Application of aquaponic ebb-tide system on tilapia (*Oreochromis niloticus*) and cyprinid (*Cyprinus carpio*) to optimize growth performance

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Abstract. The purpose of this study was to optimize the growth performance of tilapia (*Oreochromis niloticus*) and cyprinid (*Cyprinus carpio*) through aquaponic ebb-tide system. This study used a completely randomized design with 3 treatments and 3 replications: (a) aquaponic with tilapia, (b) aquaponic with cyprinid, (c) tilapia without aquaponic and (d) cyprinid without aquaponic. Water spinach used in this aquaponic system because it have the highest inorganic nitrogen reduction value in ammonia, nitrite and nitrate. The range of initial fish weight were 4-5 g and 6-7 cm length, with 1600 fish/concrete pond (sized 4x2 m²). The research was conducted for 50 days at the Center for Production, Inspection and Certification of Fishery Products, Ciganjur Jakarta. The observation variables included fish biological performance, water physico-chemical parameters and Total N analysis on water spinach. The result showed that the highest average weight was found in treatment (a) 107.14±0.14g with daily growth rate of 14±0.043 g. The survival rate between treatments (a) and (b) was not significantly different (P>0.05), respectively 88.70±0.60 and 83.08±0.55. Water spinach biomass of two harvests from 3 replications were 100.04kg (a) and 93.57kg (b). While the absorption percentage of Total N in water spinach were 35.63% for treatment (a) and 34.25% for treatment (b).

Keywords: aquaponic ebb-tide; cyprinid; tilapia; water spinach plants

1. Introduction

Metabolic processes that occur in fish bodies such as the accumulation of waste from feed residues and metabolic products that play an important role in productivity and survival on aquaponic system are influenced by various factors, including: water discharge, substrate, types of aquatic plants, harvesting time and plant density [6]. Aquaculture waste is generally in the form of suspended solids and dissolved nutrients, especially nitrogen and phosphorus. The accumulation of organic waste has the potential to increase ammonia levels and decrease the oxygen solubility furthermore can affect the nitrification process. Ammonia is a metabolic waste that is directly toxic to fish and the result of catabolism of feed protein, which is excreted around 60-80% by fish into the aquatic environment [1].

Aquaponics is one of the aquaculture systems that can reduce toxins in the culture media by maintaining water quality for a certain period time without disturbing the growth of cultured fish by using plants as biofilters. To substitute the value of wasted feed, the aquaponic ebb-tide system innovation is believed to be growing rapidly to overcome water quality problems. The principle of this system is to recycle waste from aquaculture activities produced by fish into a source of energy and

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nutrients for other commodities [19] so as to produce byproducts that can be harvested and can reduce environmental impacts [13]. Aquaponic ebb-tide system designed with a water supply regulation on the principle of a vacuum pump. When the water in the plant media has reached a certain height, the water will automatically be wasted back into the pond, then the water rises and falls again and so on. Technically, the aquaponics system will be able to increase the production capacity of fish farmers. The placement of vegetable plants on pond side so that the waste from the nutrient-rich fish pond can be converted into plant biomass which can be added value in production, as well as a biofilter to remove ammonia waste, so that the condition of the pond water media remains suitable for the growth and survival of fish cultured. Vegetable plants in the context of aquaponics are seasonal plants that produce leaves, for example water spinach, which functions to transform metabolic waste from intensive aquaculture as an organic fertilizer for plants [20] and reuse wastewater after through the biofiltration process [22]. The use of water spinach in the aquaponic system can reduce ammonia by absorbing aquaculture waste using plant roots [4].

The selection of freshwater fish commodities for business needs should be selected for the types of fish that meet several criteria such as being able to be stocked with high density, fast growing, resistant to water quality conditions and have economic value. In tilapia fish meat has a high protein nutritional value [11]. According to Setijaningsih and Gunadi [14], to increase the production, tilapia culture should carried out intensively which characterized by highly stocking density and high protein feed content. Meanwhile, the cyprinid (Cyprinus carpio L.) is a freshwater fish commodity with the highest production and cultivated commercially in all provinces in Indonesia [12]. The cyprinid has a very high tolerance to the environment media [18]. However the research of the application of the aquaponic ebb-tide system on the culture of tilapia and cyprinid to optimized growth performance never been done. The research objective was to determine the optimization of the aquaculture production of tilapia and cyrinid in aquaponic ebb-tide system.

2. Method

The research was carried out at the Center for Production, Inspection and Certification of Fishery Products in the Ciganjur area, South Jakarta. The research used 2x4x1 m3 concrete pond and designed with an aquaponic ebb-tide system. The aquaponics ebb-tide system consisted of a water pump and an ebb-tide container that functions to distribute water to all connected plant media containers. The water flow mechanism was regulated by an "automatic siphon" which works on the principle of a vacuum pump. When the water in the planting medium has reached a certain height, the water will automatically be disposed of back into the pond, then it goes up and down again and so on. The plant media container was consisted of a 10 liter plastic bucket and connected with a PVC pipe. Plant substrates consisted of split stones and fern roots. Furthermore, the fish pond and plant substrate container were formed into a connected aquaponic ebb-tide systems (Figure 1).

The tested fishes were tilapia (Oreocromis niloticus) and cyprinid (Cyprinus carpio) with an average weight of 4-5 g and average length of 7-9 cm, were stocked with a density of 1600 fish/pond. The plant used was water spinach. The research treatments were: (a) aquaponic with tilapia, (b) aquaponic with cyprinid, (c) tilapia without aquaponic, and (d) cyprinid without aquaponic. The researches were conducted for 50 days. During culture, tilapia and cyprinid were fed with artificial feed with 5% of the fish biomass/day with a frequency of 2 times a day, in the morning and in the evening. Water spinach plant (Ipomoea aquatica) seed were 7 cm height and stocked with 7 plants/bucket [17].

Water quality parameters observed for 50 days of culture included: temperature, pH, and dissolved oxygen. Biological fish data (absolute weight gain, survival rate, and daily growth rate) and total N removal rate were evaluated and calculated according to the following formula:

\[
\text{Absolute weight gain (g fish}^{-1}) = \text{Final body weight} - \text{Initial body weight}
\]

\[
\text{Survival rate} \times 100 = \left( \frac{\text{Final number of fish}}{\text{Initial number of fish}} \right) \times 100
\]
Daily growth rate (%) = (Ln final body weight – Ln Initial body weight)/No. of days x 100

Total N removal rate (%) = (Influent-Effluent)/Influent x 100

The sampling of the fish conducted every 10 days on each aquaponic ebb-tide systems. The sampling of water spinach weight conducted every 20 days. The research design used was a completely randomized design (CRD), each treatment with three replications. Data on water quality were analyzed descriptively. Regarding the biological fish data (absolute weight gain, daily growth rate and survival rate) one-way analysis of variance (ANOVA) was used. If there were significant differences among treatments, the analysis was continued with Duncan’s test at a confidence level of 95%.

3. Result and discussion

3.1. Result

3.1.1. Fish growth performance. The application of aquaponic ebb-tide system in the tilapia and cyprinid culture can significantly increase the absolute weight gain, because with this system the pond water medium were maintained. During 50 days of culture with aquaponic ebb-tide system, treatment with water spinach and without water spinach plants obtained the highest absolute weight gain in treatment A of 107.14±0.14g followed by treatment B of 89.85±0.02 g, 71.01±1.00 g for treatment C and 69.98±0.01 g for treatment D (figure 1). The results of the variance analysis showed that the treatments were significantly different (P <0.05).

Aquaponic ebb-tide system used split stone and fern roots as the plant substrate, and the presence of roots in water spinach plants which was thought to be more effective in maintaining water quality because more particles are caught or stuck, thereby increasing the reduction of nitrogen and phosphate, this showed that the balance ecosystem started to appear, where the reduction of waste from fish became a source of energy for plants [3]. The used of aquaponic media in anaerobic and aerobic condition can also provide a place for the growth of bacteria which convert nitrite to nitrate, the form that can be utilized by plant to grow [25].

This result also in lined with the research of Setijaningsih and Suryanigrum [16], that water spinach is more effective in utilizing nutrients, so that it can improve water quality and can increase fish growth [4]. The difference in weight resulted differences in the growth rate of fish. In treatment A reached to
2.14±0.043%; 1.80±0.002% in treatment B then without aquaponics or conventional systems in treatment C and D were 1.46±0.005% and 1.40±0.009%, respectively (figure 2).

The aquaponics ebb-tide system also had a positive effect on the survival of tilapia and cyprinid. The survival rate were in line with weight gain and daily growth rate which indicated a relationship with water quality. The highest survival rate was 88.70±0.60% in treatment A and 83.08±0.55% in treatment B, compared to treatment without aquaponics or conventional at 68.23±0.41% in treatment C and 63.08±0.93% in treatment D (figure 3). The used of water spinach was better than mustard green in relation to the value of specific growth rate, daily growth rate, food conversion ratio, survival rate and fish biomass on aquaponic resirculation system [24].

![Figure 2](image.png)

**Figure 2.** (a) Absolute weight gain, (b) Daily growth rate.

![Figure 3](image.png)

**Figure 3.** Survival rate of tilapia and cyprinid in every treatment during experiment.

3.1.2. Water spinach weight. Water spinach in the aquaponics system functioned as the phytoremediators [5], which was able to reduce ammonia by absorbing cultured wastewater using plant roots [4]. The effectiveness of the system was also indicated by the successful growth of aquatic plants.
This system allows plants to grow by utilizing nutrients from fish culture waste, namely ammonia from food waste and fish metabolic waste. The total weight of water spinach was harvested twice in one cycle of tilapia and cyprinid culture. The highest yields were achieved in treatment A of 100.04 kg and 93.57 kg in treatment B (figure 4).

3.1.3. Total N reduction (%) by water spinach (Ipomoea reptans). The high percentage of nitrogen reduction in tilapia and cyprinid culture media with aquaponic ebb-tide system in each treatment indicated that the lower nitrogen concentration in the fish culture water medium. The results of the calculation of the total N reduction by water spinach plants were obtained at 35.63% in treatment A and 34.25% in treatment B (Table 1). The process of nitrogen reduction in fish culture water media through aerobic and anaerobic conditions, which was the presence of organic nitrogen in the water through the hydrolysis process and the transition from NH$_4^+$-N under aerobic conditions. NH$_2^+$-N is oxidized to nitrite (NO$_2^-$-N) by Nitrosomonas sp and after that to nitrate (NO$_3^-$-N) by Nitrobacter sp. N element is an element that is very important for plant growth because it is an important part of the protoplasm, enzymes, biological catalysts that function to accelerate the growth process. The reduction percentages of TN and TP by water spinach plants that have been done show different results, the results of the average reduction rate of N-Total and P-Total (%) in the treatment of 120 minutes retention time on water spinach plants gave the TN reduction results of 10.54±0.33% and TP 38.24±0.82% [15], the integrated aquaculture of the IMTA system resulted for TN and TP reduction were 32.54% and 47.62%, respectively [14]. Nitrogen uptake by plants played an important role in avoiding the accumulation of nitrate in aquaponic, which was proven that the plant specie had significant influence on nitrogen transformation in aquaponics [23].

![Figure 4. Water spinach eight during culture tilapia and cyprinid with ebb-tide aquaponic at two time harvest.](image)

| Parameter       | Treatment | Concentration (mg L$^{-1}$) | Removal rate (%) |
|-----------------|-----------|-----------------------------|------------------|
|                 |           | Influent | Effluent |                   |
| Total Nitrogen  | A         | 0.7944   | 0.5113   | 35.63             |
|                 | B         | 0.7515   | 0.4941   | 34.25             |
3.1.4. Water quality parameter. Water quality parameter during the experiment can be seen on table 2.

Table 2. Water quality parameter during the experiment.

| No | Parameter                        | Treatment          |
|----|----------------------------------|--------------------|
|    |                                  | A                  |
| 1  | Temperature (°C)                 | 27.50-28.00        |
| 2  | Dissolved oxygen (mg L⁻¹)        | 4.30-5.85          |
| 3  | pH                               | 6.90-7.45          |

The temperature range during tilapia and cyprinid culture in aquaponic ebb-tide system were 27-29 °C. The temperature range was still optimal for the growth rate of tilapia and cyprinid. This was in line with the statement of Khairuman and Amri (2013) [9] which stated that tilapia can grow normally in a temperature range of 14-38 °C and a temperature range of 25-32 °C for cyprinid [5]. Temperature range which tends to change is caused by the weather changing during tilapia and cyprinid culture with aquaponic ebb-tide system. According to FAO (2014) [8], the temperature range for fish and plant culture with the aquaponic systems were 18-30 °C. The results obtained in this experiment were optimal for the growth of tilapia and cyprinid cultured in both aquaponic and conventional ponds.

Dissolved oxygen concentration in fish cultured with an aquaponic ebb-tide system were classified optimal for fish growth. The range of dissolved oxygen concentration during the experiment ranged from 2.95-5.37 mg L⁻¹. This ranged has met the oxygen needs for tilapia fish culture. Kordi (2010) [10] stated that the optimal growth of tilapia culture required an oxygen concentration at least 3 mg L⁻¹. The dissolved oxygen concentration in this experiment was also considered normal for cyprinid culture. Dissolved oxygen concentration in ponds that was optimal for cyprinid growth were >4 mg L⁻¹ [21].

The pH measurement data during the study showed a range between 6.35-7.45 (Table 1). This value were still within a tolerable range for the culture of tilapia and cyprinid. Kordi (2010) [10] stated that the suitable pH value for tilapia culture was 6-8.5. The pH value that tilapia could tolerate was between 5-11. An optimal pH value for cyprinid culture ranged from 6.5 to 8.5 [21]. A high pH value (> 9) will resulted in the decreased of fish growth, while a low pH (<4.5) caused water quality to be toxic to fish, which also can resulted to the decrease of the fish growth.

4. Conclusions
The tilapia and cyprinid culture with an aquaponic ebb-tide system using water spinach plants showed a good growth performance, the daily growth rate were obtained at 2.14% for tilapia and 1.80% for cyprinid, with survival rates of tilapia and cyprinid were 88.70±0.60% and 83.08±0.55 respectively.

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