Omni-Akuatika Special Issue The 4th KRIPIK-SciFiMaS 2022: 81 - 89
ISSN: 1858-3873 print / 2476-9347 online

Research Article

journal homepage: http://ojs.omniakuatika.net

Effectiveness of Different Vegetable Plants on Intensive Culture of Catfish (*Clarias* sp.) using Aquaponic Ebb-tide System

Lies Setijaningsih, Imam Taufik, Dewi Puspaningsih*

Research Institute for Freshwater Aquaculture and Fisheries Extention Jl. Sempur No. 1, Bogor 16154, West Java, Indonesia

**Corresponding author: d_puspaningsih@yahoo.com*

Received 9 November 2021; Accepted 24 February 2022; Available online 18 April 2022

ABSTRACT

The culture of fish and vegetable plants in aquaponic ebb-tide system is based on the principle of zero-waste aquaculture. The purpose of this study is to see how effective the use of different vegetable plants in an aquaponic ebb-tide system for intensive culture. As much as 3000 catfish (*Clarias* sp.) were stocked per pond (measuring 4 x 2 m^2), with individual lengths of 8-10 cm. A completely randomized design (CRD) with three treatments and three replications was used in this study. With 60 days of observation, the research treatments included a variety of vegetable plants: (A) water spinach, (B) caisin, and (C) no plants (control). Absolute weight gain and survival rate, water physico-chemistry parameters, Total N and Total P analyses on vegetable plants among the observation parameters. Treatment was found to have the highest average weight gain and survival rate (73.63 g and 87.41%, respectively). Water spinach biomass was 102 kg at the end of the study, whereas caisin biomass was 72.54 kg. Total N and Total P absorption percentages in water spinach were 38.72% and 54.43%, respectively, while 36.00% and 49.55% in caisin. The catfish condition factor showed correlation coefficients with fish weight R2 = 0.978, R2 = 0.956, and R2 = 0.357 and R2 = 0.892, R2 = 0.8215 and R2 = 0.369 for length in the water spinach, caisin, and control treatments, respectively. This study's analysis of water quality parameters indicated that the A treatment had the lowest levels of ammonia, nitrite, and nitrate when compared to the B and C treatments.

Keywords: catfish, aquaponic ebb-tide, water spinach, caisin

ABSTRAK

Budidaya ikan dan tanaman sayuran dengan akuaponik sistem pasang surut didasarkan pada prinsip budidaya tanpa limbah. Tujuan dari penelitian ini adalah untuk melihat seberapa efektif penggunaan tanaman sayuran yang berbeda dalam akuaponik sistem pasang surut untuk budidaya intensif. Ikan lele (*Clarias* sp.) ditebar sebanyak 3000 ekor per kolam (ukuran 4 x 2 m^2), dengan panjang individu 8-10 cm. Rancangan Acak Lengkap (RAL) dengan tiga perlakuan dan tiga ulangan digunakan dalam penelitian ini. Dengan pengamatan selama 60 hari, perlakuan penelitian meliputi berbagai tanaman sayuran: (A) kangkung, (B) caisin, dan (C) tanpa tanaman (kontrol). Pertambahan bobot mutlak dan tingkat kelangsungan hidup, parameter fisika-kimia air, analisis Total N dan Total P pada tanaman sayuran adalah beberapa parameter yang diamati. Perlakuan A diketahui memiliki rata-rata pertambahan berat ikan dan tingkat kelangsungan hidup tertinggi (masing-masing 73,63 g dan 87,41%). Biomassa kangkung pada akhir penelitian adalah 102 kg, sedangkan biomassa caisin adalah 72,54 kg. Persentase penyerapan total N dan P total pada kangkung masing-masing sebesar 61,56% dan 46,92%, sedangkan pada caisin sebesar 54,43% dan 36,00%. Faktor kondisi ikan lele menunjukkan koefisien korelasi dengan bobot ikan sebesar R^2 = 0,9837, R^2 = 0,9655, dan R^2 = 0,3524; dan dengan panjang ikan sebesar R^2 = 0,8954, R^2 = 0,8438, dan R^2 = 0,3612 masing-masing pada perlakuan kangkung, caisin, dan kontrol. Analisis parameter kualitas air pada penelitian ini menunjukkan bahwa perlakuan A memiliki kadar amonia, nitrit, dan nitrat yang paling rendah jika dibandingkan dengan perlakuan B dan C.

Kata kunci: Ikan lele, akuaponik pasang surut, kangkung, caisin

http://dx.doi.org/10.20884/1.oa.2022.18.S1.984

1. Introduction

The development of aquaponic systems has attracted the attention of various groups in the field of aquaculture, starting from observers, researchers, to fish farmer. This is related to the increasing knowledge about the impact of aquaculture waste on the aquaculture system itself which resulted in a decrease in carrying capacity which will eventually decreasing the production. This problem arises as a result of the accumulation of fish waste (faeces and urine) and uneaten feed. At a feed conversion rate (FCR) of 1.2, it means that in 1.2 kg of feed, will be produced waste of 780 g of dry weight feed, and including (72.22%) the nitrogen in it will be wasted into the waters. The higher the feed conversion rate, the greater the waste generated in the fish farming system (Gunadi 2012; Edwards 2015).

To restore the value of wasted feed, efforts have been made by placing plants hydroponically with economic value 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 farmed fish's survival and growth.

Aquaponic ebb-tide system is an innovation in freshwater fish farming which working system is that the water supply for plants will periodically rise and fall like tides, the mechanism is regulated by an "automatic siphon" which works 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 goes up and down again and so on. It should be understood that vegetable plants in the aquaponic are annual plants that produce leaves such as water spinach, caisin, spinach which function to absorb waste resulted from intensive culture as an organic fertilizer for plants (Vesely et al. 2011) and reuse wastewater that has gone through the biofiltration process (Wahap et al., 2010).

Water spinach (*Ipomoea aquatica*) and Caisin (*Brassica oleracea* var. Acephala) are both fibrous root. Water spinach plants in an aquaponic system function as phytoremediators (Effendi et al. 2015 and Indah et al. 2014), capable of reducing ammonia by absorbing waste water using plant roots (Dauhan et al, 2014). Caisin is a plant that is rich in vitamins, calcium, fiber, minerals and protein. The green color of caisin vegetables contains very high vitamins A, C, E, and K and is thought to be a plant that can absorb organic matter (Andreeilee *et al*., 2014). Research on aquaponic ebb-tide system using water spinach and caisin plants in catfish farming has never been done. The aim of the study was to obtain the best biological performance of catfish cultured using aquaponic ebb-tide system with different types of vegetable plants.

2. Material and Method

The research was conducted at the Center for Production, Inspection and Certification of Fishery Products located in the Ciganjur area, South Jakarta, Indonesia. The application test in the field used a concrete pond sizing 2x4x1 m^2 and designed with an aquaponic ebb-tide system. It consists of a water pump and a reservoir that functions to distribute water to all interconnected plant media containers. The water flow mechanism is 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 wasted back into the pond, then go up and down again and so on. The planting media container is a plastic bucket with a volume of 10 liters, connected with a paralon pipe. Planting media consisted of split stones and fern roots. Furthermore, fish tanks and planting media containers are formed into a series of aquaponics systems (Figure 1).

The plants used are water spinach and caisin. The test fish were catfish (*Clarias* sp) with individual weight of 10 -12 cm which were stocked with a density of 3000 fish/pond. The research treatments using vegetable plants consisted of: (a) water spinach, (b) caisin, (c) without plants (control), held for 60 days. During culture, catfish were fed with artificial feed and given as much as 5% of the weight biomass with a feeding frequency of 2 times/day, in the morning and in the evening. In one planting media container, water spinach and caisin are planted with 7 stalks of plants (Setijaningsih and Setiadi 2012).

Parameters observed during 60 days of culture included: fish biological performances and plant productivity. Water quality parameters included: temperature, pH, dissolved oxygen, ammonia, nitrite, nitrate, Total N and Total P. Growth of fish and plants is measured every 10 days in each series of aquaponics systems. Vegetable plant productivity is counted at each harvest, while fish productivity is calculated at the end of the research. The research design used a completely randomized design (CRD), each treatment repeated three times. The harvest of water spinach and caisin were

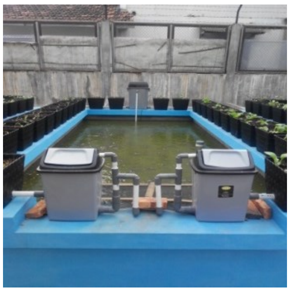

Planting media container with a filter that prevented the planting medium from entering the water channel

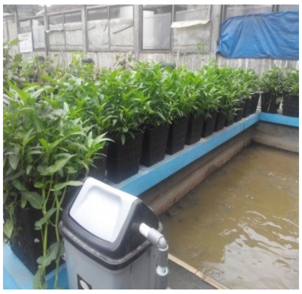

Split stone filter


Using a net, insulated the stone filter so that it did not contact with the fern roots.


Fern roots filter


Seen from above, ebb-tide filter design, water from the pond get into the ebb-tide container then flowed into the planting medium


The water supply from the plant container entered the sump container on a regular basis, and the mechanism is controlled by an automatic siphon that operated on the concept of a vacuum pump.


An aquaponic ebb-tide system with water spinach plant


Seen from the side, an aquaponic ebb-tide pond system with water spinach plant

Figure 1. An aquaponic ebb-tide system

analyzed for their N and P content. The fish data collection were processed using Analysis of Variance (ANOVA) to determine whether there was an interaction effect between the treatments given. If there is a difference effect, then it is continued with Duncan's Multiple Distance test with a significance level of 5% to find out which treatment gives the highest and lowest results.

3. Result and Discussion

3.1. Absolute Weight and Length Gains of Catfish

The increase in absolute weight and length gain of catfish reared for 60 days showed that treatment A had the highest absolute weight and length and statistical test results showed that treatment A was significantly different ($P < 0.05$) with treatments B and C (Figure 2). Treatment B was not statistically different ($P > 0.05$) with treatment C. The results of analysis of variance showed that all treatments had a significant effect on absolute weight and length. The differences in the absolute weight and length gain of catfish in aquaponic ebb-tide system with the application of different types of vegetable plants is influenced by plant growth rate. The water spinach plant creates a better balance of ecosystems, which is the adequacy of space and feed to support the life of fish and vegetable plants. The difference in the absolute weight gain of catfish on water spinach and Caisin on catfish culture in aquaponic ebb-tide system is influenced by root biomass factors. Root biomass is strongly influenced by the number of roots. The greater the number of roots, the more effective the absorption of culture waste, where more particles are caught or attached, thereby increasing the absorption of N and P nutrients so that the water spinach plant nutrition is fulfilled and the water spinach grows fertile. The water flow from the catfish culture media is used as a nutrient by vegetable plants, then the water that has biofiltration process is reused as an energy source to the fish culture media pond (Crooker & Contreras, 2010). The impact is water quality in the pond is maintained and the fish growth became faster. This is also mentioned by Setijaningsih and Suryanigrum (2015) which stated that water spinach is more effective in utilizing nutrients, so that the water that has undergone biofiltration will be accepted as a medium for increased the catfish growth.

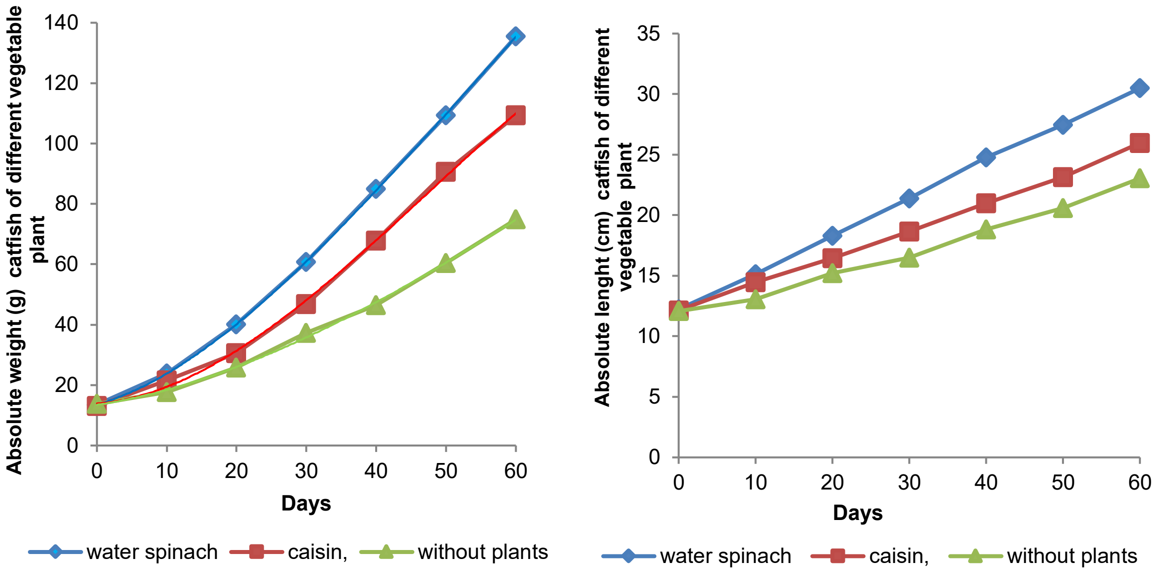


Figure 2. Absolute weight (g) and length (cm) of catfish during 60 days of culture

3.2. Survival Rate

Survival is the percentage of fish that live at the end of culture. After passing the 60-day rearing period. The results of the calculation of catfish survival rate in all treatments ranged from 58.58 to 87.41% (Figure 3). The results of the analysis of variance showed that treatment A, B, and C had a significant effect on survival ($P < 0.05$). The highest survival rate was found in treatment A. This is line with the observations of Effendi et al. (2015), who discovered that catfish treated with kale and a recirculating system had a greater survival rate than mustard greens and controls. After that, followed by treatments B and C. The difference in the average of survival rate in all treatments were influenced by water quality parameters such as temperature and dissolved. According to Monalisa and Minggawati (2010), temperatures that are too low or too high from the optimal range can cause the fish death because there is not enough energy produced for living activities. Survival is also affected by the process of nutrient absorption by vegetable roots. Many roots in vegetable are able to maintain good water quality, so fish's survival rate is high. The low survival rate in treatment C was due to the imbalance between energy for movement and energy for growth.

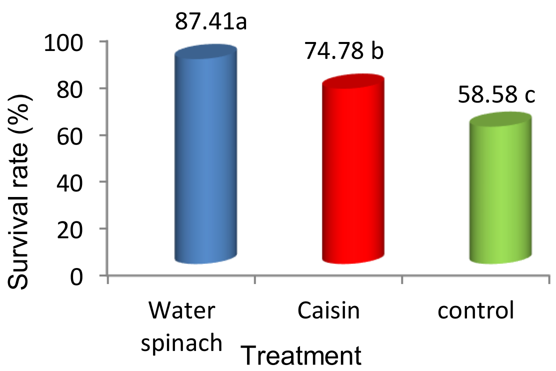


Figure 3. Catfish survival rate for 60 days of culture

3.3. Percentage of Reduction of TN and TP

The absorption percentage of Total Nitrogen (TN) and Total Phosphate (TP) in vegetable plants showed different results between treatments A and B, which were 61.56% and 54.43% for TN respectively and were 46.92% and 36% for TP the absorption values respectively. This results showed different with others experiment, Hum et al. (2008) mentioned that the absorption percentage of TN and TP are 41.5% and 75.5%, respectively, while Setijaningsih and Gunadi (2016) resulted 32.54% and 47.62% respectively. The results of the average reduction rate of N-Total and P-Total (%) in the treatment of retention time of 30, 60 and 120 minutes on water spinach yields 3.12±0.48, 8.33±0.35, 10.54±0.33% for N reduction respectively, and 13.05±0.48, 16.99±0.57, 38.24±0.82% for P reduction respectively (Setijaningsih and Umar 2015). Factors that affect the absorption ability are influenced by water discharge, substrate, types of vegetable plants, harvesting time and plant density greatly affect the absorption percentage (Enduta et al., 2009).

In intensive fish farming, the crucial problems is the high nitrogen waste and its derivatives produced from feces, urine, and uneaten feed residue. Ammonia which is a waste from feed residues and fish metabolism products (faeces and urine) is converted by bacteria found in plant growth media and fish rearing media into nitrite and nitrate. Meanwhile nitrate, ammonium, and phosphate are compounds needed for plant growth as a source of energy so that water quality conditions in aquaponic ebb-tide system going better. The results of the calculation of the percentage reduction of ammonia, nitrite and nitrate in water media were the highest achieved in treatment A followed by treatment B and treatment C, each of which was 25.36%; 23.97% and 16.74% for ammonia, 1.40%; 1.01% and 0.66% for nitrite and 17.56%, 11.34% and 6.66%. for nitrate. Ammonia reduction in treatments A and B showed in line between the number of plant stems and the utilization of wasted waste. In addition, the lush for plants. Planting density also provides conditions for a high level of competition, as a result, plants will always absorb higher nutrients. According to Setiadi et al. (2017), nitrate can be absorbed by plants ranging from 30–90% and phosphate ranging from 20–70%. The value of phosphate reduction in pond water media in each treatment was 1.40; 1.01 and 0.66% respectively.

3.4. Biomass of Vegetable Plants

Water spinach and caisin were harvested twice for 60 days of catfish culture. Biomass of the vegetable plants was obtained 2 times harvested from three replications (Figure 4). The weight of the water spinach (treatment A) was higher than that of the caisin plant in treatment B. This is possible because the water spinach plant has a large number of roots so it has enough space for a place to attach or catch bacteria. The more fertile the plant, the roots, stems and leaves of water spinach plants will also absorb more nutrients. In addition, plant fertility results in plants always being in a state of nutrient deficiency, resulting in high absorption. Overall, vegetable plants, both water spinach and caisin, create productive organic plants in catfish farming using an aquaponic ebb-tide system. This is because the element N was available from catfish feces, which contains microorganisms and a high quantity of dissolved organic matter, and it plays a important function in supporting roots in order to increase photosynthetic yields, which can then effect plant growth and development (Delaide et al., 2016).

3.5. Condition Factor

The condition factor (K) describes the physical and biological environmental conditions of the fish that change as a result of the interaction of feed factors, indicating variations in feed availability and serving as a general indicator of fish condition. Conditional factor information is critical for aquaculture system management because it identifies the specific conditions that occur in cultured fish (Araneda et al., 2008). The correlation between condition factors and the total length of catfish showed a high correlation factor in the treatment of water spinach and caisin, which was about 89% and 84% respectively, and a low correlation value

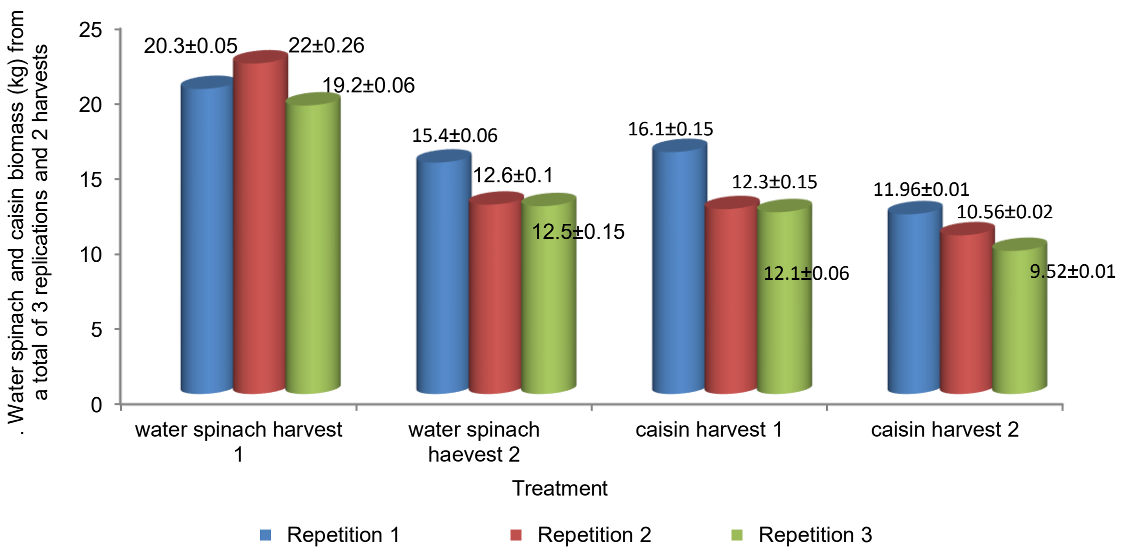


Figure 4. Water spinach and caisin biomass (kg) from 3 replications and 2 harvests during catfish culture

was found in the control (without treatment) which was 36% (Figure 5).

The correlation between condition factors and weight revealed a positive trend in weight as fish growth factors increased. The correlation value was low, at 35%; however, in the treatment of water spinach and caisin, the correlation values reached 98% and 96%, respectively (Figure 6). The size of the correlation value is a measure of an individual's thinness and thickness. Seasonal and cultural conditions are thought to cause variations in correlation values. Conditional factors, according to Jones et al. (1999), are the outcome of external factors such as food availability and seasonal conditions, as well as internal factors such as parasite problems and diseases.

3.6. Water Quality

a) Temperature

The difference of water quality allegedly giving an influence on fish life. Temperature parameters need to be measured and observed regularly because they affect the sustainability of fish and plant life in aquaponic cultivation. The temperature measured in all catfish rearing ponds decreased from day 0 to day 60. The measurement results show that the lower the temperature, the higher the pH value. A pH level that is too alkaline or too acidic will cause the fish to move passively. According to WHO, the temperature range for aquaponic fish and plant cultivation is 18 – 30 °C (FAO 2014). Several research results state that the water temperature in fish farming with aquaponic systems ranges from 28.5 – 30.2 °C (Wahyuningsih 2015); 27 – 29 °C (Delis 2016); and 27.90 – 30.70 °C (Setijaningsih and Umar 2015). The temperature range of rearing media in all rearing ponds is in the optimal temperature range for catfish. So that the temperature value is still supporting the survival and growth of fish.

b) pH value

The pH value is included as a chemical factor that affects the living conditions of organisms in the waters and plays an important role in physiological processes (Kwong et al.

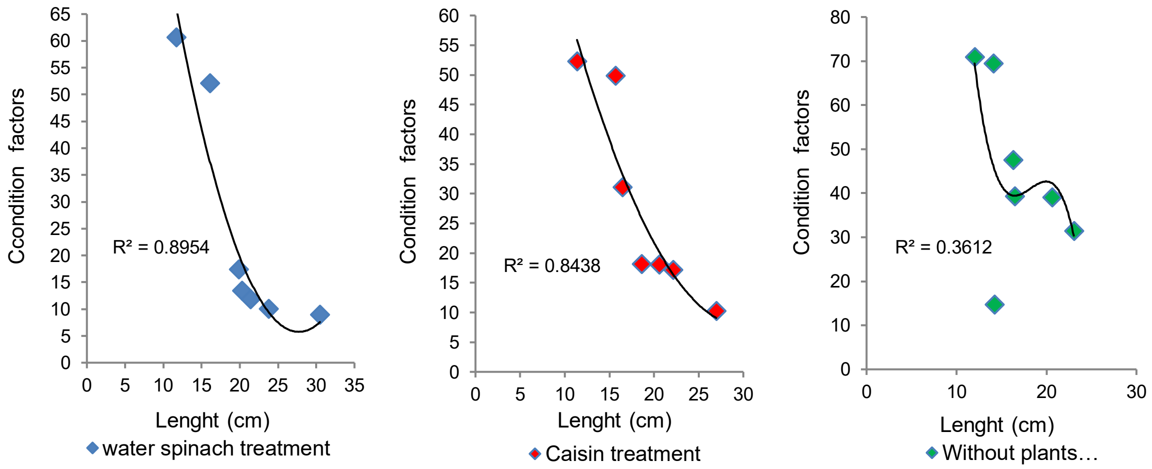


Figure 5. Correlation between condition factors and fish length

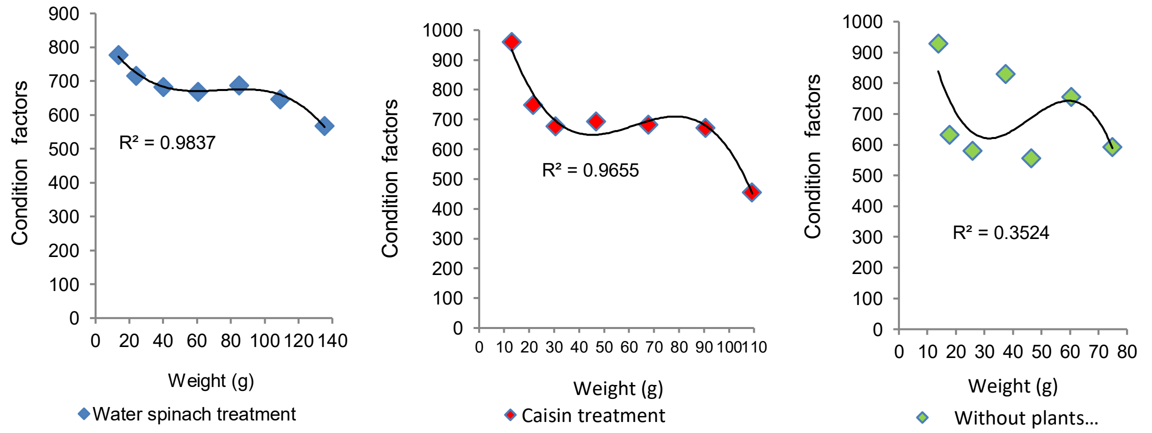


Figure 6. Correlation between condition factors and fish weight

2014). The pH value in all treatment pond units showed that the initial pH value of the water samples from the inlet, middle and outlet points was low, but over time the catfish rearing increased the pH value, with a range at the inlet being higher than at the midpoint of the pond and outlet. The range of pH values in all catfish rearing ponds is very volatile. These conditions are influenced by the temperature value. The highest pH value is found on day 60. High and low pH concentrations in water affect the ability of an aquatic organism to replace body ions and gases with water in the environment of living organisms. If there is a failure of the ion exchange process, it will cause sub-lethal effects such as decreased growth and death (Froese and Pauly, 2014).

c) Dissolved oxygen

The need for dissolved oxygen is influenced by the high and low temperature. At high temperatures, the dissolved oxygen demand of organisms in the ecosystem becomes high and the toxicity of ammonia becomes high so that it is dangerous for fish survival. The effect of temperature on plants is related to the ongoing process of photosynthesis. The results of the analysis of water quality from the three treatments of catfish rearing ponds are contained in appendix 1. Indicating that the highest dissolved oxygen concentration was found in the treatment of pond A. In this study, the availability of dissolved oxygen was different based on the types of plants, especially in the number of plant roots. The absorption process is influenced by rooting. High root biomass will be better in terms of removing or depositing contaminants and providing more space for bacteria and their activity in absorption.

In the filtering process there is a nitrification process, where in this process there is the use of oxygen by nitrifying bacteria which causes low oxygen solubility. According to Froese & Pauly (2014) the optimum range of dissolved oxygen in fish rearing ranges from 2-3 mg/L. However, the value of the level of oxygen consumption varies depending on the species, size, activity, sex, level of feed consumption, temperature, and dissolved oxygen concentration in the water. The oxygen concentration at the beginning of maintenance was low but until the 60th day was increased. This happened in all catfish rearing treatment pond units.

d) Ammonia, nitrite and nitrate

Ammonia (NH_3) is an inorganic nitrogen that dissolves easily in water. The breakdown of organic nitrogen (protein, urea, and feces) and inorganic nitrogen (decomposition of organic matter by microbes or fungus) are the sources of ammonia in the water (Boyd. 2015). This is demonstrated by the difference in fish and vegetable yields among treatments. The results of the ammonia concentration measurement in the water showed that the highest ammonia concentration during the study was observed in the treatment of catfish rearing without using vegetable plants, which was 0.608 mg/L. (Table 7). Because the waste accumulated over time, the ammonia content increased till the end of maintenance. However, the total ammonia level in the aquaponic system during the study was still safe, according to the Molleda (2007) criteria, which stated that freshwater fish were tolerant to total ammonia levels up to 2.0 mg/L. Furthermore, according to Boyd (2015), the normal quantity of ammonia in unpolluted waters is less than 0.25 mg L-1, whereas the concentration in polluted waters is less than 1.0 mg L-1. The water spinach treatment (a) had the lowest ammonia content, followed by the caisin plant treatment (b). The process of catfish culture in an aquaponic ebb-tide system running well is characterized by a decrease in ammonia concentration. Ammonia is converted to nitrite by *Nitrosomonas* bacteria, which is then oxidized to nitrate under aerobic conditions by *Nitrobacter* bacteria (Saptarini, 2010). Furthermore, the dissolved oxygen content influences the decrease in ammonia concentration. If the

Table 7. Ammonia, nitrit and nitrate rate for 60 days of culture

Parameters	Treatment	Days						
		0	10	20	30	40	50	60
Amonia	Water Spinach	0.0003	0.0127	0.0061	0.0120	0.2916	0.1876	0.178
	Caisin	0.0023	0.0004	0.0023	0.0058	0.3887	0.3687	0.323
	Without Plant	0.0004	0.0005	0.0078	0.0125	0.4425	0.4960	0.608
Nitrit	Water Spinach	0.079	0.026	0.051	0.055	0.038	0.035	0.0861
	Caisin	0.091	0.037	0.058	0.072	0.045	0.012	0.0999
	Without Plant	0.095	0.052	0.065	0.099	0.052	0.015	0.1075
Nitrat	Water Spinach	0.083	0.029	0.029	0.088	0.115	0.111	0.161
	Caisin	0.067	0.018	0.035	0.122	0.162	0.138	0.190
	Without Plant	0.058	0.021	0.031	0.109	0.157	0.142	0.217

dissolved oxygen in the fish rearing media is low, the ability to oxidize ammonia to other products ($NH_3 \rightarrow NH_4^+ \rightarrow NO_2^- \rightarrow NO_3^-$) is reduced.

The existence of nitrite illustrates the ongoing biological activity of overhauling organic matter with very low dissolved oxygen concentrations. On catfish-based rearing for 60 days, the measured nitrite concentration was in the range of 0.015 – 0.1075 mg/l (Table 7). The optimum nitrite concentration for fish rearing, according to Boyd and Zimmerman (2000), is between 0.1 and 0.7 mg/l. The nitrite concentration in treatment c was greater than in treatments a and b. The increase in nitrite concentration is thought to be caused by the process of nitrification, specifically the oxidation of ammonia to nitrite, which causes the concentration of nitrite to rise.

Nitrate (NO_3^-) is the most common type of nitrogen found in natural waterways, and it is an important nutrient for plant and algae growth. Nitrates are highly soluble in water and have a long half-life (Effendi, 2003). Under optimal conditions, the nitrification process by nitrifying bacteria transforms approximately 93-96 percent of ammonia to nitrate in the biofiltration unit (Tyson, 2007). In this research, the detected nitrate concentrations for each treatment ranged from 0.018 to 0.217 mg/l (Tab 7). This value is still included in the range for typical cultured water media, according to Lawson (1995), nitrate concentration in the waters must be less than 1 mg/l. The range of nitrate values in this culture is higher than the range of nitrite values; this is due to the nitrite in the water medium being oxidized to nitrate, which causes the nitrite concentration in the water to be less than the nitrate concentration.

4. Conclusions

An aquaponic ebb-tide system using water spinach and caisin plants could effectively eliminate intensive waste culture of Catfish (*Clarias* sp.), which showed with the best biological performance of weight gain and survival rate with water spinach treatment (73.63 g and 87.41% respectively). Total N and Total P absorption percentage also showed with water spinach treatment (38.72% and 54.43%). The highest weight and length conditional factor obtained at water spinach treatment with the value of 0.978 and 0.892.

References

Araneda, M., E.P. Perez, dan L.E. Gasca. 2008. White shrimp *Penaeus vannamei* culture in freshwater at three densities: condition state based on length and weight. Aquaculture, 283:13–18. doi: 10.1016/j.aquaculture.2008.06.030.

Andreeilee, B.F., Santoso, M., dan Nugroho, A. 2014. Pengaruh jenis kompos kotoran ternak dan waktu penyiangan terhadap produksi tanaman Caisin (*Brassica rapa* sub.chienensis) organik. Produksi Tanaman, 2 (3): 190-197.

Boyd CE. 2015. Water quality. Springer Science. 2(2): 133–136. New York (US).

Boyd, C., S. Zimmerman. 2000. Grow-out systems – Water Quality and Soil Management. Freshwater Prawn Culture: The Farming of *Macrobrachium rosenbergii*, chapter 14, page: 221- 238. Blackwell Publishing Ltd.

Crooker, P.C., & Contreras, J.O. 2010. Bioremediation of aquaculture wastes. Current opinion in biotechnology.21:313- 317.

Dauhan, R., Efendi, E., & Suparmono. 2014. Efektifitas sistem akuaponik dalam mereduksi konsentrasi amonia pada sistem budidaya ikan. e-Jurnal Rekayasa dan Teknologi Budidaya Perairan, Vol. III No 1 hal 297-302.

Delis PC. 2016. Fitoremediasi menggunakan akar wangi (*Vetiveria zizanioides* l. nash) dalam pengolahan limbah budidaya perikanan dengan sistem resirkulasi. [Tesis]. Bogor: Insitut Pertanian Bogor.

Delaide, B., Goddek, S., Gott, J., Soyeurt, H. and Jijakli, M.H. 2016. Lettuce (*Lactuca sativa* L. var. Sucrine) growth performance in complemented aquaponic solution outperforms hydroponics. Water, 8 (10): 467.

Edwards P. 2015. Aquaculture environment interactions: Past, present and likely future trends.Aquaculture.447:2–14.[diakses pada: doi: 10.1016/j.aquaculture.2015.02.001].

Effendi H, Utomo BA, Darmawangsa GM, Hanafiah DA. 2015. Waste water treatment of freshwater crayfish (*Cherax quadricarinatus*) culture with lettuce (*Lactuca sativa*). International Journal of Applied Environmental Sciences. 10(1): 409–420.

Effendi, H., Utomo, B.A., Darmawangsa, G. M., dan Karo-Karo, R.E. 2015. Fitoremediasi limbah budidaya ikan lele (*Clarias* sp.) dengan kangkung (*Ipomoea aquatica*) dan Caisin (*Brassica rapa* chinensis) dalam sistem resirkulasi. Ecolab, 9 (2): 47-104.

Enduta, A., Jusohb, A., Alib, N., Wan Nikc, W.N.S., & Hassand, A. 2009. Effect of flow rate on water quality parameters and plant growth of water spinach (*Ipomoea aquatica*) in an aquaponic recirculatingsystem. Desalination and Water Treatment, 5: 19-28.

[FAO] Food and Agriculture Organization. 2014. Small scale aquaponic food production integrated and fish farming. FAO Fisheries and Aquaculture Technical Paper. 589: 21–34.

Froese R, Pauly D. Editors. 2014. FishBase. World Wide Web electronic publication. www.fishbase.org.

Gunadi, B., Suryono, D.D., Krettiawan, H., Febrianti, R. & Lamanto. 2012. Efektivitas Sistem Heterotrofik untuk Pengendalian Limbah Amonia pada Budidaya Ikan Lele. (Prosiding Indoaqua - Forum Inovasi Teknologi Akuakultur 2012. Pusat Penelitian dan Pengembangan Perikanan Budidaya, Tahun 2012. ISBN 978-979-789-041-4.Hal.991-997.

Hum, H., Aoy, S., Yang, X.E.,& Lit, Q. 2008. Treating eutrophic water for nutrient reduction using an aquatic macrophyte (*Ipomoea aquatica* Forsskal) in a deep flow technique system. Aquaculture, 95: 607-615.

Indah L. S, Hendrarto, B., dan Soedarsono P. 2014. Kemampuan eceng gondok (*Eichhornia* sp.), kangkung air (*Ipomoea* sp.), dan kayu apu (*Pistia* sp.) dalam menurunkan bahan organik limbah industri tahu (skala laboratorium). Diponegoro Journal of Maquares, 3 (1): 1–6.

Jones, R.E., R.J. Petrell and D. Pauly C. 1999. Using modified length-weight relationships to assess the condition of fish. Aquacultural Engineering 20 : 261-276

Kwong RWM, Kumai Y, Perry SF. 2014. The physiology of fish at low pH: the zebrafish as a model system. Journal of Experimental Biology. 217: 651–662.

Monalisa, S.S dan I. Minggawati. 2010. Kualitas air yang mempengaruhi pertumbuhan ikan nila (*Oreochromis* sp.) di kolam beton dan terpal. Jurnal of Tropical Fisheries 5(2): 526-530.

Rumhayati B. 2010. Studi senyawa fosfat dalam sedimen dan air menggunakan teknik diffusi gradien in thin films. Jurnal Ilmu Dasar 11(2): 160–166.

Setijaningsih L dan Gunadi B, 2016. Efektivitas substrat dan tumbuhan air untuk penyerapan hara nitrogen dan total fosfat pada budidaya ikan berbasis sistem integrated multi-trophic aquaculture (IMTA). Prosiding Forum Inovasi Teknologi Akuakultur 2016.

Setijaningsih L. 2012. Pertumbuhan Ikan Mas (*Cyprinus carpio*) dengan Perbedaan Jarak Tanam Tanaman Kangkung *(Ipomoea aquatic*a) pada Sistem Akuaponik. Prosiding Indoaqua-Forum Inovasi Teknologi Akuakultur 2012, Makassar 8-11 Juni 2012.

Setijaningsih L, L. H. Suryaningrum. 2015. Pemanfaatan Limbah Ikan Lele (*Clarias batrachus*) Untuk Ikan Nila (*Oreochromis nilotitus*) Dengan Sistem Resirkulasi. Berita Biologi, 14 (3) : 287 – 293.

Setijaningsih L, Umar C. 2015. Pengaruh lama retensi air terhadap pertumbuhan ikan nila (*Oreochromis niloticus*) pada budidaya sistem akuaponik dengan tanaman kangkung. Berita Biologi Jurnal ilmu-ilmu Hayati LIPI. 14(3): 267–275.

Saptarini, P. 2010. "Efektivitas Teknologi Aquaponik Dengan Kangkung Darat (*Ipomoea reptans*) Terhadap Penurunan Amonia pada Pembesaran Ikan Mas". Skripsi. Departemen MSP FPIK, Institut Pertaian Bogor, Bogor.

Tyson, R.V. (2007). Reconciling pH for ammonia biofiltration in a cucumber/tilapia aquaponics system

using a perlite medium. [Disertasi]. University of Florida. 119 hal.

Veselý T, Tlustoš P, Száková J. 2011. The use of water lettuce (*Pistia stratiotes* L.) for rhizofiltration of a highly polluted solution by cadmium and lead. Inter. J. of Phytoremediation. 13(9): 859–872.

Wahap N, A Estim, YS Kian, S Seno and S Mustafa. 2010. Producing Organic Fish and Mint in an Aquaponic System, 319. Borneo Marine Research Institute, Sabah, Malaysia.

Wahyuningsih S. 2015. Pengolahan Limbah Nitrogen Dari Kegiatan Budidaya Ikan Nila (*Oreochromis niloticus*) Pada Sistem Akuaponik. [Tesis]. Bogor: Insitut Pertanian Bogor.