

Analysis of Aquaponic-Recirculation Aquaculture System (A - Ras) Application in the Catfish (*Clarias gariepinus*) Aquaculture in Indonesia

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Abstract

Water quality and waste management are significant problems for aquaculture in Indonesia, including catfish (*Clarias gariepinus*) aquaculture. A combination of Aquaponics Systems and Recirculating Aquaculture Systems (A-RAS) has been developed to address this problem. This study analyzed A-RAS application for catfish (*Clarias gariepinus*) aquaculture by comparing water quality and production indicators between A-RAS and conventional methods. The results show that temperature, pH, dissolved oxygen, total organic matter, ammonia, nitrate and nitrite in A-RAS technology were 28.0-30.0°C, 6.5-7.9, 3.8-7.8 mg/L, 18.54-24.97 mg/L, 0.12- 0.28 mg/L, 0.12-0.13 mg/L, and 0.04-0.13 mg/L, respectively. Survival Rate, Feed Conversion Ratio, and harvest in A-RAS application were 85.5%, 1.1, and 26 kg/m³, respectively. A-RAS technology can maintain water quality to be reused in cultivation and increase yields by about 13%. Besides, water spinach can be an additional income for farmers.

Introduction

Catfish (*Clarias gariepinus*) is widely cultivated in various regions in Indonesia. Catfish (*C. gariepinus*) aquaculture faces obstacles related to water quality and waste management (Henriksson et al., 2017; Tran et al., 2017). Ineffective water management has made many catfish farmers change their pond water frequently (Panase et al., 2018; Ekasari et al., 2016). This problem has led to an increase in water use for catfish cultivation, making it difficult for catfish farming to develop in areas facing water availability problems. Hence, the limitation of decent water restrains the development of aquaculture in Indonesia.

Along with frequent water changes during the aquaculture process, catfish farmers usually dispose of waste directly into the environment. The waste often causes environmental pollution because it is not treated before disposal. Therefore, the development of aquaculture innovation is fundamentally essential to develop catfish farming in Indonesia into sustainable aquaculture practices.

Various technologies have been developed to solve the water quality and waste management problems in aquaculture (Yi et al., 2018; Pouil et al., 2018; Yamazaki et al., 2018). One of the innovations is the combination of aquaponics systems and recirculation aquaculture systems. The Aquaponics – Recirculation Aquaculture

System (A-RAS) is being developed by the Coastal and Marine Research Center of the University of Brawijaya. The technology's basic principle is to integrate the Recirculation Aquaculture System and the Aquaponics system, which serve as a biological filter system to maintain the water quality in the aquaculture (Maigual-Enriquez et al., 2002; Azaria & Rijn 2018; Badiola et al., 2018). The A-RAS is developed to maintain the water quality so that it can be reused. The technology will decrease the waste discharge from aquaculture production.

This study aims to analyze the application of A-RAS technology in the catfish (*C. gariepinus*) aquaculture. The indicator to evaluate the A-RAS technology is water qualities (i.e., temperature, pH, dissolved oxygen, total organic matter, ammonia, nitrate, and nitrite), and production indicators (i.e., survival rate, food conversion ratio, and harvest). This study indicates that the A-RAS can increase the effectiveness and efficiency of the catfish (*C. gariepinus*) aquaculture. The application of A-RAS makes water quality can be continuously maintained to fulfill the catfish's ideal requirement. Moreover, the A-RAS application increases the quality of the production indicators and provides water spinach as an additional income to the farmers.

Materials and Methods

A-RAS construction

A-RAS integrates water spinach aquaponics and recirculation aquaculture system (Figure 1). The

aquaponics acts as a bio filter to reduce aquaculture waste. A-RAS also operates swirl and bio ball filters to maintain water quality during cultivation. The feeds were given two times a day with a dose of 5-6 % of fish weight. Water replacement in ponds (about 30% of the water volume) was carried out when DO and water pH exceed the maximum standard for catfish life. The control of this experiment is a pond cultivated conventionally. In this control pond, feeding was given using the same method as the A-RAS pond, but water changes were carried out when the DO and the water's pH had passed the ideal quality standard for catfish farming. Therefore, in control ponds, water changes were carried out more frequently than in A-RAS ponds.

The pond construction uses an iron frame with a High-Density Polyethylene (HDPE) membrane. The diameter of the pool is 3 m with a pool height of 1.25 m. The pools were filled with water up to a height of 0.9 m. The stocking density used was 2000 fish/pond using fingerlings (± 2.1 g/fish). Fish were harvested after 60 days of cultivation with an average size of 100 g/fish.

Water spinach was sown until it was approximately 10 cm in size before being used in A-RAS construction. The media used to grow water spinach in A-RAS was Rockwool media placed in a plastic tube (5 cm in diameter and 7 cm high). Water spinach is harvested every 30 days (average stem length is 30 cm) and replaced by new water spinach (10 cm).

The construction for growing water spinach is a PVC pipe with a diameter of 75 mm. This PVC pipe is perforated with a hole diameter of 5 cm with a distance between holes is 25 cm. This hole is used to insert the

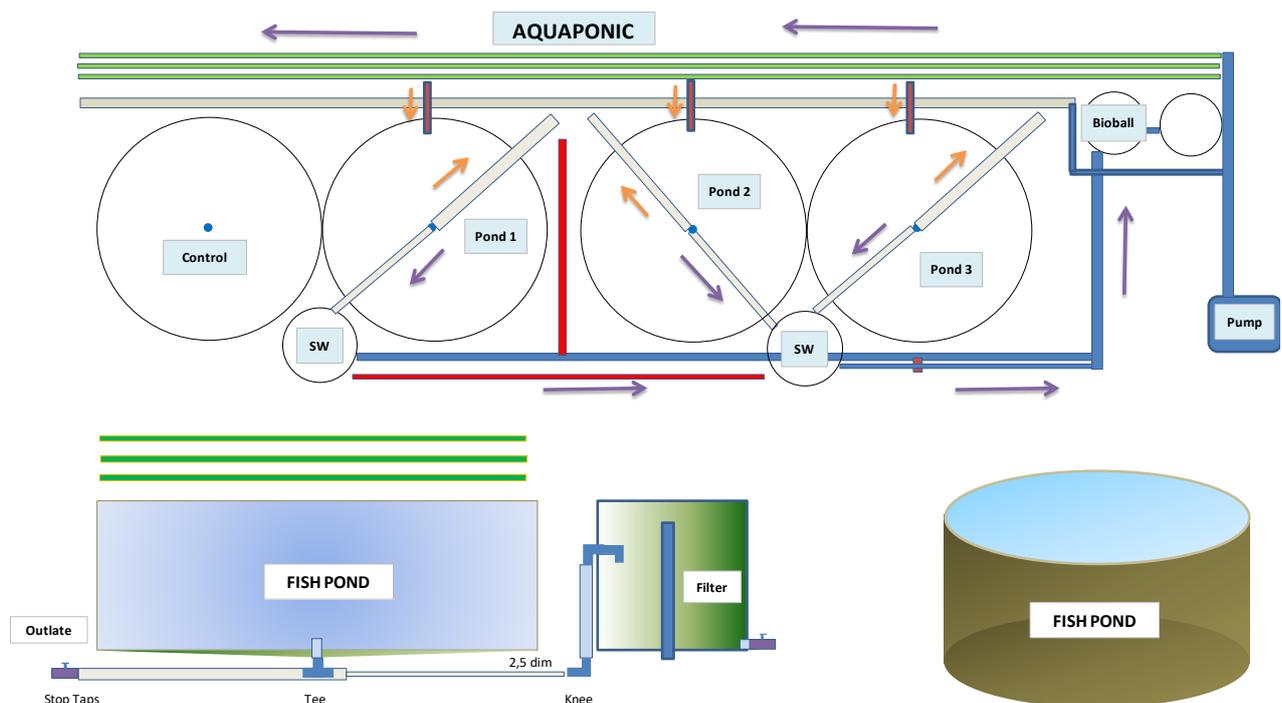


Figure 1. Design of the A-RAS technology for the catfish (*C. gariepinus*) aquaculture. SW is a swirl filter, Bio ball is the filter using bio balls as a substrate for microbes, and the arrows are the water flow direction.

plastic tube used to grow the water spinach. The aquaponics construction in A-RAS consists of 7 PVC pipes with a length of 15 m each.

Water quality measurement

Temperature, pH, dissolved oxygen, total organic matter, ammonia, nitrate and nitrite were measured in this study. Temperature, pH and dissolved oxygen were measured daily using a Digital Integrated thermometer, pH meter and DO meter. Total organic matter, ammonia, nitrate and nitrite were measured in 0, 15, 30, 45, and 60 days of culture. Water qualities in the 3 ponds of A-RAS construction were measured and the average values were used. In the case of control ponds, the measurements were carried out in 3 replications.

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Aquaculture production indicator

The aquaculture production indicator analyzed in this study were Survival Rate, Food Conversion Ratio, and Harvest Production. The Survival Rate was calculated based on the equation (1):

$$SR = \frac{N_t}{N_0} \times 100\% \quad (1)$$

SR is survival rate (%), N_t is the number of fish that live at the end of the cultivation period, and N_0 is the number of fish that live at the beginning of the cultivation period. Food conversion ratio calculated based on the equation (2);

$$FCR = \frac{\text{Feed given}}{\text{Weight gain}} \quad (2)$$

FCR is the food conversion ratio, which is defined as the mass of the input divided by the output (mass of feed per mass of harvested fish). The feed given is the given feed (kg), while Weight gain is the bodyweight of harvested fish (kg).

Results and Discussion

This study analyzes the application of the Aquaponics – Recirculation Aquaculture Systems (A-RAS) in the catfish (*C. gariepinus*) aquaculture. The main indicators in the analysis are water quality and aquaculture product parameters. The detailed analysis is described below.

Water quality during fish cultivation

A-RAS was designed to maintain the water quality during fish cultivation. Hence, waste discharge and water exchange can be minimized because water can be reused during the cultivation process. In order to analyze the achievement of this aim, the water qualities (i.e., temperature, pH, dissolved oxygen, total organic matter, ammonia, nitrate and nitrite) during catfish

Table 1. Statistical analysis results

| Parameters | N | Mean | StDev | SE Mean | Difference | P-value |
|--------------------|----|--------|--------|---------|------------|---------|
| <i>Temperature</i> | | | | | | |
| A-Ras | 61 | 28.831 | 0.416 | 0.053 | -0.0628 | 0.473 |
| Control | 61 | 28.893 | 0.541 | 0.069 | | |
| <i>pH</i> | | | | | | |
| A-Ras | 61 | 7.594 | 0.182 | 0.023 | -0.0107 | 0.738 |
| Control | 61 | 7.604 | 0.169 | 0.022 | | |
| <i>DO</i> | | | | | | |
| A-Ras | 61 | 5.070 | 1.110 | 0.140 | 0.338 | 0.151 |
| Control | 61 | 4.730 | 1.450 | 0.190 | | |
| <i>TOM</i> | | | | | | |
| A-Ras | 5 | 21.510 | 3.100 | 1.400 | -20.04 | 0.065* |
| Control | 5 | 41.500 | 17.400 | 7.800 | | |
| <i>Ammonia</i> | | | | | | |
| A-Ras | 5 | 0.214 | 0.073 | 0.033 | -0.695 | 0.081* |
| Control | 5 | 0.909 | 0.666 | 0.300 | | |
| <i>Nitrate</i> | | | | | | |
| A-Ras | 5 | 0.137 | 0.015 | 0.007 | -0.501 | 0.096* |
| Control | 5 | 0.638 | 0.515 | 0.230 | | |
| <i>Nitrite</i> | | | | | | |
| A-Ras | 5 | 0.097 | 0.036 | 0.016 | -0.0867 | 0.098* |
| Control | 5 | 0.184 | 0.089 | 0.040 | | |

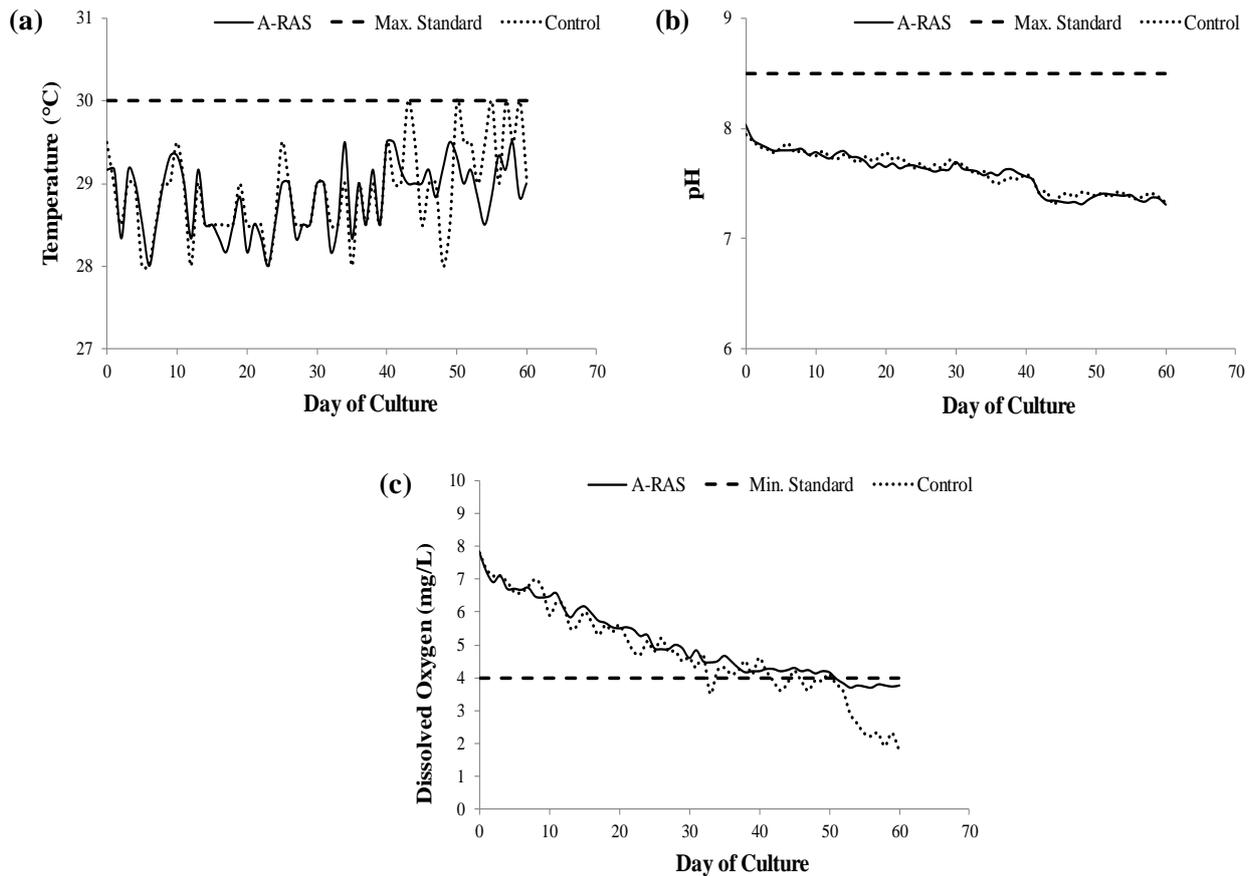


Figure 2. Temperature (a), pH (b) and dissolved oxygen (c) during catfish (*C. gariepinus*) cultivation.

(*C. gariepinus*) aquaculture using the A-RAS technology were compared to those of the conventional methods as the control of the experiments. Temperature, pH, and dissolved oxygen in the A-RAS ponds were daily measured and the results were compared to those of the control (the conventional method without A-RAS) (Figure 2). The results of data analysis using statistical analysis are shown in Table 1.

The water temperature in the catfish (*C. gariepinus*) aquaculture using the A-RAS technology ranged between 28.0 and 30.0°C. This temperature is relatively not different from the temperature of the control (conventional method) (p -value=0.473). The maximum standard of temperature for the catfish (*C. gariepinus*) aquaculture is 25-30°C (Indonesian National Standard, 2002). Thus, both the aquaculture system can provide a suitable temperature for the catfish (*C. gariepinus*). The dynamic temperature changes in this study can be caused due to the temperature dynamics of the environment around the ponds (Sabaori et al., 2016; Senff et al., 2018). The pH of the water in applying A-RAS technology ranged from 6.5-7.9. These values are relatively the same as the case of the control pond (p -value=0.738). The ideal pH to support catfish (*C. gariepinus*) is 6.5-8.5 (Indonesian National Standard, 2002). It seems that A-RAS technology and the conventional method can fulfill the pH requirement.

Dissolved oxygen (DO) in the catfish aquaculture using the A-RAS technology ranged from 3.8 mg/L until 7.8 mg/L, while the dissolved oxygen in control ranged from 1.8 mg/L until 7.8 mg/L. The minimum ideal of DO for the catfish aquaculture is 4 mg/L (Indonesian National Standard, 2002). The A-RAS technology can maintain the DO in the ideal value until about 50 days of culture, while the conventional method can provide until 40 days of culture. After 50 days of culture, the DO in the A-RAS technology slightly decreased until 3.8 mg/L in 60 days. The DO in control continuously decreases until it reaches 1.8 mg/L in 60 days of culture. Hence, A-RAS technology can provide a better value of DO than conventional technology; however, the difference was not statistically significant (p -value=0.151). The decrease of the DO can be caused by an increase in the amount of leftover feed and metabolic waste and an increase in oxygen consumption along with fish growth (Li et al., 2019; Ho et al., 2019; Hu et al., 2015). The results of this study indicate that even though the application of A-RAS the water change is carried out only once, the water quality (i.e., temperature, pH and DO) in the A-RAS ponds is not much different, even slightly better than the conventional method of replacing water up to 7 times.

The primary problem related to aquaculture's water quality is the increasing concentration of organic matter and nutrients along with the day of culture,

mainly due to the leftover feed and metabolic waste. Thus, the success of the A-RAS application is analyzed from the ability of the system to maintain water quality. The A-RAS technology is designed to maintain the water's quality to fulfill the standard threshold of catfish (*C. gariepinus*) aquaculture. In this study, the total organic matter (Figure 3a), ammonia (Figure 3b), nitrate (Figure 3c) and nitrite (Figure 3d) during catfish cultivation were measured.

Total organic matter (TOM) in the ponds with the A-RAS technology ranged between 18.54-24.97 mg/L while the control ranged between 18.21-61.34 mg/L. The ideal value of the TOM in catfish aquaculture is less than 30 mg/L (Indonesian National Standard, 2002). A-RAS application can significantly affect the TOM content in the pond (p -value=0.065) and produce a better environment than the conventional method. In the conventional method, the value of total organic matter continuously increased to exceed the ideal limit on the 15th day of culture. The biological filter provided

through the aquaponics system in A-RAS seems to filter and utilize the remaining organic matter from the fish cultivation process (Froehlich et al., 2017; Ahmed et al., 2019; Brooks & Conkle, 2019; Kurniawan & Yamamoto, 2019).

The concentrations of ammonia, nitrate, and nitrite in the ponds using the A-RAS technology ranged between 0.12-0.28 mg/L, 0.12-0.13 mg/L, and 0.04-0.13 mg/L, respectively. In the conventional method, the concentration of ammonia, nitrate, and nitrite was 0.27-1.81 mg/L, 0.12-1.36, and 0.05-2.95 mg/L, respectively. The maximum ideal concentration of ammonia, nitrate, and nitrite for catfish aquaculture are 1 mg/L, 0.15 mg/L, and 1 mg/L, respectively (Indonesian National Standard, 2002., Granada et al., 2018; Gorito et al., 2018; Groenveld et al., 2019). Application of the A-RAS can significantly impact nutrient ion concentrations in pond water compared to conventional methods (p -values for ammonia, nitrate and nitrite are 0.081, 0.096 and 0.098, respectively). The concentrations of ammonia and

Table 2. Production indicators of the catfish aquaculture

| Parameters | A-RAS | Control |
|-----------------------------------|---------------|---------|
| Survival rate (%) | 85.5 | 70 |
| Food Conversion Ratio | 1.1 | 1.7 |
| Harvest (kg/m ³) | 26 | 23 |
| Water disposal time (times/cycle) | 1 | 7 |
| Additional product | Water spinach | - |

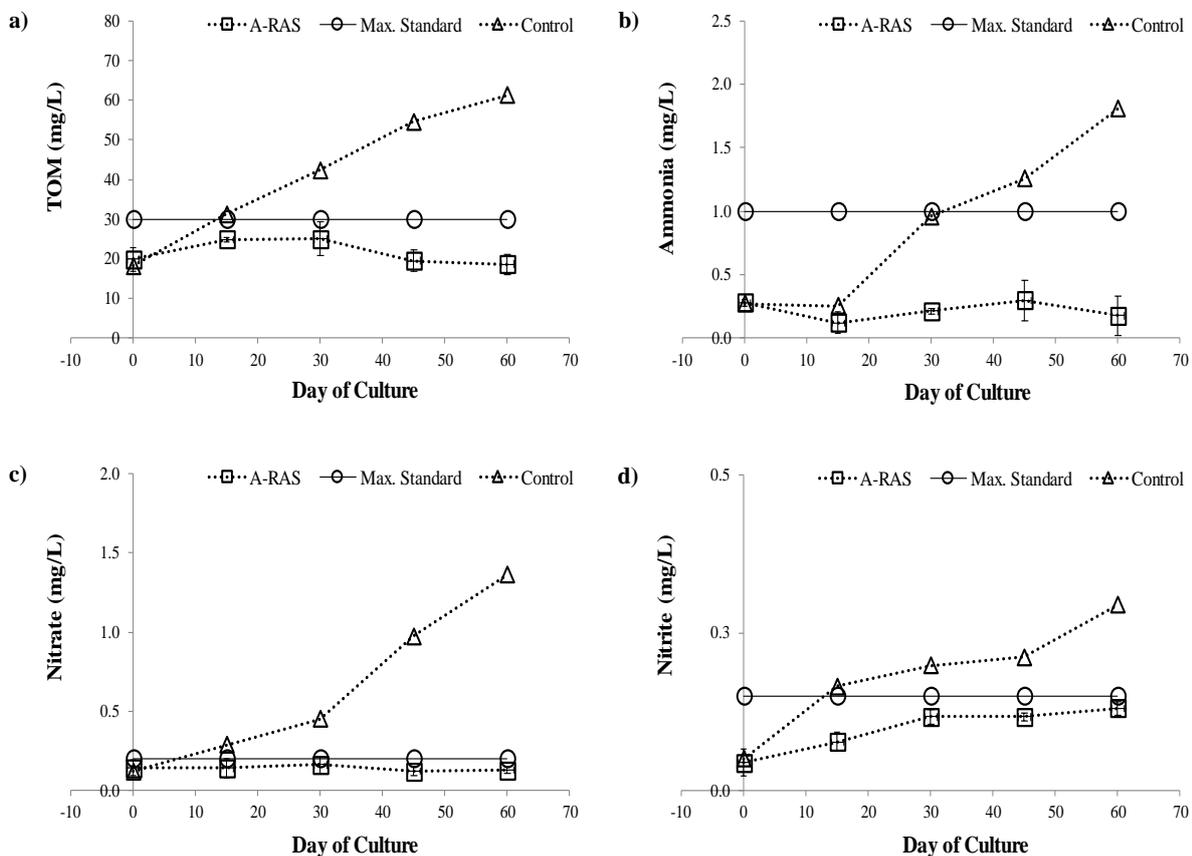


Figure 3. Total organic matter (a), Ammonia (b), Nitrate (c), and nitrite (d) during catfish (*C. gariepinus*) cultivation.

nitrate in the ponds using the A-RAS technology were relatively stable from the beginning until the end of cultivation. On the other hand, the concentration of ammonia and nitrate in the conventional method continuously increases until it exceeds the ideal concentration. The nitrite concentration in the ponds using the A-RAS technology is slightly increased and still in the ideal range for catfish, whereas the conventional method continuously increases until it exceeds the ideal concentration for the catfish aquaculture. These results suggested that the A-RAS technology application can always maintain the water quality in the ideal range for the catfish aquaculture.

The cultivation system built-in A-RAS provides a water recirculation system by utilizing a swirl filter and bio ball filter to clean the pond's aquaculture waste. After this filtering process, the water flows into the aquaponics system, which uses the water spinach as a biological filter. Water spinach in aquaponics construction plays a role in absorbing excess nutrient ions in water. Therefore, A-RAS can maintain the quality of pond water so that it continues to be used in catfish farming.

Aquaculture production indicator

In order to analyze the application of A-RAS technology in catfish (*C. gariepinus*) aquaculture, the production indicators of the A-RAS were compared to those of the conventional method (control) (Table 2). The results in Table 2 suggest that applying the A-RAS technology can improve all aquaculture production indicators compared to those of the control (conventional method). A-RAS technology can increase the survival rate and harvest while decrease food conversion ratio and water disposal.

This study suggests that A-RAS can provide better aquaculture production than the conventional method. The application of the technology can decrease waste disposal because the water quality can be maintained in the ideal range for catfish aquaculture, and thus, can be reused. Moreover, applying A-RAS technology may also produce water spinach as an additional product for the fish farmers every 30 days. This study suggested that A-RAS technology can improve catfish aquaculture production while maintaining environmental sustainability.

Conclusion

This study analyzes the application of the Aquaponics – Recirculation Aquaculture System (A-RAS) in the catfish (*C. gariepinus*) aquaculture. The results show that the values of temperature, pH, dissolved oxygen, total organic matter, ammonia, nitrate and nitrite ranged between 28.0-30.0°C, 6.5-7.9, 3.8-7.8 mg/L, 18.54-24.97 mg/L, 0.12-0.28 mg/L, 0.12-0.13 mg/L, and 0.04-0.13 mg/L, respectively. The survival rate values, food conversion ratio and harvest are 85.5 %,

1.1, and 26 kg/m³, respectively. This study suggests that the A-RAS technology can maintain water quality in the ideal range for the catfish aquaculture, and thus, can be reused in the aquaculture. The application of the A-RAS can increase the harvested product by about 13%. Moreover, the water spinach used as a biological filter in the aquaponics systems can increase the farmers' income. According to the result of this study, applying A-RAS technology may improve catfish aquaculture and support sustainable aquaculture development in Indonesia.

Ethical statements

All applicable international, national, and/or institutional guidelines for the care and use of animals were followed.

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Author Contribution

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Funding acquisition: Arning Wilujeng Ekawati, Siti Mariyah Ulfa, Citra Satrya Utama Dewi, Andi Kurniawan

Conflict of Interest

The authors declare that they have no conflicts of interest.

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