wide range of environmental parameters, can live with versatile of feed and are fast growing fish species [6, 7].

The selection of plant species in aquaponics system is important. Lettuce, herbs, okra and especially leafy greens have low to medium nutritional requirements and are well suited to aquaponics system. Plants yielding fruits like tomato, bell pepper and cucumber have higher nutritional requirement and perform better in a heavily stocked and well established aquaponics system [8]. Several warm-water and cold water fish species are adapted to recirculating aquaculture which includes tilapia, trout, perch, Arctic char and bass. Moreover, most commercial aquaponics system in North America is based on tilapia. Furthermore, tilapia is tolerant of fluctuating water conditions such as pH, temperature, oxygen and dissolved solids [9]. Decaying organic matters can help to fertilise ponds, at the same time provides good environment for growing plants which are less prone to disease unlike soil. Raft aquaponics is one of the ways to use aquaculture site for vegetable production and can help to overcome nutritional demand for the growing population. Therefore, the experiment was carried out to see the feasibility of raft and rack based vegetable culture in high density polyculture fish pond in Mymensingh region, Bangladesh.

## MATERIALS AND METHODS

The experiment was conducted for a period of 90 days during September to November, 2011. The ponds under trial are situated near the Faculty of Fisheries, Bangladesh Agricultural University (BAU), Mymensingh. All the selected ponds were in same size (3.14 decimal) and used for treatments  $T_1$ ,  $T_2$  and  $T_3$  where  $T_3$  was control. In  $T_1$  raft was placed on water surface and rack on the pond dyke for vegetable production. On the other hand, only raft was placed in pond 2 ( $T_2$ ). The ponds were renovated and prepared following the standard procedure prior to stocking fish. After pond preparation, Pungasius and tilapia fingerlings were collected and released in the

ponds at the rate of 33,650 and 16,000 per hectre respectively. Stocking size of pungasius was  $9.1 \pm 0.26$  cm and  $6.5 \pm 0.33$  g in length and weight, whereas, tilapia was  $10.2 \pm 0.56$  cm and  $56.3 \pm 0.54$  g. The fish was fed pelleted feed twice daily 1<sup>st</sup> in the morning at 9:00 am and 2<sup>nd</sup> in the evening at 5:00 pm at the rate of 5% of fish body weight during first month which was reduced to 3% for the 2<sup>nd</sup> and 3<sup>rd</sup> month.

Raft was prepared with locally available and low cost materials such as bamboo splits, iron wire, plastic thread and disposable plastic water bottles. Bamboo splits were tied with wire to make the frame of 36 ft<sup>2</sup> (6 ft x 5 ft) raft. One liter disposable plastic water bottles were used to float the raft and two liter bottles were used for planting vegetables where coconut husk and breaklets were used as substrate in the bottles. Equal size rafts were used in treatment  $T_1$  and  $T_2$  which covered 2.57% of total pond area. Thirty six saplings 12 each of water spinach, pudina and okra were planted in the rafts in  $T_1$  and  $T_2$  treatments. Several pores were made in the bottles to exchange water and pass the plant roots. On the other hand, a three storied rack was made with the same materials and 24 bottles 8 in each row were hanged one over another. A separate platform was made to place an aquarium where pond water was installed manually and siphoned to the upper most bottles which then poured to the second and third bottles and finally to the pond. No fertilizers as well as pesticides were used but IPM technique was applied to eradicate the insecticides. Fish sampling was done monthly using cast net to adjust the feeding rate, by measuring the length and weight of fish and to observe the health condition. Water quality parameters such as  $\text{NH}_4/\text{NH}_3$ ,  $\text{NO}_3$ ,  $\text{NO}_2$ ,  $\text{PO}_4$ , pH and dissolved oxygen were measured fortnightly using Sera test kits. Number of flowers, fruits and fruits weight were recorded. All the sampling data were incerted in the Microsoft Excel 7 for analysis.

## RESULTS

The growth of pungasius and tilapia in raft and rack aquaponics system indicated that the growth rate varied in the treatments.  $T_1$  showed significantly the highest growth and survival rate among all the treatments. The net length gain of individual pungasius in  $T_1$  and tilapia in  $T_2$  was higher (18.42 cm and 17.4 cm respectively) and net weight gain of individual pungasius and tilapia in  $T_1$  treatment was higher than the  $T_2$  and  $T_3$  (58.91 and 61.7 gm respectively). The survival rate of pungasius and tilapia were also found highest in  $T_1$  which were 95 and

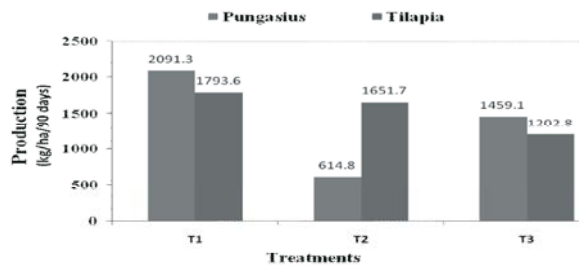


Fig. 1: Production of Pungasius and Tilapia in all treatments in raft and rack based aquaponics system

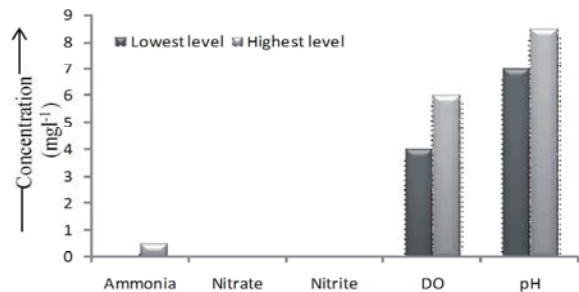


Fig. 2: The lowest and highest range of Ammonia, Nitrate, Nitrite, DO and pH in the experimental ponds

93% respectively. The production of pungasius and tilapia was also highest in T<sub>1</sub> than the other two treatments which were 2091.3 and 1793.6 kg/ha/90 days, respectively (Figure 1). Percent SGR per day of pungasius in T<sub>1</sub>, T<sub>2</sub> and T<sub>3</sub> were 2.57, 1.27 and 2.36, whereas, in case of tilapia, were found 0.822, 0.795 and 0.438 for the treatments of T<sub>1</sub>, T<sub>2</sub> and T<sub>3</sub> respectively. The % SGR per day was highest for both the pagasius and tilapia in T<sub>1</sub> than in T<sub>2</sub> and T<sub>3</sub> treatments.

**Water Quality Parameter:** Usually water quality parameters proportionately deteriorated with the increasing fish density in culture ponds. The following water quality parameters were tested using Sera test kits NH<sub>4</sub>/NH<sub>3</sub>, NO<sub>3</sub>, NO<sub>2</sub>, PO<sub>4</sub>, DO, pH and temperature. There were no significant differences among the water quality in all the treatments but slightly improvement were notice in the treatment T<sub>1</sub>. That means more fish can be added in the ponds. The range of the parameters in three experimental ponds is given in the Figure 2.

In all the three treatments the NH<sub>4</sub>/NH<sub>3</sub> concentration was 0.5 mg L<sup>-1</sup> during the first month of the experiment. However, NH<sub>4</sub>/NH<sub>3</sub> concentration was reduced to 0 mg L<sup>-1</sup> later months of the experiment in T<sub>1</sub>, but in T<sub>2</sub>

and T<sub>3</sub> the concentration was the same. Moreover, NO<sub>3</sub> and NO<sub>2</sub> concentration was zero throughout the experimental period in all the treatments. The dissolve oxygen concentration was same in all the treatments (6 mg L<sup>-1</sup>) except in T<sub>3</sub>, where oxygen concentration was 4 mg L<sup>-1</sup> in the first month. The pH range was varied in between 7 and 8.5 in all the treatments during the experimental period, which is acceptable for aquaculture. Phosphate concentration was varied most in different treatments during the experimental period. In T<sub>1</sub>, phosphate concentration was between 0.05-0.5 mg L<sup>-1</sup>. The phosphate concentration was found 0.05 mg L<sup>-1</sup> in the first sampling in September and the highest in the last sampling in November. On the other hand, phosphate concentration was in between 0.25-1.0 mg L<sup>-1</sup> in T<sub>2</sub> and 0.1-0.5 mg L<sup>-1</sup> in T<sub>3</sub>. The water temperature range was in between 29-35°C during the experimental period and average daily water temperature in September, October and November was 31.8°C, 32.6°C and 31.2°C respectively.

**Vegetable Production:** During the 90 days culture period water spinach was harvested three times, once in every month, whereas, pudina and okra was harvested once at the end of the experiment. In T<sub>2</sub>, similar results were observed for water spinach, pudina and okra. The production of pudina, water spinach and okra from raft aquaponics were about 760, 1025, 205 and from rack aquaponics were 2460, 1969, 492 kg/ha respectively in treatments T<sub>1</sub>. On the other hand, production of pudina, water spinach and okra from the raft aquaponics were 923; 763 and 215 kg/ha/90 days respectively in treatment T<sub>2</sub> (Table 1). In addition, some okra plants were disease infected and did not gave fruits.

**Cost-Benefit Analysis of Raft Vegetation:** Floating raft preparation, sapling and planting materials costs are the total cost of the raft vegetation and labour cost is not included here. Cost-benefit analysis, of raft vegetable in 1 ha pond area in different combination of raft covering, is done by considering only those vegetables which gave good production in 3 months. The cost of raft and rack making for this experiment was calculated about Tk 241 and 200 respectively. Sapling cost is taken into account as 1 Tk for 10 saplings of water spinach, pudina and okra. Per kg water spinach, pudina and okra selling price were calculated BDT 15, 300 and 20 respectively (Table 2). Although cost of all the materials has been taken into consideration in calculation of rafts and rack but this can be minimised when waste materials would be used for the purposes. Pudina production was highly profitable for

Table 1: Vegetable production per hectare in raft and rack aquaponics systems in three months

Treatments					
T <sub>1</sub>				T <sub>2</sub>	
Raft aquaponics		Rack aquaponics		Raft aquaponics	
Name of Crops	Production (kg/ha/90 days)	Name of Crops	Production (kg/ha/90 days)	Name of Crops	Production (kg/ha/90 days)
Water spinach	1025	Water spinach	2460	Water spinach	923
Pudina (mint)	760	Pudina (mint)	1969	Pudina (mint)	763
Okra	205	Okra	492	Okra	215
Total	2050	Total	4922	Total	1901

Table 2: Benefit-Cost Ratio in raft and rack aquaponics systems for water spinach, pudina and okra

Items	Raft Aquaponics System			Rack Aquaponics System		
	Water spinach	Pudina	Okra	Water spinach	Pudina	Okra
Cost of materials for each Raft/Rack in BDT	241			200		
Total raft and rack required/ha pond	2,990			4,000		
Total cost for Raft, Rack and Planting Pots in BDT	720,590	720,590	720,590	800,000	800,000	800,000
Sapling and Seed Cost in BDT	10,764	32,324	10,764	9,600	57,658	9,600
Planting cost	5000			4500		
Water pumping cost	0			100,000		
Planting Density/ha	100,000	100,000	100,000	300,000	300,000	300,000
Production Cycle (Days)	90	90	90	90	90	90
Cycle per year	2	2	2	2	2	2
Production kg/ha	10,000	8,000	2,000	30,000	24,000	6,000
Sale Price/kg in BDT	15	300	20	15	300	20
Total cost in BDT	736,354	757,914	736,354	914,100	962,158	914,100
Total Income in BDT	300,000	4800,000	80,000	900,000	14400,000	240,000
Benefit Cost Ratio	0.41	6.33	0.11	1.00	14.97	0.26

1 USD= 81 BDT in 2012

90 days culture period for both the system and benefit-cost ratio for pudina production was about 6.33 in raft and 14.97 in rack system.

## DISCUSSION

In Bangladesh land area is decreasing with the increasing population. So, we need to integrate of culture system for instance aquaponics system. Swingle [10] mentioned that pH range of 6.5 to 9.0 is suitable for pond fish culture. On the other hand, pH value more than 9.5 is unsuitable because free CO<sub>2</sub> will not be available at high pH value. Ali [11] recorded pH range of 7.5-9.5 in a freshwater pond. DoF [12] reported that the range of pH of a suitable water body for fish culture would be 6.5-8.5. The average pH value was recorded 7-8.5 in all the three

treatments during the present investigation which somehow matched with the study of Swingle [10], Ali [11] and DoF [12], suitable for fish culture. Alim [13] carried out an experiment at the Field Laboratory Complex of BAU in four treatments and recorded range of dissolved oxygen 1.2 to 8.5 mg L<sup>-1</sup>. Our present finding is more or less similar to Alim [13]. Bhuiyan [14] stated in his study that the concentration of phosphate-phosphorus ranged from 0.20 to 0.40 mg L<sup>-1</sup> is a good productive level. Raihan [15], Alim [11] and Ferdous [16] in their study found average phosphate-phosphorus of 0.56 to 1.11 mg L<sup>-1</sup>, 0 to 1.79 mg L<sup>-1</sup> and 0 to 3.98 mg L<sup>-1</sup>, respectively in different research ponds of BAU, Mymensingh. In the present investigation PO<sub>4</sub> level was varied during the experimental period and it was in between 0.05-1.0 mg l<sup>-1</sup>. Raihan [15] recorded ranges of nitrite-nitrogen from 0.001 to 1.048 mg L<sup>-1</sup> in his study. And in another study, Alim

[13] recorded nitrite-nitrogen ranges from 0 to 1.021 mg L<sup>-1</sup>. Mollah and Haque [17] recorded nitrate-nitrogen values range from 0.091 to 0.770 mg L<sup>-1</sup>. Rakocy [9] indicated that in a tilapia/floating lettuce aquaponic system, each square meter of hydroponic growing area removed 0.56 g of ammonia-nitrogen, 0.62 g of nitrite-nitrogen, 0.83 g of total nitrogen and 0.17 g of total phosphorus per day. In the present study, NO<sub>3</sub> and NO<sub>2</sub> concentration were found 0 mg L<sup>-1</sup> throughout study period, whereas, NH<sub>4</sub>/NH<sub>3</sub> concentration was found 0-0.5 mg L<sup>-1</sup> and temperature range was in between 29-35°C. The water quality parameters were within the suitable range during the present study.

In the present study, T<sub>1</sub> gave the higher fish production (Pangasius 2091.3±0.001 and Tilapia 1793.6±0.001 kg/ha/90days) than in T<sub>2</sub> and T<sub>3</sub>. This indicated that the waste utilization by the vegetables was higher in T<sub>1</sub> than in T<sub>2</sub> and T<sub>3</sub>. Ghaly [18, 1] stated that high-value vegetable crops, such as tomato, lettuce, cucumber and sweet basil have cultured in hydroponics media. Rakocy [19] at the University of Virgin Islands (UVI) developed a commercial-scale aquaponic system that run continuously for more than five years, have been raised Basil, lettuce, okra and other crops successfully, with outstanding quality and yields. In the present experiment water spinach, pudina and okra were cultured in T<sub>1</sub> that showing good production in raft and rack aquaponics. The raft and rack preparation cost could be minimized by using locally available low cost and unconventional materials. The raft preparation cost could be minimized when it would be used for several cycles of production. The aquaponics could be one of the great potential future means of crop production for our country to combat against malnutrition and adaptation to climate change. Therefore, further research is needed to make the aquaponics system affordable and user friendly to all.

## SUMMARY AND CONCLUSION

It is proved that aquaponics system is environmental friendly soilless fish and vegetable production system. The systems improved the high density fish pond water quality and increase fish production. The system can be used in draught prone, flood prone and coastal saline affected soil region to produce fish and vegetable round the year. The aquaponics system could be used in urban areas and can reduce food transport cost and minimize global warming. Using solar power energy the cost of electricity could be reduced and make the technology more user friendly.

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