Water quality dynamic, production and profitability of catfish, *Clarias* sp. cultured at different design construction of aquaponic

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**Abstract.** Aquaponic is an integrated culture between fish and plant. This technology is eco-friendly, social and economic accepted by fish farmers. Recently, aquaponic is very popular in Indonesia. The study aims to determine water quality dynamic, catfish and vegetable production, and profitability at different design construction. The different of design constructions as a treatment were as followed: A) aquaponic bed and B) aquaponics bucket. The result showed that water quality dynamic both of two types such as dissolved oxygen (DO) concentration showed decreased but nitrite, nitrate, total ammonia (TAN), and phosphate concentrations were increased with increasing culture period which aquaponic bed was better than that of aquaponics bucket. The removal efficiency of nitrite, nitrate, TAN, and phosphate at aquaponic bed were higher than that of aquaponics bucket. Growth, survival, and biomass both of catfish and vegetable (water spinach) at aquaponic bad were higher than that of aquaponics bucket (P<0.05). The profitability of aquaponic bed was better than that of aquaponics bucket. Design construction and aquaponic bed seemed to be suitable, benefit, and easier to manage at the time for cleaning and harvesting.

1. Introduction

Water pollution is the main problems in developing countries including Indonesia. This condition caused by wastewater from industry, settlement, and other anthropogenic activity has discharged directly into water surface which affect the aquatic organism and human health[1]. On the other hand, crops protection using pesticide (e.g. insecticide, moluscicide, and fungicide) have been applied many times in order to maximize crops production [2]. In addition to an intensive aquaculture system has also influenced to the aquatic environment[3].

Catfish (*Clarias* sp.) culture is commonly cultured at high stocking density in Indonesia. The advantages of catfish culture are easy to culture, tolerant to extreme environment, high stocking, fast growth, and high market demand. Thus, this species is one of freshwater species which used for food security, besides tilapia, and common carp[4]. Therefore, an intensive system has been applied to fulfill the market demand. The fish farmer believes that intensive culture system can increase fish produce and profit. However, an intensive culture system has resulted in the high waste-by product which high containing nitrogen and phosphor elements that obtained from feces, urine, and uneaten food. The negative impact of the waste-by product from aquaculture activity to environmental aquatic are, eutrophication (algae bloom), some of the nitrogen compound (i.e. ammonia and nitrite) are toxic
to aquatic organisms including fish [5]. Therefore, the aquaculture technique is low waste, water conserve, and land limited is needed in terms of aquaculture sustainability.

Recently, Aquaponic technology is the one of aquaculture system which eco-friendly and profitable. Aquaponic is an integrating farming system between fish and plant. The advantages of linking crop production and the culture of fish are shared startup, operating, and structure cost; recirculation tank waste nutrient and removal by plants, thus reducing water usage and waste discharge to the environment; and increased profit potential by simultaneously producing two cash crops [6]. Vegetables are produced by aquaponic system free pesticide and artificial fertilizer, thus it is good for human health [7]. The design construction of aquaponic should have a balance between fish and plant to increase production [8]. There is a lot of aquaponic design construction have been made in the world but the information of successful fish and plant production which related to design construction of aquaponic is still lack. The build of aquaponic construction have to consider the materials used is chip and easy to get anywhere, and the materials usage are not containing toxic agent. The objective of this experiment is to determine the water quality dynamic, fish performances, plant production, and profitability in relation to different design construction.

2. Materials and methods

2.1. Time and experiment location

The experiment was conducted from April to August 2017 at Research Station for environment Technology and Toxicology Freshwater Aquaculture, Cibalagung, Bogor, West Java, Indonesia. Research Institute for Freshwater Aquaculture and Fishery Extension, Bogor, West Java, Indonesia.

2.2. Catfish culture

Catfish, *Clarias* sp. with 7.50±0.82 cm in total length and 2.72±0.53 g in body weight was used. Stocking density was 1000 fish/m³. Artificial diet was fed 5%/day/biomass. Catfish was cultured for 100 days. Six of concrete ponds which size of 2 m length x 2 m width x 1 m depth each were used. All pond was completed by aeration and aquaponic unit which depended on the treatment. Ten fish were taken as a sample to measured length and weight gains every ten days.

2.3. Aquaponic design constructions

Two design construction of aquaponic were set up namely bucket and bed design. Fish pond with 12 buckets (bucket with a volume of 15 L as a plant container) aquaponic unit was completed by settling tank as a physical filter using 100 L plastic barrel and two bucket with volume of 50 L (containing bioball) as a biological filters were placed on the left and right sides (Figure 1). In bucket aquaponic unit containing 24 buckets (equal to 360 L). Fish pond with bed aquaponic unit was completed by aeration and four plastic barrels which two plastic barrels as physical filters and the others for biological filters that containing bioball (Figure 2). Fiber tank with the size of 1.5 m length x 1 m width x 0.24 m depth (equal to volume of 360 L) was used as a plant container. A physical filter containing lime stone with a diameter of 4-5 cm was placed on the bottom, thereafter gravel stone with a diameter of 2-3 cm. Concrete pond with the size of 4 m length x 2 m width x 1 m depth was used as catfish culture. Wood charcoal with a diameter of 2-3 cm was used for substrate medium of plant grow.
Figure 1. Layout of bucket aquaponic unit

Figure 2. Layout of bed aquaponic unit
2.4. Vegetable plants
The vegetable plants such as water spinach, caisim, and tomato were used. Three kinds of seedling vegetables with of 6-7 cm height were planted. The number of vegetable namely 24 seedlings for caisim and tomato while 24 clumps of water spinach (one clump consisted of 15 seedlings) were used for one unit of aquaponic.

2.5. Data parameters observed
Data of biological performances of catfish such as survival, biomass, and vegetable production were observed. Feeding conversion ratio was also observed. Water quality parameter such as temperature, dissolved oxygen, total ammonia (TAN), nitrite, nitrate, and phosphate, and total organic matter (TOM) was monitored from day 0 to day 20 where next monitored was conducted every 5 days. To measure temperature, pH, and DO using water checker was applied. The others water quality parameter was analyzed at the laboratory based on the procedure of SNI [9][10][11].

Survival rate was calculated based on formula:

\[ SR = \left( \frac{N_t}{N_0} \right) \times 100\% \]  
(1)

Where:
SR = Survival Rate (%)
Nt = Number of fish by the end of experiment

Biomass of fish was calculated using formula:

\[ B = W \times N \]  
(2)

where:
B = Biomass
W = Average of weight (g)
N = Number of population at the end of experiment

Removal efficiency (RE) was calculated based on formula:

\[ RE \% = \frac{C_{inlet} - C_{outlet}}{C_{inlet}} \times 100 \]  
(3)

where:
RE = Removal efficiency (%)
C_{inlet} = Concentration of pollutant inlet (mg/l)
C_{outlet} = Concentration of pollutant outlet (mg/l)

2.6. Statistical analysis
The treatment of this experiment consisted of two treatments which bucket and bed aquaponic design constructions as a treatment with three replications. Data of survival, length, weight, FCR, and biomass of catfish and vegetable production were analyzed using \( t \) test. Water quality parameters were analyzed using descriptive.

3. Results
3.1. Water quality dynamic and removal efficiency
Water quality parameters such as temperature, pH, dissolved oxygen (DO), total ammonia (TAN), nitrite, nitrate, phosphate, and total organic matter (TOM) on the fish pond during culture period between bucket and bed aquaponic design constructions are presented in Figure 3. The removal efficiency of TAN, nitrite, nitrate, and phosphate during the culture period are presented in Figure 4.
Figure 3. Water quality dynamic such as Temperature, DO, pH, TAN, nitrite, nitrate, phosphate, and TOM observed during culture period between bucket and bed aquaponic design constructions.

Figure 4. The percentage of removal efficiency of TAN, nitrite, nitrate, and phosphate between bucket and bed aquaponic design construction during the culture period.
Water quality dynamic such as temperature was almost the same pattern both of bucket and bed aquaponic but pH value at bucket aquaponic showed decreased by the end of the culture period. Dissolved oxygen (DO) whether bucket or bed showed a decrease at the end and DO at bucket aquaponic was lower than that of bed aquaponic. TAN, nitrite, nitrate, phosphate, and TOM at bucket aquaponic showed increased with increasing culture period while at bed aquaponic TAN and Phosphate relative constant and nitrite showed decreased by the end of the experiment, except for nitrate was increased on day 6 up to day 30, thereafter declined and it showed lower than bucket aquaponic. It was clear that water quality such as TAN, nitrite, phosphate, and TOM at bucket aquaponic was higher than that of bed aquaponic (Figure 3). This indicated that bed aquaponic design construction was better than that of bucket aquaponic in term of water quality. Bed aquaponic design construction was higher in related to nitrate compared to the bucket.

All data of removal efficiency such as TAN, nitrite, nitrate, and phosphate (Figure 4) showed that bed aquaponic design construction was higher than that of the bucket. This indicated that bed aquaponic design construction was better than that of the bucket.

3.2. Catfish performances and vegetables production

Survival, final length and weight, feeding conversion ratio (FCR), feed usage, and biomass of catfish is presented at table 1. Vegetables such as water spinach, caisim, and tomato production are presented in Figure 5.

**Table 1.** Survival, final length and weight, FCR, feed usage, and biomass of catfish, *Clarias* sp cultured between bucket and bed aquaponic design construction.

| Parameters          | Aquaponic       |
|---------------------|-----------------|
|                     | Bucket | Bed       |
| Initial Length (cm) | 7.50±0.82 | 7.50±0.82 |
| Final Length (cm)   | 24.11±1.74 | 25.32±1.56 |
| Initial Weight (g)  | 2.72±0.53 | 2.72±0.53 |
| Final Weight (g)    | 86.57±1.82a | 89.57±1.12b |
| SR (%)              | 77.39±1.1a | 80.44±1.03b |
| FCR                 | 1.1±0.7a | 1.14±0.5a |
| FEED (Kg)           | 443.85±3.2a | 482.9±3.6b |
| Biomass (Kg)        | 403.5±5.4a | 423.6±8.9b |

Remarks: Value followed the same letters are not significantly different (P>0.05).

Catfish cultured at bed aquaponic design construction was better than that of the bucket in term of weight, survival, and biomass even if the feed usage was higher than that of the bucket.
Vegetable production at bed aquaponic design construction such as water spinach (4.86±0.78 Kg) and caisim (3.42± 0.44 Kg) was higher than that of water spinach (3.00±0.52 Kg) and caisim (2.67±0.19 Kg) at bucket design construction (P>0.05). Tomato cultivated at bed aquaponic was also higher than that of the bucket but not significantly different (P>0.05). This indicated that bed aquaponic was suitable for leaf vegetable.

3.3. Profitability between two aquaponic design constructions
Profitability of catfish cultured between bucket and bed aquaponic design constructions are shown in Table 2.

Table 2. Benefit-cost of catfish, *Clarias* sp cultured between bucket and bed aquaponic design construction

| No. | Description                | Volume | Unit | Price (IDR) | Total     |
|-----|----------------------------|--------|------|-------------|-----------|
| I   | Production cost            |        |      |             |           |
| 1   | Seed                       | 4500   | Fish | 150.00      | 675,000.00|
| 2   | Artificial diet            | 443.85 | Kg   | 10,000.00   | 4,438,500.00|
|     | Total                      |        |      |             | 5,113,500.00|
| II  | Income                     |        |      |             |           |
| 1   | Fish Yield                 | 403.5  | Kg   | 15,000.00   | 6,052,500.00|
| 2   | Vegetable yield            |        |      |             |           |
|     | Water spinach              | 9      | Kg   | 10,000.00   | 90,000.00 |
|     | Caisim                     | 8      | Kg   | 10,000.00   | 80,000.00 |
|     | Tomato                     | 9.36   | Kg   | 15,000.00   | 140,400.00|

Figure 5. Vegetables production such as water spinach, caisim, and tomato cultivated between bucket and bed aquaponic design constructions
Benefit-cost between bucket and bed aquaponic design constructions were almost the same even if the bed was slightly benefit from bucket with the margin of 28,600 IDR.

4. Discussion

4.1. Water quality dynamic and removal efficiency

Water quality is a critical factor when culturing any aquatic organism. Optimal water quality varies by species and must be monitored to ensure growth and survival. The quality of water in the production system can significantly affect the organism health and costs associated with getting of product. The present experiment shows that some of water quality parameters such as DO, TAN, and nitrite concentrations at bucket aquaponic were beyond the optimal range. The DO affect the growth and survival, the DO with less than 1 mg/L is the death of fish, 1-3 mg/L has a sublethal effect on growth and feed utilization less than 4 is slow growth, and more than 14 mg/L is gas disease occurs[12]. The catfish and other air-breathing fishes can survive in low DO concentration of 4 mg/L[13]. The present experiment shows that catfish, *Clarias* sp cultured at bucket aquaponic was below 1 mg/L up to day 100 but the fish were still surviving even if low in growth and survival than that of catfish cultured at bed aquaponic (Figure 3). Ammonia and nitrite are toxic for fish where nitrite is more toxic. Ammonia is the by-product from protein metabolism excreted by fish and bacterial decomposition of organic matter such as wasted food and feces. Ammonia (NH3+) is extremely toxic while the ionized form NH4+ is not and both of the forms are grouped together as a total ammonia (TAN). Nitrite is an intermediate product of the aerobic nitrification bacterial process. Produced by autotrophic bacteria (e.g. *Nitrosomonas* sp) combining oxygen and ammonia [12] Moreover, > 1 mg/L nitrite concentration is lethal and > 2 mg/L is acceptable. The present experiment shows that nitrite concentration at bucket aquaponic was > 0.1 mg/L and bed aquaponic was < 0.1 mg/L (Figure 3). Whether bucket or bed aquaponic are beyond the optimal range, although catfish at bed aquaponic is better than that of bucket aquaponic. This can be explained that growth and survival at bucket are low. The nitrite in the water should not exceed 0.5 mg/L. [13]. Therefore, the present experiment shows the catfish cultured both bucket and bed aquaponic are still surviving and grow. Suggesting that such concentration may be still within in tolerate range for catfish culture. The increase of TAN, nitrite, nitrate, phosphate, and TOM by the end of the experiment may be accumulated of the feces and uneaten food increase with
increasing culture period. Water quality at bed aquaponic is better than that of the bucket, suggests that the design construction may affect the water quality. It is clear that bed aquaponic has completed by two physical filters and the placement of the two biological filter tanks are placed after aquaponic bed. This design may also affect the water quality. It seems that the bucket aquaponic is not sufficient in term of reducing such pollutants. The system design, materials construction, and placement of the components of physical and biological filter tanks is correlated to the purification of pollutants in the aquaponic which recirculating system [8].

Removal of pollutant by biofilter and aquaponic has an indicator of the system that system is good during the operation[14]. The present experiment shows that bed aquaponic is higher in term of removal such pollutants than that of bucket (Figure 4), suggesting that bed aquaponic is more efficient in absorbing the nutrient where the nutrient passed through aquaponic area compared to bucket. If the water passes through aquaponic container, it should enough the flow, retention time, and the distribution of water when entering the aquaponic area must be the same portion. This condition in order to the pant has a time for absorbing the nutrient [8].

4.2. Catfish performances and vegetables production
Catfish performances such as survival, growth of length and weight, and biomass at bed aquaponic is better than that of bucket. This suggests that design aquaponic construction affect the water quality which influenced fish growing and surviving. The design construction has also affected the vegetables production. This can be proved that bed aquaponic shows better in water quality parameter and it has produced nitrate concentration and removal efficiency (Figure 3 and 4) are higher than that of bucket. Thus, vegetable plants can growth maximize due to optimal they absorb the nutrient such as nitrate and phosphate.

4.3. Profitability between two aquaponic design constructions
The design construction, ration between fish and plant, fish and plant species usage, materials utility of aquaponic, and rearing management, component system, and scale have been influenced the benefit-cost[15]. The present experiment shows that benefit-cost between bed aquaponic and bucket is almost the same (Table 2) even if the bed aquaponic has a margin about Rp. 28600. The slightly of benefit caused by the food usage where the price of an artificial diet is expensive. This factor can affect the profitability, although the biomass of catfish and vegetable production are higher at bed aquaponicdue to artificial diet used at bed aquaponic is higher compare to bucket, thus this condition affects the benefit-cost.

5. Conclusion
Bed aquaponic design construction is better than that of bucket in term of water quality, removal efficiency, catfish performance, and vegetable production. Benefit-cost has also bed aquaponic is better than that of bucket but it is not clearly the margin between bed and bucket aquaponic constructions.

6. References
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