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# Feasibility Study of Aquaponics in Polyculture Pond

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**Abstract:** The study was conducted to see the feasibility of raft aquaponics in polyculture pond. Three experimental ponds (with an area of 5.2, 3.12 and 3.12 decimal) were selected where the third one was considered as control pond. Locally available cheap materials were used in preparing rafts, e.g., bamboo splits, iron wire, plastic thread and disposable plastic water bottle. Okra *(Abelmoschus esculentus)*, water spinach (*Ipomoea aquatica*), pudina (*Mentha arvensis*), brinjal (*Solanum melongena*), tomato (*Lycopersicon esculentum*), giant taro (*Alocasia macrorrhiza)* and Indian spinach-red (*Basella rubra*) saplings were planted in the raft. Pond 1 and 2 were found to be covered with 4.12% and 2.56% with raft vegetable respectively. The percentage of specific growth rate (SGR) per day for Pangas (*Pangasius hypophthalmus)* was 2.57, 1.27 and 2.36 but it was found to be 0.822, 0.795 and 0.438 for Tilapia (*Oreochromis mossambicus*) in ponds 1, 2 and 3 respectively. For both fishes, the highest growth was found in pond 1. The production from each raft for *pudina*, water spinach and okra was about 266.7, 333.3 and 66.7 g respectively. Only *pudina* production was well enough to get benefit from raft vegetable culture and benefit-cost ratio of *pudina* production was about 7.82. In the study period giant taro showed good growth. Fruits and flowers were observed in Indian spinach-red and brinjal respectively at the end of the study period. Brinjal plants was affected by disease and tomato plants did not survive in the pond condition due to algae and other fouling clog on the roots which prevented nutrients up take from the pond water.

**Key words:** Aquaponics · Feasibility · Polyculture · Cost-Benefit Ratio · Infection and Fouling

## INTRODUCTION

Fisheries sector, contributes about 3.74 % to GDP, play a vital role in boosting the socio-economic development of Bangladesh [1-3] and aquaculture is currently playing a big part in meeting the increasing demand for fishery products [4, 5]. Like all other food production process, aquaculture is also facing challenges for sustainable development. Recently, Food and Agriculture Organization (FAO) has emphasized on enhancement of fish production through integrated aquaculture-agriculture farming systems. In this case practices of aquaponics can partially be a good option for sustainable aquaculture development. Aquaponics is a bio-integrated system that links recirculating aquaculture with hydroponic vegetable, flower and /or herb production to serves as a model of sustainable food production. Water is reused through biological filtration and recirculation. A great potential for aquaponics to fill the void seen in many third world countries where adequate protein sources and vegetables are not available for consumption due to droughts, poor farming techniques and other effects of cultural poverty causing a chronically malnourished population. In addition, the potential for providing food for marketing, thus increasing income and sense of self reliance, is also great for this technology [6]. Developed countries concerns about pollution issues have raised interest in aquaponics system as a valid option to get rid of aquaculture wastes through the production of high value vegetables [7, 8]. In Bangladesh growing problems with, increasing demand of nutrition for the growing population and lack of available land for increasing cultivation, can be solve with integration of culture system by using same resources in

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the production of more than one crop. Aquaponics is one of the ways of using aquaculture site for the production of vegetables also and that may help to overcome the increasing demand of nutrition. The objectives of the present study is to minimize investment capital and operation costs while concurrently maintaining stable, reliable, economically sound food production through fish culture.

## MATERIALS AND METHODS

**Pond Selection and Preparation:** Three experimental ponds, with an area of 5.84, 3.14 and 3.14 decimal, were selected for the present study. Ponds were dried for one week after draining the water completely. Then liming was done with at the rate of 275 kg/ha. Inlet and overflow pipes were covered with screen nets during water intake to prevent wild fish. The fertilization rate by CRSP (Collaborative Research Support Program) methods was 28 kg N/ha/week and 7 kg P/ha/week, giving N: P ratio of 4:1.

**Fish Stocking and Feeding:** Pangas and tilapia fingerlings were collected from local hatchery of Mymensingh. Stocking size of pangas and tilapia was 9.1± 0.26 cm and 6.5±0.33 g and 10.2±0.56 cm and 56.3±0.54 g respectively. Pangas and tilapia were stocked in all ponds at the rate of 33,650 and 16,000 fingerlings per hectare respectively. Acclimatized the fish for 30 minutes and gently released the fish into pond. The floating feeds were supplied twice daily at the rate of 5% of the body weight during the first month and then the feeding rate was reduced 3% for the 2nd and 3rd month. Raft was prepared with locally available and low cost materials.

**Preparing Rafts and Planting Vegetables:** The materials used in preparing rafts were bamboo splits, iron wire, plastic thread and disposable plastic water bottle. Bamboo splits were tied with wire to make frame of raft which is 35 $ft^2$ (length=7ft and width = 5ft) in area. Disposable plastic water bottles were used as float in raft; they were tied parallel to the bamboo splits with plastic thread. Each raft contained 20 slots to planting vegetables. Three rafts was used in pond 1 which covered about 4.12% of the total pond area and only one raft used in pond 2 which covered about 2.56% of the total pond area. Sixty saplings were used in 3 rafts in pond 1 and 20 saplings were planted in pond 2. This study was conducted in the month from September to November hence vegetables like okra, water spinach, *pudina*, *brinjal*, tomato and Giant taro were planted in the raft. Some *puishak* was also planted in 2nd pond. Coconut husk and break-lets were used as substrate in the bottle. Several pores were made in the bottle for passing the plant roots into the water.

**Fish Sampling:** Sampling was done at an interval of one month by using cast net to adjust the feeding rate by measuring the length (with an ordinary scale) and weight of fish (by a sensitive portable electronic balance, Model AK- 3000H AFD) and to observe the health condition.

**Physicochemical Parameters of Water:** Temperature, $NH_4/NH_3$, $NO_3$, $NO_2$, $PO_4$, pH and dissolve oxygen were measured every 15 days interval. Chemical test kits were used to test the physico-chemical parameters. A hand held thermometer was used to measure the water temperature of the pond.

## RESULTS AND DISCUSSION

**Fish Growth:** The growth parameters of pangasius and tilapia in different ponds in terms of weight gain, length gain, % weight gain, % length gain, SGR % per day, survival (%) and production (kg/ha/90 days) were calculated (Table 1). Growth of pangasius and tilapia indicated that the growth rate varied in different ponds. Pond 1 showed significantly highest growth and survival rate among all the ponds. % SGR per day of pangasius in pond 1, 2 and 3 were respectively 2.57, 1.27 and 2.36 that means the highest growth of pangasius found in pond 1. In case of tilapia % SGR per day were found 0.822, 0.795 and 0.438 for the ponds of 1, 2 and 3 respectively.

**Vegetable Production:** Rakocy *et al.* [9] developed commercial-scale aquaponics systems that have been raised Basil, lettuce, okra and other crops successfully with outstanding quality and yields. In the present experiment a chart of analysis of raft vegetable production in experimental pond 1 and 2 is given in Tables 2 and 3; which showed that there was similarity in vegetable production in both the ponds. Some *brinjal* plants gave flowers only but no fruits were seen due to disease. Tomato plants did not survive in the pond condition due to algae and other fouling clog on the roots which block the nutrients up take from the pond water.

**Water Quality Parameter:** In pond 1, $NH_4/NH_3$ concentration was $0.5 mgl^{-1}$ in the 1st month of culture and in the later months the level was found $0 mgl^{-1}$. In pond 2, the concentration was found $0.5\ mgl^{-1}$ only in the last month otherwise it was $0\ mgl^{-1}$. In pond 3, first 2 months

Table 1: Growth parameters of pangas and tilapia in three different ponds

| | Pangasius | | | Tilapia | | |
|---|---|---|---|---|---|---|
| Parameters | Pond 1 | Pond 2 | Pond 3 | Pond 1 | Pond 2 | Pond 3 |
| Mean initial length(cm) | 9.1±0.26 | 10.2±0.56 | | | | |
| Mean final length (cm) | 18.4±0.65 | 13±0.70 | 14.5±0.28 | 16±0.6 | 17.4±0.53 | 15.8±0.34 |
| Mean length gain (cm) | 9.3±0.33 | 3.9±0.47 | 5.4±0.23 | 5.8±0.45 | 7.2±0.37 | 5.6±0.65 |
| % length gain | 102.2±2.34 | 42.85±2.34 | 59.34±2.34 | 56.86±1.37 | 70.6±1.37 | 55±1.37 |
| Mean initial weight (g) | 6.5±0.33 | 56.3±0.54 | | | | |
| Mean final weight (g) | 65.41±0.35 | 20.3±0.53 | 54.2±0.28 | 118±0.34 | 114.7±0.54 | 83.53±0.34 |
| Mean weight gain (g) | 58.91±0.56 | 13.8±0.65 | 47.7±0.23 | 61.7±0.56 | 58.4±0.43 | 27.23±0.28 |
| % weight gain | 906.3±2.57 | 212.35±2.07 | 733.85±1.57 | 109.6±2.34 | 103.73±2.23 | 48.37±1.87 |
| % SGR per day | 2.57±0.0014 | 1.27±0.0013 | 2.36±0.0014 | 0.822±0.0012 | 0.795±0.0023 | 0.438±0.0013 |
| Survival rate (%) | 95±1 | 90±1 | 80±2 | 95±1 | 90±2 | 90±0 |
| Production (kg/ha/90 days) | 2091.3±0.001 | 614.8±0.01 | 1459.1±0.002 | 1793.6±0.001 | 1651.7±0.001 | 1202.8±0.002 |

Table 2: Vegetable production in pond 1 during experimental period

| Plant type | Number of plantation | Percentage of plantation (%) | Number of harvest | Production (g) |
|---|---|---|---|---|
| Water spinach | 16 | 26.67 | 3 | 1000 |
| Pudina | 16 | 26.67 | 1 | 800 |
| Okra | 10 | 16.67 | 1 | 200 |
| Giant taro | 12 | 20 | Nil | Yet to harvest |
| Tomato | 2 | 3.33 | Nil | No production |
| Brinjal | 4 | 6.67 | Nil | No production |

Table 3: Vegetable production in pond 2 during experimental period.

| Plant type | Number of plantation | Percentage of plantation (%) | Number of harvest | Production (g) |
|---|---|---|---|---|
| Water spinach | 4 | 20 | 3 | 250 |
| Pudina | 4 | 20 | 1 | 200 |
| Okra | 4 | 20 | 1 | 80 |
| Giant taro | 4 | 20 | Nil | Yet to harvest |
| Indian spinach (red) | 4 | 20 | Nil | Yet to harvest |

Table 4: Cost of raft preparation with planting materials

| Materials | Amount | Cost (Tk*) |
|---|---|---|
| Bamboo | 3 pieces | 270 |
| Metal wire | 1.5 kg | 60 |
| Bottle (float) | 320 pieces | 530 |
| Bottle (planting pot) | 100 pieces | 250 |
| Bricks (for brick lets) | 12 pieces | 36 |
| Coconut fiber | 3 kg | 60 |
| Total cost | ••••• | 1,206 |
| Cost of preparation of each raft | ••••• | 241.2 |

*1 Tk = 0.013US$

Table 5: Projected cost of raft vegetable from 1 ha pond area

| Percentage of pond | 25% | 50% | 75% |
|---|---|---|---|
| Pond area covered | 26,943 $ft^2$ | 53,885 $ft^2$ | 80,828 $ft^2$ |
| Raft required | 770 | 1,540 | 2,309 |
| Number of sapling | 15,400 | 30,800 | 46,180 |
| Cost of raft | 185,724 Tk | 371,448 Tk | 556,931Tk |
| Types of seed | Water spinach | Pudina | Okra |
| Cost of seed | 1,540 Tk | 914 Tk | 4,618 Tk |
| Total cost | 187,264 Tk | 372,362 Tk | 561,549 Tk |

Table 6: Production from raft vegetation in different percentage of pond area covering for 1 ha pond

| | Water spinach | | Pudina | | Okra | |
|---|---|---|---|---|---|---|
| Plant name | Kg/ha/90days | Tk/ha/90 days | Kg/ha/90Days | Tk/ha/90 days | Kg/ha/90days | Tk/ha/90 days |
| 25% pond area covered | 5,133 | 76,992 | 4,107 | 1,642,872 | 1,027 | 20,535 |
| 50% pond area covered | 10,266 | 153,985 | 8,214 | 3,285,744 | 2,054 | 41,069 |
| 75% pond area covered | 15,399 | 230,977 | 12,322 | 4,928,616 | 3,080 | 61,604 |

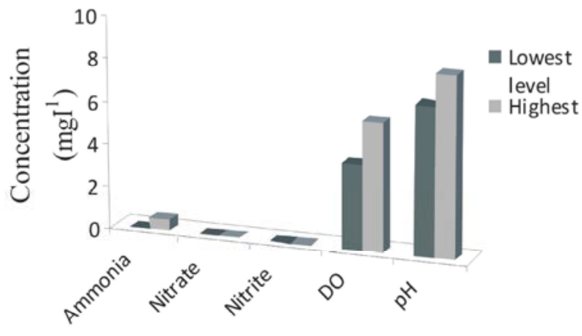


Fig. 1: Concentration range of Ammonia, Nitrate, Nitrite, DO and pH

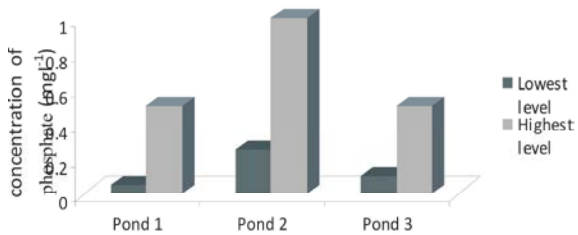


Fig. 2: Concentration range of phosphate in different ponds.

the concentration of ammonia was recorded 0.5mgl$^{-1}$ and in last month it was 0mgl$^{-1}$. In 3 experimental ponds ammonia concentration was in the range of 0-0.5 mgl$^{-1}$ which is in the tolerable limit for the fish. $NO_3$ and $NO_2$ concentration was zero (0) throughout the experimental period in all the ponds (Fig. 1). Steve and Rinehart [10] stated that fish raised in recirculating tank require good water quality. Critical water quality parameters include dissolved oxygen, carbon dioxide, ammonia, nitrate, nitrite, pH, chlorine and other characteristics. The stocking density of fish, growth rate of fish, feeding rate and volume and related environmental fluctuations can elicit rapid changes in water quality; hence, constant and vigilant water quality monitoring is essential.

$PO_4$ level varied during the experimental period and it was in between 0.05-1.0 mgl$^{-1}$. In the experimental ponds phosphate concentration was found higher in pond 2 and 3.The concentration was in between 0.05-0.5 mgl$^{-1}$ in the pond 1 that was in the lowest level (Fig. 2).

Boyd [11] stated that tolerable limit of $PO_4$ is 0.005-0.2 mgl$^{-1}$ which is good for pond aquaculture. This variation in the phosphate concentration might be the cause that hampered and made difference in fish production. Temperature of water during the experimental period was in between 29-35°C. Average daily water temperature in September, October and November was 31.8°C, 32.6°C and 31.2°C respectively. DeLong *et al.* [12] found that at a temperature range of 27 to 29 °C, tilapia grow at optimal rates.

**Cost-Benefit Analysis of Raft Vegetation:** Cost of floating raft preparation and planting materials include the cost of bamboo, metal wire, floating bottle, planting pots, brick-lets, coconut fiber etc. The cost of making 5 rafts for this experiment is given in the Table 4. Cost of making raft is calculated about 241.2 Tk. Sapling cost is taken in account as 1 Tk for 10 saplings of water spinach and okra. Each kg of *pudina* was calculated 400Tk.

In the experimental period the production from each raft of pudina, water spinach and okra was about 266.7 gm, 333.3 gm and 66.7 g respectively. The cost of raft vegetable in 1 ha pond for different pond area covering with the raft is given in the Table 5.

Production of water spinach, pudina and okra from 1 ha pond area is given in the Table 6. Here market price of water spinach, pudina and okra is assumed as 15 Tk, 400 Tk and 20 Tk respectively.

Ghaly *et al.* [13] stated that high-value vegetable crops, such as tomato, lettuce, cucumber and sweet basil have cultured in hydroponics media. It is more desirable to grow high priced crops such as herbs to get the best profit per unit area of hydroponics bed. Production attained in this experiment showed that only pudina production is profitable from raft vegetable culture and benefit-cost ratio for pudina production was about 7.82.

## CONCLUSION

The present research is conducted to assess the feasibility of raft based aquaponics in poly culture pond with the objectives of utilizing the resources more efficiently. The study was conducted in three ponds where pangasius and tilapia were stocked in all ponds. Pond 1 and pond 2 were covered with 4.12% and 2.56% of raft vegetable culture respectively. Pond 3 kept as a control. Record of water quality parameters were taken in every fifteen days interval. Water spinach, pudina and *brinjal* production was calculated as 266.7 g, 333.3 g and 66.7 g respectively at the end of the culture period from each raft. Only *pudina* production was profitable from raft vegetable culture and benefit-cost ratio for pudina production was about 7.82. On the other hand, highest growth of pangasius and tilapia were found in pond 1 where % SGR per day was respectively 2.57±0.0014 and

0.822±0.0012. Overall cost could be minimized by using unused and locally available materials and considering one year life time of raft vegetation that is 3 to 4 production cycle in a year from each raft. Intensification of culture system and well pest management scheme also improve the production of the vegetables.

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