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The effect of comparison of aquaponics and modified conventional aquaculture systems on the content of Copper, Iron and Zinc

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ABSTRACT

This study was conducted to compare water quality (DO, COD, BOD, Cu, Fe, and Zn) in aquaponic systems and modified conventional aquaculture systems). In aquaponic units, recirculation continues, water used for *Oreochromis niloticus* culture comes out of the fish pond tank (FPT) which contains waste of fish metabolism, food that is not eaten, and other wastes.The first wastewater passes through a mechanical tank-1 (MT-1) which filters solid waste and then passes through a biofilter tank (BT) which oxidizes ammonia to nitrite, and nitrate. then flows to the mechanical tank-2 (MT-2) , nutrient water moves to hydroponic plants (HP), and finally the water returns to the fish pond tank (FPT), and so on. The same thing happens with modified conventional aquaculture systems, with only 1 unit mechanical tank, and without hydroponic plants. Furthermore, the data obtained to be compared. Aquaponic system, water quality parameter values (DO was 3.3329 mg/L; COD was 4.397 mg/L; BOD was 1.248 mg/L; Cu was 0.045 mg/L; Zn was 0.197 mg/L and was 0.240 mg/L) and modified conventional aquaculture systems (DO was 3.199 mg/L; COD was 7.309 mg/L; BOD was 0.903 mg/L; Cu was 0.054 mg/L; Zn was 0.210 mg/L and Fe was 0.506 mg/L). The use of an aquaponic system was more effective than a modified conventional aquaculture system because the aquaponic system was supported by the presence of MT-1, BT, MT-2, HP, and FPT, while the modified conventional aquaculture systems were only supported by MT, BT, and FPT.

Key words : *Aquaponic, Modified conventional aquaculture, Water quality, Hydroponic, Biofilter*

Introduction

Most heavy metals that enter the environment come from human activities. But heavy metals in the environment do not by themselves endanger living organisms. Heavy metals are dangerous if they enter the metabolic system of organisms in excess of the threshold. The threshold for each type of heavy metal and for each type of organisms is different. Heavy metals enter the human and animal metabolic systems can be done directly or indirectly. Direct entry occurs with water drunk, along with inhaled air, or through contact with the skin. Indirect intake occurs along with the ingredients eaten. In this case the source of heavy metals in soil, water, and air. With the intermediary of plants that absorb heavy metals, then accumulate and stay in the body tissues of organisms for a long time will become toxic, and according to (Darmono, 2006) such properties are called biomagnification.

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Among the toxic elements that are useful or even needed cannot be clearly separated. These properties are not something essential elements but something relative with regard to the number of elements absorbed and the resistance of beings to the elements concerned. Heavy metals Fe, Cu, and Zn are micronutrients needed by plants, but in large quantities they are toxic. Small amounts of Ni and Cd are thought to carry out important physiological roles in plants but in more toxic quantities. Cr is very toxic to plants, while its role as the nutrient is unknown. However, this element is necessary for humans and mammals because of their participation in glucose metabolism. The role of Pb as a plant is also unknown. This element is the main chemical pollutant for the environment and is very toxic to plants, animals, and humans (Mengel and Kirkby, 1987).

One solution to the problem of improving water quality, and minimizing heavy metals is the use of aquaponic which is a combination of aquaculture and hydroponic technology, aimed at maintaining fish and plants in an integrated system (Wahap *et al.,* 2010, FAO, 2014; Kyawa *et al.,* 2017; Deswati *et al.,* 2018; Deswati *et al.,* 2019; Racocy, 1984; Racocy *et al.,* 2006). Most people associate plants with hydroponics because both use water that is rich in nutrients and both do not use soil media. Fish and plants are cultivated together in a recirculating ecosystem that utilizes natural nitrogen-fixing bacteria to convert fish waste into plant nutrients. Waste products from aquaculture systems function as nutrients for hydroponic systems. With a combined recirculation system, there is no need to dispose of water or filtrate or add chemical fertilizer, making it sustainable and environmentally friendly. The interaction between fish and plants produces an ideal environment to grow so it is more productive than traditional methods (Wahap *et al.,* 2010; Nicolae *et al.,* 2015; Shafeena, 2016; Ng *et al.,* 2016; Goddek and Keesman., 2018).

Aquaponics is an ecological system that is balanced between fish, vegetables, and microorganisms in the circulation process without the expenditure of water pollution and low carbon production. Fish are fed and excrete waste, and then the bacteria are broken down into nutrients. Plants utilize some of these nutrients and in the process of filtering water in biofilter systems (Nicolae *et al.,* 2015; Bosma *et al.,* 2017). By applying the principle of recirculation, water from the medium of fish maintenance is channeled to hydroponic plant media then the nutrients contained in the flow of water are absorbed by plants so that the water can be reused in fish maintenance (Wahap *et al.,* 2010; Chaves *et al.,* 1999; Timmons and Ebeling, 2002). Therefore, this allows sustainable plant growth without using chemical fertilizers and fish with a lower water budget.

Furthermore, to reduce the content of heavy metals and other by products that are potentially toxic from fish waste, water circulation is carried out (Deswati *et al.,* 2019; Rakocy, 1984; Collins *et al.,* 1975), utilizing plants as biofilter (Lewis *et al.,* 1978; Naegel, 1977; Sneed *et al.,* 1975), and bio ball and bio coral as well as biofilter (Suantika *et al.,* 2016; Nurhidayat *et al.,* 2012). With the right choice of fish and plant species, aquaponics serves as a model for sustainable and environmentally friendly food production. Because aquaponics saves energy, prevents the disposal of waste into the environment, provides organic fertilizers for plants, re-uses wastewater through biofiltration and ensures higher food production per unit area through multiple crops, is worthy of being treated as a green technology working model (Wahap *et al.,* 2010).

In this study compared water quality (DO, COD, BOD, Cu, Fe, and Zn) in aquaponic systems and modified conventional aquaculture systems.

Experimenital

Instruments and materials

The equipment used in this study were Atomic Absorption Spectrophotometer (AAS) (Variant) 1unit, analytical balance (Shimadzu) 1 unit, FPT fish tank 2 units, mechanical tank (MT) 3 units, biological tank (BT) 2 units, hydroponics (HP) 1 unit, PVC pipe, water pump 1 unit, high blower 1 unit, netpot 50 units, desiccator 2 units, burette 5 units and glass equipment commonly used in the laboratory.

The materials used in this study were fish feed, vegetable seeds (pakcoy), planting media (rockwool), length of fish 3-5 cm, number of fish 500 pieces, volume of water 3 m^3, double distilled water, and chemical ingredients needed.

Research procedure

Aquaponic and Modified Conventional Aquaculture Systems

Aquaponic and modified Conventional Aquaculture Systems (Figure 1) uses a series of water streams consisting of fish ponds (diameter 300 cm and height 100 cm), MT (150 dm^3), and BT (150 dm^3). Furthermore, for aquaponic systems equipped with hydroponics, namely pakcoy plants grown in rockwool media. Each fish pond is filled with fresh water originating from 3 m^3 of research well water, and water intake is carried out using a water pump. Water is not given any treatment, except aeration with a high blower, and is intended for the availability of oxygen in the optimal pool. When the initial sampling is carried out, the aeration is turned off, and the results of the initial quality data analysis are used as the basis for the time of stocking the fish.

Before fish are stocked into fish ponds, acclimatization is done first by matching the temperature of the fish's origin to the temperature of the new fish pond, with the aim that the fish do not stress, and die. The stocked fish is nila fish (*Oreochromis niloticus*), the size of length ± 3-5 cm, weight ± 4 g/piece using a stocking density of 500 fish/3 m^3 of water. *Oreochromis niloticus* was chosen as a test animal because of its easy breeding, rapid growth, omnivore, and high tolerance (Popma and Masser, 1999). The fish feed (pellet) used was Prima Feed PF 1000 which was mixed with *Nitrosomonas* bacteria using a dose of 2 kg of fish feed per 50 mL of bacteria.

The composition of MT consists of plastic filters (thick 3 cm, 3 units), and floating stone (as much as 3 kg), while BT composition is plastic filter (3 cm thick, 3 units), bio ball (300 units), and biocoral (4 kg), which functions as a bacterial growth medium.

In aquaponic system, recirculation continues, water used for nila fish (*Oreochromisniloticus*) cultivation comes out of FPT which contains waste metabolism of fish, food that is not eaten, and other impurities. The wastewater first passes through MT-1 which filters solid waste and then passes BT which oxidizes ammonia to nitrite, and nitrate. The water then moves MT-2, and hydroponic plant (HP) where the plant absorbs nutrients, and finally, the water returns to the FPT (Endut 2011; Delaide *et al.*, 2017).

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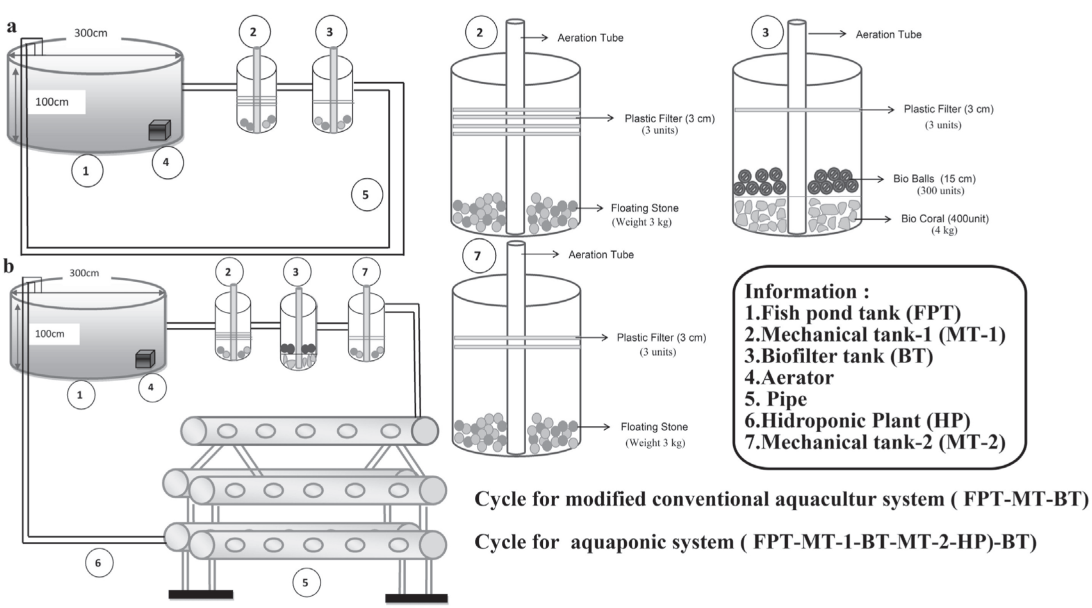

Fig. 1. Modified conventional aquaculture systems (a); Aquaponic systems (b)

Preparation of planting media

The planting media used is Rockwool with a size of 40x30 cm, then cut into 1x1 cm to facilitate the transfer of seedlings from the seedling media into the netpot. Netpot functions as a planting medium to support plants so that plant stems can stand firmly, then the netpot is connected with flannel cloth which functions as an absorbent of water that passes through the system, so that the water can be stored in the planting media, and nutrients in the water can be absorbed by plants. Pakcoy plant seeds before being planted in rockwool planting media (40 pakcoy seeds), are sown for 2 weeks.

Data Analysis

The study was conducted for 40 days, and sampling was carried out on days 0, 10, 20, and 40. Water quality parameters measured in this aquaponic system, namely: dissolved oxygen (DO), chemical oxygen demand (COD), the biological oxygen demand (BOD), and metals (Cu, Fe and Zn). The limit of optimal tolerance allowed for plant organisms, fish and bacteria is probably not the same, hence compromising water quality is needed Compromised water quality parameters for documented aquaponic systems are: temperature (^oC), pH, DO (mg/L), ammonia (mg/L), nitrite (mg/L), and nitrate (mg/L) (WHO, 2014; Anonymous, 2014). Regarding the compromised water quality parameters it has not been documented, so as a comparison of COD, BOD, and metals (Cu, Fe, Zn), a tolerance limit approach is used from Republic of Indonesia Government Regulation No. 82 of 2001. Furthermore, water quality data from aquaponics systems and modified conventional aquaculture systems were compared using the t test. Especially for samples taken from hydroponics, it is only done on aquaponic systems.

Results and Discussion

Analysis of DO

DO is one of the water qualities that are very important for the three organisms involved in aquaponics: plants (> 3 mg / L), fish (4-6 mg / L) and bacteria (4-8 mg / L) to determine the sustainability of the aquaponic system. The tolerance range is relatively similar for all three organisms, but there is a need to compromise and therefore some organisms will not function at optimal levels. Oxygen requirements compromise all three organisms > 5 mg / L (FAO, 2014).

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Figure 2, DO on day 0, which is 7.40 mg/L, has met FAO Standards (> 5 mg/L) and Republic of Indonesia Government Regulation No. 82 of 2001, which is > 3 mg/L, because both the aquaponics system and the modified conventional aquaculture system do not yet function. The high DO is due to oxygen aeration that has met the permissible standards, and the absence of fish in the FPT. Naturally, the condition of fish can survive in water, because of simple aeration. But in intensive production systems with higher fish densities, this DO diffusion amount is not enough to meet the demands of fish, plants, and bacteria. Use of a water pump to create a dynamic flow of water, and use an aerator (high blower) that produces air bubbles in the water. Water movement and aeration are important aspects of each aquaponics unit.

In the aquaponics system , samples of days 10, DO that meets the minimum standards, namely FPT, and HP water samples. Samples of days 20 to 40, DO tend to decrease after passing FPT because the oxygen is used by fish to breathe and bacterial activity to decompose ammonia into nitrite and nitrate, and the photosynthesis process of plant plankton has not taken place optimally. In general, DO values are taken from FPT and HP > 3 mg/L and are still within tolerance limits. On the 40^{th} day DO concentration in the fish tank was 2.299 mg/L which was not in accordance with the established tolerance limit, resulting in 40 fish deaths.

BT is an important medium for growing bacteria. At 40-day sampling, DO values (<3 mg/L), meant that bacterial growth was not optimal so that it would affect the performance of bacteria to convert toxic ammonia to nitrite and eventually to nitrate, which became a source of hydroponic plant nutrients.

In modified conventional aquaculture systems, water samples were taken from FPT, MT, and BT.

Figure 2, it is obtained that all tanks tend to decline. In general, the DO value is taken from FPT > 3 mg/L, means that the oxygen supply from aeration and photosynthesis works well. DO values at 20th-day sampling (MT was 1.469 mg/L; BT was 1.469 mg/L) and 40th-day sampling (MT was 1.533 mg/L) were very low (<3 mg /L), indicating that fish, plants, and bacteria were not yet integrated, so aquaponics system is not optimal.

In an aquaponics system, the average DO value (3.329 mg/L) is greater than the DO value of the modified conventional aquaculture system (3.199 mg/L), meaning that the presence of hydroponic plants in aquaponic systems has an important role to supply oxygen.

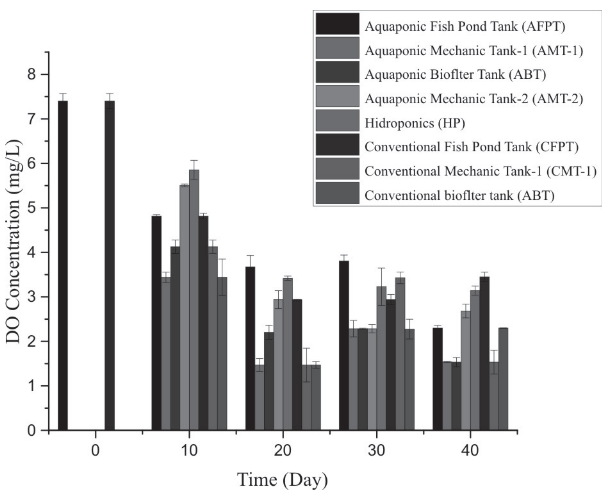

Fig. 2. DO concentration in aquaponicsand modified conventional aquaculture systems

Analysis of COD

COD is the total amount of oxygen needed to chemically oxidize organic matter and is one indicator of chemical water pollution. Foods that are not eaten, feces, plankton, and other impurities are the main sources of organic waste and are the main cause of high COD concentrations. The COD value of aquaponics and modified conventional pond systems on day 0 was 6.675 mg/L because the two systems were not functioning (Figure 3).

In aquaponic systems, the COD value in FPT tends to decrease, except for the 30th-day sampling. The same trend of the decline occurred in sampling in MT-1, MT-2, BT, and HP. This condition indicates that the aquaponics system is running well because the bacteria in BT have converted some of the poisonous substances into non-toxic substances so that less O_2 is needed to oxidize organic matter (Yavuzcan Yildiz, 2017). While the COD value after passing the hydroponic circuit on days 10 – 40, (4.306; 2.184; 4.025; 2.147) mg/L, and this condition can occur due to the presence of decaying roots and leaves on hydroponic plants.

In the aquaponics system, on day 30, the COD value increases on FPT. Increased COD concentration results in a decrease in DO in water because oxygen is needed by fish to breathe and improve the nitrification process. The COD values on the 10th and 20th days decreased at BT, one of the reasons was that bacteria had transformed organic matter into organic matter using less oxygen[4,24,25].

Figure 3, the COD value in the modified conventional aquaculture system is higher than the aquaponic system. The high concentration of COD is caused by the increase of organic compounds derived from organic waste and the absence of hydroponic plants which can reduce the absorption of inorganic nutrients. The highest COD value occurred at sampling 30 days, the same as the case with the aquaponic system. However, in the modified conventional aquaculture system, COD values were higher than aquaponic ponds and were still below the permissible limit of 25 mg/L (Republic of Indonesia Government Regulation No. 82 of 2001).

In the aquaponics system, the average COD value (4.397 mg/L) is smaller than the COD value of the modified conventional aquaculture system (7.306 mg/L), and the aquaponics system requires less oxygen to decompose the organic material into inorganic. Therefore the aquaponic system func-

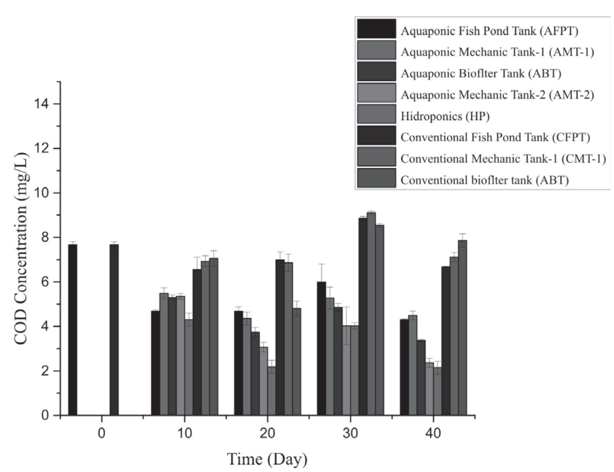

Fig. 3. COD concentration in aquaponics and modified conventional aquaculture systems

tions more optimally than a modified conventional aquaculture system.

Analysis of BOD

BOD is a value that indicates the amount of dissolved oxygen needed by microorganisms (bacteria) to decompose organic matter in aerobic conditions. The maximum allowable tolerance value is 3 mg/L (Republic of Indonesia Government Regulation No. 82 of 2001).

Figure 4, the BOD value at the first sampling (3.664 mg/L) and samples of days 10 at BT was 3.545 mg/L exceeded the maximum allowable (3 mg/L). This condition indicates that nitrifying bacteria have not worked according to the principle of aquaponics. In the FPT, feeding of fish is done by mixing 2 mL of bacteria per 2 kg of fish feed, so that in the FPT an oxidation process occurs that is the change in ammonia to nitrite. In MT-2, *Nitrobacter* spbacteria were added to convert nitrite to nitrate,

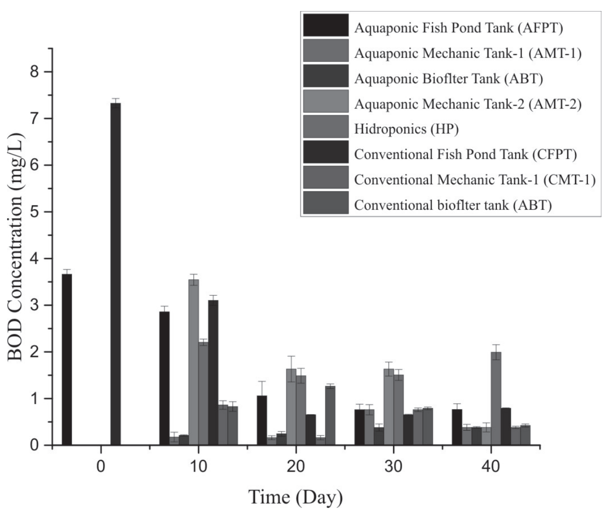

Fig. 4. BOD concentration in aquaponics and modified conventional aquaculture systems

so that the BOD concentration increased. On HP, the BOD concentration decreases again, because plants absorb organic matter, so that organic material degraded by microbes decreases, so the dissolved oxygen content is higher (FAO, 2014).

Figure 4, on day 20 the BOD value in FPT is smaller than the allowed quality standard. At FPT, the value of BOD was 1.061 mg/L and rose at MT-2 was 1.632 mg/L. This condition occurs because of the addition of *Nitrobacter* sp bacteria and back down after passing through hydroponic plants that absorb organic matter. On the 30th day, the highest BOD value is in MT-2 because of the addition of bacteria and back down after passing the HP series. On the 40th day the highest BOD concentration is in the HP. Increasing the BOD value indicates that water quality is getting worse, where plants can no longer absorb organic substances in water. This condition is characterized by changes in the color of pakcoiplants which become brownish and decaying. Decreasing plant quality is caused by a lack of nutrients obtained from fish feed.

In aquaponic systems, BOD was 1.218 mg/L and the modified conventional aquaculture system BOD was 0.903 mg/L, and both systems are still smaller than the allowed quality standard (<3 mg/L), meaning that both systems are running well.

Analysis of Cu

Cu metal acts as a constituent of enzymes, chlorophyll and helps metabolize carbohydrates and proteins. Cu metal is needed by plants and fish in small amounts, the maximum permissible concentration is 0.02 mg/L (Republic of Indonesia Government Regulation No. 82 of 2001).

Figure 5, the value of Cu on day 0 is 0.0452 mg / L, and the 10th day decreases because some are used for fish growth. In MT-1, BT, and MT-2, the value of Cu increases, presumably because of the excess content of Cu in water, and also from the fish feed. In pakcoy plants, the value of Cu returns to decrease, because the pakcoy requires a little metal to grow so that the value of Cu is reduced.

On the 20th day, the Cu content increases in the FPT. This increase occurs because of the accumulation of fish feed continuously, and then Cu metal decreases after the HP because some metals are used for plant growth.

On the 30th day, Cu content decreases, it is assumed that Cu metal settles at the bottom of the pond so that the metal content in the water decreases. In addition, Cu is used by fish and plants as nutrients for growth.

On the 40th day, Cu metal content continues to decline and almost meets the optimal permissible standard, which is <0.02 mg /L (Republic of Indonesia Government Regulation No. 82 of 2001). Cu metal concentration decreases after passing MT-1, BT, MT-2, is caused by pumice, and bio coral which functions as an adsorbent that absorbs Cu metals (Babakhani *et al.*, 2016). Furthermore, the concentration of Cu increased after passing through the HP, it is assumed that Cu which is a micronutrient is needed by plants. However, there is a high availability of this element in the solution and this causes a portion of Cu to be absorbed directly by the plant, and some of it attaches to the plant roots and Cu is partially dissolved by water (Alkorta *et al.,* 2010).

In modified conventional aquaculture system (Figure 5), Cu metal content on the 10th day increases due to excess fish feed accumulation. On the 20th day, the levels of Cu also increase. caused by added feed without the absorption of Cu by plants. On the 30th and 40th day the Cu content decreases, due to the deposition of metals at the bottom of the pool so that the measured levels of Cu are less. On the 40th day, small metal Cu concentrations of 0.02 mg/L, means that this system is feasible to develop.

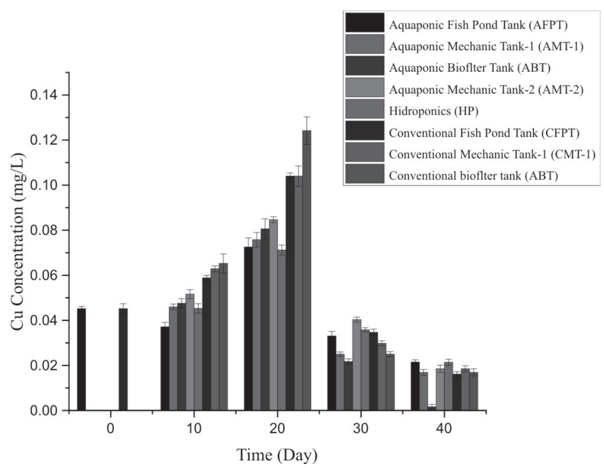

Fig. 5. Cu concentration in aquaponics and modified conventional aquaculture systems

Analysis of Zn

In hydroponic plants, Zn metal acts to increase the rate of metabolic reactions as a function of enzymes, synthesize plant growth, and also produce chlorophyll and carbohydrates.

Figure 6, on day-0 the Zn metal content is equal to 0.052 mg /L, then on day-10, the Zn metal is absorbed by the fish so that it decreases in water. In MT-1 Zn content increases, due to overfilling of fish feed. But the BT tank goes back down because it has passed MT-1, which filters out excess food debris. After passing through hydroponics Zn decreases because Zn is absorbed by plants.

On the 20th and 30th day Zn levels increase, because of the high levels of Zn in water that can come from the fish feed, but on HP Zn levels experience a slight decrease because some Zn is absorbed by plants for growth. On day 40, Zn levels continued to increase on FPT and decreased again on HP, which indicates the absorption of Zn content by plants.

In modified conventional aquaculture system, Zn obtained on day 0 is 0.052 mg/L and continues to increase on days 10 and 20. On day 30, Zn decreases due to Zn metal that settles at the bottom of FPT, so that Zn content in the water a little. On day 40, Zn levels continue to increase because there is no absorption by plants.

From the data obtained, the levels of Zn in modified aquaponics and conventional aquaculture systems are very high and have exceeded the water quality standard, which is equal to 0.05 mg/L (Republic of Indonesia Government Regulation No. 82 of 2001).

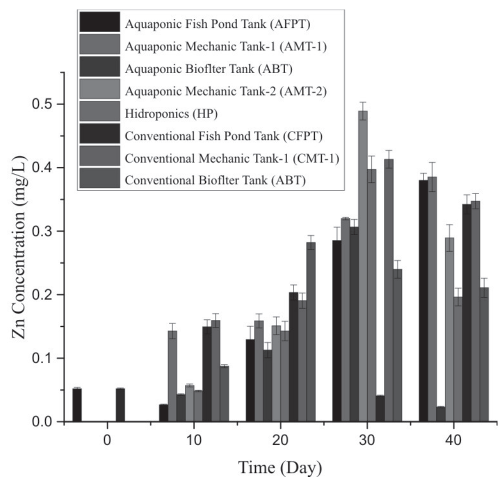

Fig. 6. Zn concentration in aquaponic and modified conventional aquaculture systems

Analysis of Fe

Fe plays an important role in the formation of chlorophyll in plants. On day 0, Fe content of 0.1074 mg/L, on the 10th day increased in FPT and MT-1, due to the ineffectiveness of the aquaponic system. At BT and MT-2 the metal content of Fe has decreased because there are BT compositions and MT-2 compositions which can adsorb Fe metal. On HP, the metal content of Fe is reduced because some are absorbed by plants as nutrients.

On the 20th to 40th day the Fe content increases, due to increased levels of Fe derived from fish feed. The Fe content decreases after passing the HP. But on the 40th day, the metal content of Fe increases, indicating high Fe content in plants. On the 40th day, unhealthy and decaying plants are obtained from the leaves.

Modified conventional aquaculture system obtained a very high Fe content at 40 days at 1.98 mg/L, and higher than aquaponic system (0.615 mg/L), due to the absence of HP in modified conventional aquaculture systems. Based on Republic of Indonesia Government Regulation No. 82 of 2001 states that the content of Fe is not required because Fe is a nutrient needed by living things.

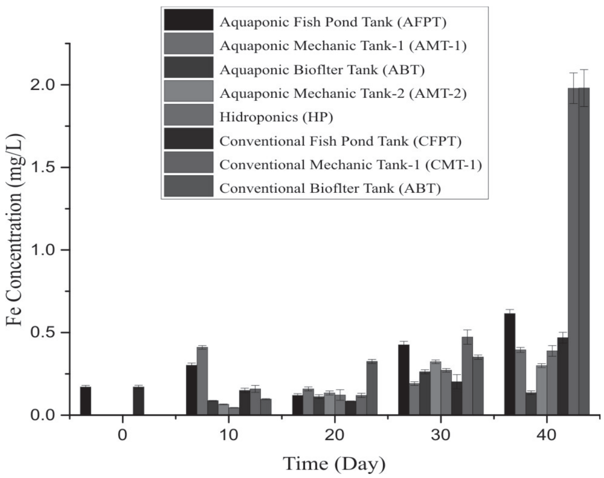

Fig. 7. Fe concentration in aquaponics and modified conventional aquaculture systems

Conclusion

It can be concluded that the use of an aquaponic system was more effective than a modified conventional aquaculture system, because the aquaponic system was supported by the presence of MT-1, BT, HP, MT-2, and FPT, while the modified aquaculture systems were only supported by MT, BT, and FPT.

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References

Alkorta, I., Becerril, J.M. and Garbisu, C. 2010. Phytostabilization of metal contaminated soils. *Environmental Health*. 2 (25) : 135-146.

Babakhani, N., Khorm, M.R. and Sobhanardakani, S. 2016. Kinetic study of heavy metal ions removal from aqueous solutions using activated pumice tone. *Environmental Health Engineering and Management Journal*. 3(1) : 47-53.

Bosma, R.H., Lacambra, L., Landstra, Y., Perini, C., Poulie, J., Schwaner, M.J. and Yin, Y. 2017. The financial feasibility of producing fish and vegetables through aquaponics. *Aquacult. Eng*. 78 : 146–154.

Chaves, P.A., Sutherland, R.M. and Laird, L.M. 1999. An economic and technical evaluation of integrating hydroponics in a recirculation fish production system. *Aquac. Econ. Manag.* 3(1) : 83–91.

Collins, M., Gratzek, J., Shotts Jr., E., Dawe, D., Campbell, L., and Senn, D., Nitrification in an aquatic recirculating system. *J. of the Fish. Res. Board of Can.* 32(ll): 2025-2031.

Darmono., *Environmental and pollution relations with toxic compounds of metal*. UI Press, Jakarta, 2006.

Delaide, B., Delhaye, G., Dermience, M., Gott, J.,Soyeurt, H. and M. Haissam, M. 2017. Plant and fish production performance, nutrient mass balances, energy and water use of the PAFF Box, a small-scale aquaponic system. *Aquacultural Engineering*.

DeLong, D.P. and Losordo, T.M. 2012. *How to start a biofilter*. Southern Regional Aquaculture Center, SRAC Publication No. 4502. National Institute of Food and Agriculture, United States Department of Agriculture.

Deswati, Febriani, N., Pardi, H., Yusuf, Y., Suyani, H. 2018. Applications of aquaponics on pakchoy (*Brassica rapa*L) and nila fish (*Oreochromis niloticus*) to the concentration of ammonia, nitrite and nitrate. *Orient. J. Chem.* 34(5): 2447-2455.

Deswati, Muchtar, A.K., Abe, E.F., Pardi, H., Yusuf, Y. and Suyani, H. 2019. Copper, iron and zinc contents in water, pakcoy (*Brassica Rapa* L.) and tilapia (*Oreochromis niloticus*) in the presence of aquaponics. *Rasayan J.Chem.* 12(1) : 40-49.

Endut, A., Jusoh, A., Ali, N., Wan Nik, W.B. and Hassan, A. 2011. Nutrient removal from aquaculture wastewater by vegetable production in aquaponics recirculationsystem. *Desalin, Water Treatment*. 32 (1–3): 422–430.

FAO Fisheries And Aquaculture Technical paper 589. *Small Scale Aquaponic Food Production Integrated Fish and Plant Farming*, 2014.

Goddek, G. and Keesman, K.J. 2018. The necessity of desalination technology for designing and sizing multi-loop aquaponics systems. *Desalination.* 428 : 76–85.

Kyawa, T.Y. and Ngb, A.K. 2017. Smart Aquaponics System for Urban Farming. *World Engineers Summit - Applied Energy Symposium & Forum: Low Carbon Cities & Urban Energy Joint Conference, WES-CUE 2017, 19–21 July 2017*, Singapore. ScienceDirect. *Energy Procedia*. 143 : 342–347.

Lewis, W.M., Yopp, J.H. and Schramm, J.H.L. 1978. Use of hydroponics to maintain quality of recirculated water in a sh culture system. *Trans. Am. Fish. Soc*. 107: 92–99.

Marlina, E. and Rakhmawati, 2016. Study of ammonia content in tilapia (*Oreochromisniloticus*) using tomato aquaponict technology (*Solanumlycopercium*). *Proceedings of the Fifth Annual National Seminar on the Results of Fisheries and Marine Research,* 181-187,

Mengel, K. and Kirkby, E.A. 1987. *Principle of Plant Nutrition*. 4th edition. Int. Potash Inst. Bern.

Naegel, L.C.A. 1977. Combined production of sh and plants in recirculating water. *Aquaculture*. 10 : 17–24,.

Nicolae, C.G., Popa, D.C., Turek, R.A. 2015. Dumitrache F., Mocuþa, D. and Elia, E., Low-tech aquaponic system based on an ornamental aquarium, Scientific Papers: Series D, *Animal Science*, vol. LVIII, pp. 385–390.

Nurhidayat, K., Nirmala. Djokosetiyanto, D., 2012. Effectiveness of biofilter media performance in the recirculation system on water quality for the growth and survival of rainbow red fish (*Glossolepisinsicus* Weber). *J. Ris. Aquaculture*. 7(2): 279-292.

Popma, T. and Masser, M. 1999. *Tilapia Life History and Biology*. SRAC Publication. 283

Rakocy, J.E. 1984. A recirculating system for tilapia culture and vegetable hydroponics. In: Smitherman, R.O., Tave, D. (Eds.), *Auburn Symposium on Fisheries and Aquaculture.* Auburn, AL, pp. 103–114.

Rakocy, J.E., Masser, M.P. and Losordo, T.M. 2006. *Recirculating Aquaculture Tank Production Systems: Aquaponics—Integrating Fish and Plant Culture*. *SRAC Publication.* 454.

Djokosetiyanto, D., Sunarma, D.A. 2006. Widanarni. Changes in ammonia (NH_3-N), nitrite (NO_2-N) and nitrate (NO_3-N) in maintenance media of red tilapia (*Oreochromis* sp.) *J. Indones. Aquacult.* 5(1) : 13-20.

Shafeena, T. 2016. Smart aquaponics system: challenges and opportunities. *Europ. J. of Adv, in Eng. and Tech.* 3(2): 52–55.

Sneed, K., Allen, K. and Ellis, J. 1975. Fish farming and hydroponics. *Aquac. Fish Farmer*. 2 : 18–20.

Suantika, G., Pratiwi, M.I., Situmorang, M.L., Djohan, Y.A., Muhammad, H. and Astuti, D.I. 2016. Ammonium removal by nitrifying bacteria bio film on lime stone and bioball substrate established in freshwater trickling biofilter. *Pout. Fish & Widl Sci*. 4(2) : 1-6.

Timmons, M.B. and Ebeling, J.M. 2002. *Recirculating Aquaculture*. Cayuga Aqua Ventures, Ithaca, NY.

Wahap, N., Estim, A., Kian, A.Y.S., Senoo, S. and Mustafa, S. 2010. Producing organic fish and mint in an aquaponicsystem. Borneo Marine Research Institue, Sabah, Malaysia.

Yildiz, H.Y., Robaina, L., Pirhonen, J., Mente, E., Domínguez, D., Parisi, G. 2017. Fish welfare in aquaponic systems : its relation to water quality with an emphasis on feed and faeces. A Review. *Water*. 9 (13) : 1-17.