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The effectiveness of the use of filter on the tilapia growth performance, number of *Nitrosomonas* sp., and water quality in aquaponics systems

Efektivitas penggunaan filter terhadap performa pertumbuhan ikan nila, jumlah *Nitrosomonas* sp., dan kualitas air dalam sistem akuaponik

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ABSTRACT

This study aims to determine the most effective type of living filter media for the bacteria *Nitrosomonas* sp. in order to improve water quality in aquaponics systems. The method used in this study was completely randomized design, consisting of five treatments and each was repeated three times. The treatments were: A (without addition of filter media), B (addition of palm fibers, silica sand, and activated carbon), C (addition of palm fibers, silica sand, gravel, and activated carbon), D (addition of palm fibers, silica sand, rocks, and activated carbon), and E (addition of palm fibers, silica sand, bioball, and activated carbon). Parameters measured were: 1) the number of *Nitrosomonas* bacteria, 2) water quality (ammonia, nitrate, and phosphate); and, 3) productivity of fish and Chinese spinach. Data were analyzed using a descriptive method. The findings show that the highest number of bacteria was found in treatment E, 9.29×10^5 CFU/mL on the bioball filter media and 4.43×10^5 CFU/mL in rearing tanks. The best water quality was in treatment B, with a concentration of ammonia of 0.17 mg/L, nitrate of 0.33 mg/L, and phosphate of 0.54 mg/L. Plant productivity was the best in treatment B in which the average length and weight reach 48.1 cm and 11.1 grams of plant/week, respectively. The best fish growth was seen in treatment C with an absolute growth rate of 4.4 grams and a specific growth rate of 1.9%/day. The recommended filter was made of *Arenga pinnata* fibers, silica sand, gravels, and active carbon of about 2 cm thick each.The results showed that the type of filter on the aquaponic system had an effect on the amount of *Nitrosomonas* sp. in water, water quality, and the productivity of Chinese spinach.

Keywords: aquaponics, filter, water quality, *Nitrosomonas* sp.

ABSTRAK

Penelitian ini bertujuan untuk menentukan jenis filter yang paling efektif sebagai media hidup bakteri *Nitrosomonas* sp. sehingga menghasilkan kualitas air yang baik dalam sistem akuaponik. Rancangan percobaan yang digunakan adalah rancangan acak lengkap, yaitu lima perlakuan dengan tiga kali pengulangan. Perlakuan dalam penelitian ini meliputi: A (tanpa penambahan media filter), B (penambahan media filter ijuk, pasir silika, dan karbon aktif), C (penambahan media filter ijuk, pasir silika, kerikil, dan karbon aktif), D (penambahan media filter ijuk, pasir silika, batu, dan karbon aktif), dan E (penambahan media filter ijuk, pasir silika, *bioball*, dan karbon aktif). Parameter yang diamati adalah: 1) jumlah bakteri, 2) kualitas air (meliputi amonia, nitrat, dan fosfat), serta 3) produktivitas ikan dan kangkung air. Data hasil penelitian dianalisis secara deskriptif. Hasil penelitian menunjukkan bahwa jumlah kelimpahan bakteri *Nitrosomonas* sp. tertinggi terdapat pada perlakuan E, yaitu $9{,}29\times10^5$ CFU/mL pada media filter *bioball* dan $4{,}43\times10^5$ CFU/mL pada media air pemeliharaan. Adapun kualitas air terbaik yaitu pada perlakuan B dengan konsentrasi amonia 0,17 mg/L, nitrat 0,33 mg/L, dan fosfat 0,54 mg/L. Produktivitas kangkung terbaik yaitu pada perlakuan B dengan panjang rata-rata mencapai 48,1 cm dan bobot tanaman 11,1 gram/minggu. Pertumbuhan ikan terbaik terdapat pada perlakuan C, dengan nilai pertumbuhan ikan mutlak sebesar 4,4 gram dan pertumbuhan spesifik 1,9%/hari. Hasil penelitian menunjukkan bahwa jenis filter pada sistem akuaponik berpengaruh terhadap jumlah *Nitrosomonas* sp. dalam air, kualitas air, dan produktivitas tanaman kangkung. Filter yang disarankan dari hasil penelitian ini adalah yang tersusun atas ijuk, pasir silika, batukerikil, dan karbon aktif masing-masing setinggi ±2 cm.

Kata kunci: akuaponik, filter, kualitas air, *Nitrosomonas* sp., produktivitas tanaman

INTRODUCTION

Aquaponics is an aquaculture technology that integrates the cultivation of fish and plants (Danaher *et al*., 2013). In principle, aquaponics is a biointegration between aquaculture activities and hydroponic plants or vegetables that can be applied in a condition where land and water resource are limited, including in urban areas (Hermawan, 2015). In addition, waste produced by the aquaculture, such as unconsumed feed or fish feces can be used to fertilize plants with the help of nitrifying bacteria. Cultivation using aquaponics system is already done in some species of fish such as tilapia. Tilapia has favorable properties, i.e. it is easy to be cultured, grows rapidly, and is easy to grow in intensive culture system (Nugroho *et al*., 2013).

In general, aquaponics uses recirculating systems. Mulyadi and Yani (2014) stated that water recirculation in aquaculture provides biological balance, stabilizes temperature, assists oxygen distribution, and reduces the accumulation of hazardous materials. Considering a few clean water sources nowadays, it is necessary to maintain water quality in aquaculture, especially in the recirculation system. One of the ways is by using water filters. Traditionally, filters refine freshwater using certain media to produce clean water. According to Samsudari and Wirawan (2013), the filter in the recirculation system serves as a mechanical function to purify water and a biological function to convert ammonia into nitrate. Several commonly used filters in recirculation system are physical, chemical, and biological filters, such as zeolites, gravestone Taiwan *Anodonta woodiana* and lettuce *Lactuca sativa* (Putra *et al*., 2011). The aim of this study was to discover the best type of filter that is able to produce appropriate water quality that supports fish cultivation productivity in an aquaponics system that integrates tilapia fish and Chinese spinach cultivation.

MATERIALS AND METHODS

Experimental design

This study was conducted from March to May 2016 at the Ciparanje Aquaculture Laboratory, Faculty of Fisheries and Marine Science, Padjadjaran University. Water quality was tested at the Marine Resources Management Laboratory, Faculty of Fisheries and Marine Science, Padjadjaran University. Bacteria were tested at the Microbiology Laboratory, Faculty of Mathematics and Natural Science, Padjadjaran University. The experimental design used was a completely randomized design consisting of five treatments, repeated three times. The treatments are: A (without filter (control)), B (filter made of *Arenga pinnata* fibers, silica sand, and active carbon), C (filter made of *Arenga pinnata* fibers, silica sand, gravels, and active carbon), D (filter made of *Arenga pinnata* fibers, silica sand, corals, and active carbon), and E (filter made of *Arenga pinnata* fibers, silica sand, bioball, and active carbon). Parameters measured were: 1) the number of *Nitrosomonas* bacteria, 2) water quality (ammonia, nitrate, and phosphate); and, 3) productivity of fish and Chinese spinach. Each filter treatment has two cm thick. The layout of the filter used in this study is shown in Figure 1.

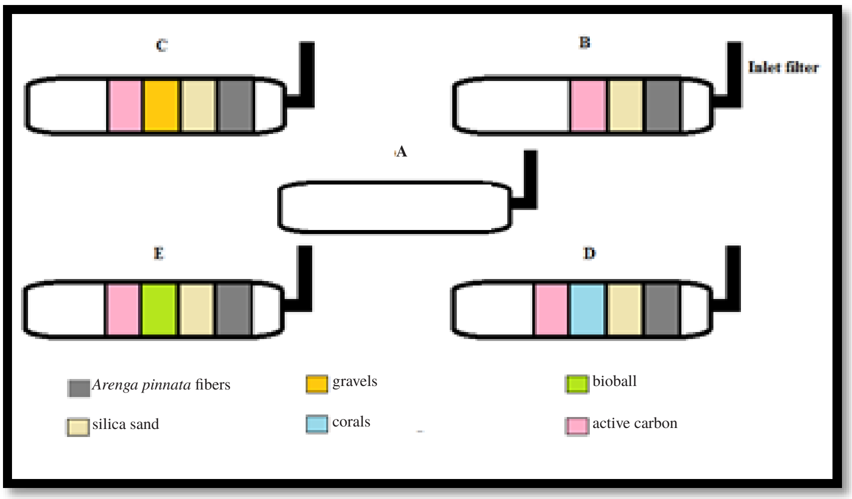

Figure 1. Filter composition layout. Treatment A uses no additional filters. Treatment B uses filters is palm fibers, silica sand, and activated carbon. Treatment C uses filters is palm fibers, silica sand, gravel, and activated carbon. Treatment D uses filters is palm fibers, silica sand, rocks, and activated carbon. Treatment E uses filters is palm fibers, silica sand, bioball, and activated carbon.

Preparation

Preparation of containers and filters

The preparation stage involved cleaning container ponds, draining ponds, the installation of tarps sizing 1×1 m, and filling water. The container used in this study was a concrete pond sizing 2×1 m which was then covered using 100×60 cm plywood and tarpaulin with a size of 1×1 m. Plants were cultivated in containers equipped with a styrofoam. The styrofoam was perforated with a 10 cm interval between holes to prevent the plants from sinking.

The filter used contained physical filtering media (*Arenga pinnata,* fibers, and silica sand), chemical filtering media (active carbon), and biological filtering media (gravels, corals, and bioball). Each filter material was inserted into a PVC pipe (diameter 2 inches, height 30 cm) with a thickness of about 2 cm each. The order of the materials was physical, biological, chemical, and another physical (only *Arenga pinnata* fiber) filtering media, respectively. The aquaponics system design used is depicted in Figure 2.

Acclimatization of fish

Acclimatization of fish was done so that the fish could adapt to the new environment would not be stressed when this study was conducted. Acclimatization was done for 4–8 days. After the fish had been able to adapt to the new environment, the fish were transferred into the rearing pond.

Planting Chinese spinach

The cultivation of the Chinese spinach was performed by moving two-week-old Chinese spinach from the initial cultivation media (soil) into the new planting media (rockwool).

Aquaponics system design

In this study, fifteen 1x1 m tarp pools were used. The pools were filled with water until it reached 30 cm. The stocking density of each pond was 100 fish/m^2. The filter was installed by tying it on a bamboo under the water gutter using wires. Before starting the aquaponics system, the initial length and weight of the fish and the length of the Chinese Spinach were measured. The plants were then moved to the cultivation media with an interval of 10 cm between plants.

Implementation

This study was conducted over 42 days. The condition of the fish, plants, and also filters were monitored every day. The fish were fed at a feeding rate of 5% of body weight three times a day (morning at 09:00 am, daytime at 01:00 pm, and the afternoon at 05.00 pm). Fish weighed and measured every two weeks. The water quality was monitored every week. Harvesting plants and counting the number of bacteria were carried out at the end of the study.

Parameters

Water quality parameters

Water quality parameters observed were temperature, acidity (pH), dissolved oxygen (DO), ammonia, phosphate, and nitrate (Nugroho & Tanjung, 2014; Boyd & Linchtkoppler, 1982).

The number of Nitrosomonas sp. bacteria

The nitrifying bacteria counted in this study was *Nitrosomonas* sp. The bacteria inoculated were collected from the pond water and from the biological filtering media used. In the middle of the study, inoculation was only done for bacteria from the pond water while at the end of the study, the inoculation was performed for bacteria from water and biological filtering media, i.e. gravels, corals, and bioball. The selective media used is a specific medium for *Nitrosomonas* (Elbanna *et al*., 2012). The observation was conducted for 2 weeks for each nitrifying bacterial inoculation.

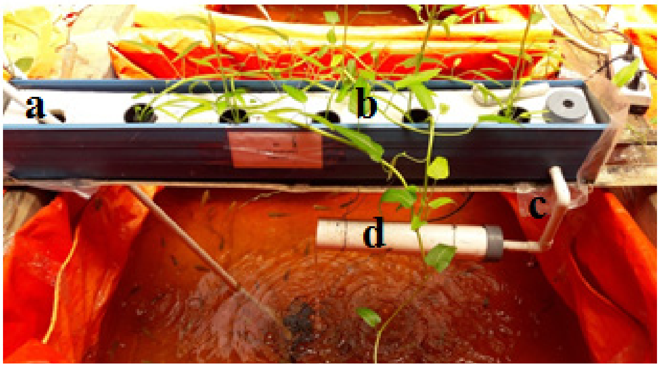

Figure 2. Aquaponics system design. (a) inlet channel, (b) Chinese spinach, (c) outlet channel, (d) filter.

The counting of the bacteria was done by total plate count (TPC) (Salosa, 2013) using the following formula:

Bacterial samples were derived from the pond water and the used biological filter media. While the research conducted at the end of the inoculation of bacteria from water and filter media. Selective medium is used for *Nitrosomonas* sp (Elbanna *et al*., 2012). These observations were made during 2 weeks for one inoculating bacteria nitrification bacteria count was calculated using total plate count (TPC) (Salosa, 2013) with the formula:

The number of bacteria (CFU/mL)
= the number of colony × 1/dilution factor

Fish and plant growth

Observations of the fish growth (sampling) were done by taking the fish at a number of 30% of the total population in each pond. After sampling, an adjustment in the amount of feed was made for the following week.

Weight gain and growth rate of the fish was calculated using the following formulas (Andriani *et al*., 2017):

a. Absolute growth

$$PM = W_2 - W_1$$

Note:
PM = Absolute growth (g)
W_1 = Initial weight of fish (g)
W_2 = Final weight of fish (g)

b. Specific growth rate

$$SGR = (\ln W_2 - \ln W_1)/T \times 100$$

Note:
SGR = Specific growth rate (%/day)
W_1 = Initial weight of fish (g)
W_2 = Final weight of fish (g)
T = The number of days during rearing period (days)

Observation of plant growth was conducted at the beginning and the end of the study. At the beginning of the study, experimental plants were weighed using a digital scale, then measured their length with a ruler before they were transferred into the new planting medium. In the middle of the study conducted in the same manner with the beginning but do crop plants by cutting the stem of the plant and be left high as about 5 cm. Harvesting the middle of this research is done to prevent the occurrence of plant death because at that time the plant has reached the size ready for consumption. At the end of the study conducted the same as in the beginning and in the middle of research. Plant weight gain was calculated by the same calculation method with the weight of fish, while the growth rate of plants is calculated by measuring the length of the plant.

The observation on the plant's growth was performed at the start, middle and at the end of the study. In the start of the study, the observation was performed by weighing the plants using a digital scale and measuring the length of the plant using a ruler before they are moved to a new planting media. In the middle of the study, the same measurements were performed but they were performed on the harvested plants. The plants were harvested by cutting the stem and left about 5 cm stem from the remaining plants. The harvesting in the middle of the study was performed to prevent plant death because at that time the plants had reached the height of ready-to-consume Chinese spinach. At the end of the study, the measurements were performed using the same method used at the start and in the middle of the study.

Data analysis

The effects of treatment on fish and plant growth were analyzed descriptively, meanwhile, water quality analyzed descriptively compared to the standards set out in the Government Regulation No. 82 of 2001 and water standards for Nile tilapia culture issued by Sukabumi Freshwater Aquaculture Development Center in 2016.

RESULTS AND DISCUSSION

Water quality parameters

The water quality is one of the parameters that can use to indicate the filter efficiency. The water quality during the study was shown in Table 1. The concentration of ammonia in this study is between 0.11 and 0.20 mg/L, while the acidity was between 7.47 and 7.52. According to the water standards (Sunarma, 2016), the concentration of dissolved ammonia in the rearing tanks is within acceptable limits for Nile tilapia culture; the threshold is <0.2 mg/L, while the optimum acidity for Nile tilapia culture is between 6.5 and 8.5. Ammonia in water is proportional to its acidity. Acidity tends to increase the concentration of ammonia, which is harmful to fish whereas basicity tends to increase the probability of ammonium hydroxide (NH_4OH) forming. The low concentration of

Table1. Water quality of the study

Treatment	Water quality					
	Ammonia	Nitrate	Phosphate	DO	pH	Temperature
A	0.11	0.76	1.23	4.3	7.5	25.6
B	0.17	0.33	0.54	5.4	7.5	26.2
C	0.18	0.58	0.44	6.1	7.5	26.1
D	0.20	0.60	0.67	4.2	7.5	26.1
E	0.17	0.49	0.73	4.7	7.5	26.1
Standard	< 0.2 mg/L	10–20 mg/L	< 1 mg/L	> 5 mg/L	6.5–8.5	25–30 °C

Note: Treatment A uses no additional filters. Treatment B uses filters is palm fibers, silica sand, and activated carbon. Treatment C uses filters is palm fibers, silica sand, gravel, and activated carbon. Treatment D uses filters is palm fibers, silica sand, rocks, and activated carbon. Treatment E uses filters is palm fibers, silica sand, bioball, and activated carbon.

ammonia is linked to the biological filter media used. Compared to physical and chemical filter media, biological media plays a more significant role in improving water quality as it harbors the necessary bacteria to decompose harmful materials dissolved in water, among which is ammonia. The value of ammonia in this study was lower than that of Mulqan *et al.* (2017) in Nile tilapia fish in aquaponic system with Chinese spinach that is 0.648–0.974 mg/L.

The concentration of nitrate in this study is between 0.33 and 0.76 mg/L. Government Regulation No. 82 of 2001 sets out the safe concentration of nitrate in Class II and Class III water as 10 mg/L and 20 mg/L, respectively. The concentration of nitrate in this study is lower when compared to the research conducted Nuwansi *et al.* (2017), whose concentration is between 1.66 and 3.36 mg/L.

Phosphate found in the rearing tanks are from residual feed and fish feces. The concentration of phosphate in this study is between 0.44 and 1.23 mg/L. Concentrated levels of phosphate in water are caused by the accumulation of residual feed and metabolic wastes, in turn decreasing dissolved oxygen levels (Lestari *et al.*, 2015). The concentration of phosphate in water is proportional to the population of phytoplankton in it. Government Regulation No. 82 of 2001 defines the safe concentration of phosphate in Class II and Class III water as 0.2 mg/L and 1 mg/L, respectively. This is in line with the results of research Hasan *et al.* (2017) which states that the treatment with aquatic plants in aquaponic reduce the phosphate concentration, due to phosphate being used by the plant as a nutrient.

The level of dissolved oxygen in this study is between 4.2 and 6.1 mg/L. The level of dissolved oxygen in some of the treatments are below acceptable amounts as the volume of the filter container is not balanced with the volume of water handled by the system. Higher levels of dissolved oxygen are is beneficial to the growth of Nile tilapia spawns. Fish requires dissolved oxygen to sustain its respiratory and metabolism functions. Low levels of dissolved oxygen hinder fish’s respiratory functions which in turn negatively affects its metabolism. Oxygen is a limiting factor, wherein insufficient oxygen affects all and every of the fish’s activities and growth. Moreover, an acute lack of oxygen causes death (Yurisma *et al.*, 2013). According to the Water Standards (Sunarma, 2016), the optimum level of dissolved oxygen for culturing Nile tilapia is >5 mg/L.

In this study, the water temperature between 25.6 and 26.2 °C. The temperature range is within the acceptable limits set out in the Water Standards (Sunarma, 2016). The optimum water temperature for Nile tilapia culture is 25–30 °C. Water temperature directly affects, among others, fish growth, dietary needs, and feed conversion efficiency (Zou *et al.*, 2016).

The number of Nitrosomonas sp.

Nitrifying bacteria in the nitrogen cycle is crucial, as it affects water quality. The number of nitrifying bacteria present in water determines the concentrations of ammonia, nitrite, and nitrate. The number of bacteria is shown in Table 2.

Treatment E contains the highest number of bacteria: 9.29×10^5 CFU/mL on the biological filter and 4.43×10^5 CFU/mL in the rearing tank. The difference in the number of bacteria in each treatment caused by differences in the available surface area. Treatment E uses bioball whereas treatment C uses gravel and treatment D uses rocks. Bioball offers greater surface area compared to gravel and rocks. Factors which affect bacteria

Table 2. Number of *Nitrosomonas* sp. in individual treatments

Treatment	Number of bacteria (CFU/mL)	
	In water	On filter
A	3.78×10^4	-
B	3.17×10^4	-
C	1.45×10^4	8.01×10^5
D	7.12×10^3	4.20×10^5
E	4.43×10^5	9.29×10^5

Note: Treatment A uses no additional filters. Treatment B uses filters is palm fibers, silica sand, and activated carbon. Treatment C uses filters is palm fibers, silica sand, gravel, and activated carbon. Treatment D uses filters is palm fibers, silica sand, rocks, and activated carbon. Treatment E uses filters is palm fibers, silica sand, bioball, and activated carbon.

growth on filters are, among others, filter surface area, water temperature, water pH, dissolved oxygen levels, and sunlight intensity (FAO, 2014). The size of the surface area of a filter media is proportional to the number of bacteria it harbors.

The number of bacteria in treatment E was in line with low ammonia concentrations at the end of the study. The number of bacteria present determines the concentrations of ammonia and nitrate in water. Weekly readings of ammonia concentration in treatment E show a steady decline compared with other treatments, due to the use of bioball as the biological filter in the treatment. Bioballs made of PVC which have a specific surface area and large cavities, harboring greater numbers of bacteria and minimizes the risk of obstruction (Alfia *et al*., 2013).

Analysis on the number of bacteria was aimed to determine the most effective biological filter to support the growth of nitrifying bacteria. The inoculated bacteria was *Nitrosomonas* sp., a nitrifying bacteria which oxidizes ammonia into nitrite. Based on observation, *Nitrosomonas* sp. are circular and white in color. Identification of bacteria using a specific medium for *Nitrosomonas*, so it can be ascertained bacteria identified was *Nitrosomonas*.

The biological role of bacteria growth in the filter media is to oxidize nitrogen from metabolism and fish feces into fertilizer. Nitrogen in water typically takes the form of nitrogen gas (N_2), ammonia (NH_3), ammonium (NH_4^+), nitrite (NO_2^-), nitrate (NO_3^-), and organic nitrogen. Organic nitrogen is a coordination complex of a number of materials such as amino acids, amino sugars, and protein (polymer) which are ready to be oxidized into ammonium by bacteria in water (Zou *et al.*, 2016).

The process of nitrification consists of two stages. The first stage is nitritation, wherein ammonia (NH_3) is oxidized into nitrite (NO_2^-) by ammonia-oxidizing bacteria (AOB), namely *Nitrosomonas* sp. The second stage is nitration, wherein nitrite (NO_2^-) is oxidized into nitrate (NO_3^-) by nitrite-oxidizing bacteria (NOB), namely *Nitrobacter* sp. (FAO, 2014). The reaction is as follows:

$$NH_4^+ + 1.5O_2 \rightarrow NO_2^- + 2H^+ + 2H_2O + 84 \text{ kcal/mole ammonia} \quad (1)$$

$$NO_2^- + 0.5O_2 \rightarrow NO_3^- + 17 \text{ kcal/mole nitrite} \quad (2)$$

$$NH_4^+ + 2O_2 \rightarrow NO_3^- + 2H_2^+ + H_2O + \text{ energy} \quad (3)$$

Nitrifying bacteria optimally growth in temperatures from 17–34 °C, pH 6–8.5, and dissolved oxygen 4–8 mg/L (FAO, 2014). The number of bacteria on the biological filter media is higher compared to that of Nurhidayat and Ginanjar (2010), i.e. 5.5×10^3 CFU/mg on the bioball and 2.64×10^3 CFU/mg on the zeolite (1 mL is equivalent to 10 mg, thus 9.29×10^5 CFU/mL is equivalent to 9.29×10^4 CFU/mL).

Fish and plant growth

Fish growth

Fish growth observed during the study that the rate of growth and absolute growth (Table 3). Specific growth rate was lower when compared to the research conducted Alfia *et al.* (2013) ranged from 2.6 to 3.3%. The difference in the percentage of the specific growth rate is presumably because stocking density used is different so it affects the fish's ability to digest food. High stocking density which can cause space to be limited so as hamper fish for food (Alfia *et al*., 2013). Fish growth in aquaponic is affected by the existences of probiotic microbes in the water. It was proven by the increasing specific growth of catfish-water spinach in the aquaponic system, namely 2.386%, with using probiotic (Primashita *et al.,* 2017). Another factor that affects fish growth is water quality. Yildiz *et al.* (2017) state the water quality, which directly affects fish health and well-being, is the key factor to be considered in all aquaponic systems.

The magnitude of the growth rate is directly proportional to the magnitude of absolute growth. The growth of tilapia fish on the best available treatment A with a growth rate of 2.1% per day and absolute growth of 5.8 grams. This shows that the use of filter is unable to increase the fish growth in an aquaponics system.

Table 3. The effect of treatment on the growth of fish

Treatment	Growth	
	Absolute (gram)	Specific (%/day)
A	5.8 ± 0.76	2.1 ± 0.10
B	3.9 ± 0.42	1.8 ± 0.10
C	4.4 ± 0.96	1.9 ± 0.15
D	3.4 ± 0.87	1.7 ± 0.11
E	3.4 ± 0.06	1.7 ± 0.05

Note: Treatment A uses no additional filters. Treatment B uses filters is palm fibers, silica sand, and activated carbon. Treatment C uses filters is palm fibers, silica sand, gravel, and activated carbon. Treatment D uses filters is palm fibers, silica sand, rocks, and activated carbon. Treatment E uses filters is palm fibers, silica sand, bioball, and activated carbon.

Plant growth

Based on the results of studies measuring the height of the plant obtained an average at 63.2 cm (Table 4). This is presumably due to differences in density are used. High plant density can lead to competitive absorption of nutrients by plants so that the plants cannot grow optimally.

The result showed that in the aquaponics system, water plant has a different response in growth. Andriani *et al*. (2017) showed that the length of water-spinach reached 20–25 cm, while on lettuce the harvesting size was reached at the fourth week with average length 27.28 cm. The Chinese spinach weights increase in an aquaponic biofilter system is influenced by the degree of utilization of nutrient derived from the degradation of residual feed and fish metabolism waste product by nitrifying bacteria (Muhammad *et al.,* 2016).

The increase in plant's length and weight does not have positive correlation due to the influence of other factors on growth, such as nutrients in the form of phosphate and nitrate and light intensity. This is apparent in treatment C where the light intensity was higher than the nutrients absorbed, leading to a condition where the plants in this treatment had the tallest height but not the biggest weight.

CONCLUSIONS

Based on its findings, this study concludes that the use of silica sand, gravels, and active carbon (treatment C) as filter media is the most effective in improving water quality so as to support aquaculture and hydroponics. The use of such filter media resulted in a concentration of ammonia of 0.18 mg/L, phosphate of 0.44 mg/L, and nitrate of 0.58 mg/L. The number of *Nitrosomonas* bacteria were 1.45×10^4 CFU/mL on the filter media and 8.01×10^5 CFU/mL in the water. The productivity of plants is high, reaching a length and weight of 63.2 cm and 7.5 grams, respectively, while the absolute growth rate of 4.4 grams and a specific growth rate of 1.9 %/day.

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Table 4. Effect of treatment on plant growth

Treatment	Height (cm)				Weight (gram/week)			
	Initial	Middle	Final	Average	Initial	Middle	Final	Average
A	8.1	75.2	20	34.43	0.9	15.4	3.3	6.5
B	9.4	96.8	76.7	61.1	1.0	18.1	24.4	14.5
C	10.8	85.9	92.8	63.2	1.1	8.3	13.2	7.5
D	11.6	90.5	47.7	50	1.3	10.2	6.7	6.1
E	11.9	104.2	48.2	55.1	1.1	5.7	24.1	13.6

Note: Treatment A uses no additional filters. Treatment B uses filters is palm fibers, silica sand, and activated carbon. Treatment C uses filters is palm fibers, silica sand, gravel, and activated carbon. Treatment D uses filters is palm fibers, silica sand, rocks, and activated carbon. Treatment E uses filters is palm fibers, silica sand, bioball, and activated carbon.

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