# PHYSICO-CHEMICAL WATER QUALITY OF CIRCULATING WATER IN DOUBLE TIER PLANTING TRAY AQUAPONIC SYSTEM

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**ABSTRACT**

*Aquaponic is a concept of cultivation of plant with soilless media through integration of fish. In this integration system, the water used for fish culture is being circulated to irrigate the plant. Waste and residue from fish tank are used for plant growth. This system introduces the concept of zero waste farming, environmental friendly and limited space agriculture. However, the relationship between water qualities based on growth substrate used must be understood. The growth media has two functions, which are as a growing substrate and bio filter. A research has been carried out in order to identify the selected physico-chemical water quality parameters presence at different growth substrate. Three treatments were used as growing substrates, which are control treatment (T1), gravel (T2) and coconut husk with charcoal combination (T3). Water spinach (Ipomoea aquatica) and tilapia (Oreochromis niloticus) were used in this study. Water spinach was cultivated in planting trays that were arranged in double tier at an aquaponic system. Water quality parameters were determined in-situ along the experimental period and taken at the inflow and outflow points of the system. Parameters tested were pH, temperature (T), dissolved oxygen (DO), electrical conductivity (EC), salinity (S) and total dissolved solid (TDS). Physico-chemical water quality at the tested system was compared to the optimum water quality for tilapia and water spinach growth. The experimental results showed that gravel was the best growth substrates that gave an optimum value of physico-chemical water quality parameters besides it significantly reduced total solid in water. There was no significant difference ($p < 0.05$) of all parameters among treatments. This paper could provide the knowledge on better agriculture water management towards sustainable agriculture.*

Keywords: Physico-chemical water quality, aquaponic system, growth substrate.

## Introduction

Aquaponic is the combination of aquaculture (the rising of fish in synthetic tanks) and hydroponic (the growing of plants without soil medium). It is a system to balance three groups of organisms in an ecosystem that includes fish, plants and bacteria (Somerville et al., 2014). The plants can be grown on soilless medium that will reduce the surface area needed for growing plants and other agriculture activities. The water will be treated from the toxic waste products that are removed by the fish and this will allow rising in large quantities in the recirculating system (Rakocy et. al., 2006). The plant will grow rapidly with aquaponic system through dissolved nutrients from fish excretions and nutrients generated from the microbial breakdown of fish wastes (Bishop et al., 2009).

In a recirculating aquaculture system, essential elements for plant growth are provided from the richness of liquid in plant nutrients derived from fish manure, decomposed organic matter, and nitrogenous waste excreted from fish fertilizers in hydroponic beds (Fox et al., 2012). Aquaponic system provides an artificial, controlled environment in optimizing the growth performance of fish and soil-less plant media. Besides, recirculating aquaculture system is also important in controlling the water quality, the production schedule as well as conserving water resources. Therefore, aquaponic is a multi-faceted system in which one component affects other components.

In addition, aquaponic system has several advantages in which it uses inorganic nutrient solutions as compared to the other systems of recirculating aquaculture and hydroponic (Samir, 2010). The hydroponic component serves as a bio filter, and therefore a separate bio filter is not needed as in other recirculating systems. Aquaponic system requires less water quality monitoring than individual recirculating systems for fish or hydroponic plant production. This system will increase the potential of the profit due to free nutrients for plants, less water requirements, elimination of a separate bio filter, and shared costs for operation and infrastructure (Rakocy et al., 2004).

Water quality parameters have to be favourable for all three groups of organisms (fish, plants and nitrifying bacteria) that rely on the same recirculating system for optimum growth. Each water quality parameter has a specific tolerance range and impact for each organism in an aquaponic unit (Somerville et. al., 2014). To maintain a healthy and balance ecosystem with water quality parameters, the requirements for growing fish, vegetables and bacteria simultaneously must be fulfilled. In order to meet some criteria and to keep the system properly functioning, the manipulation of water quality is needed.

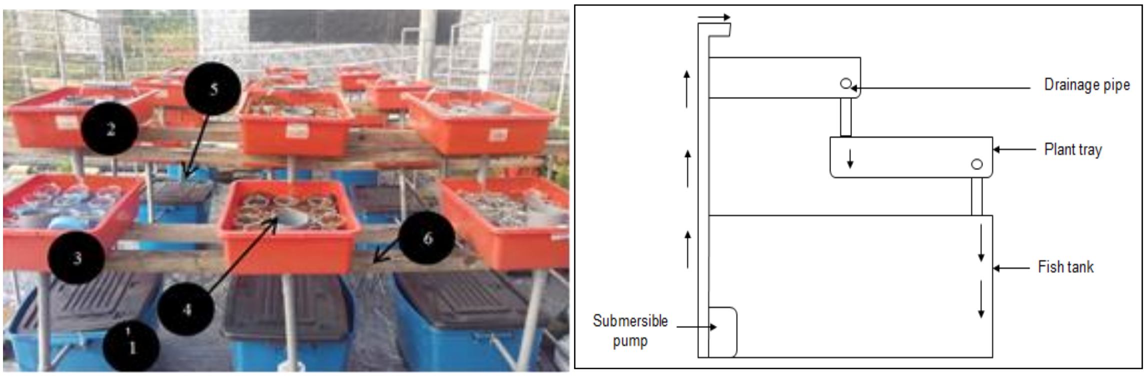
Uneaten feed of fish and waste from fish become the major issues which can influence water quality parameter of circulating water. Feeding should optimize the rapid growth from feed availability while amount of feed waste can be minimized. The major challenge for aqua culturist is maintaining water quality at preferable condition. The double tier planting tray aquaponic system does not widely be studied especially on the suitability of physic-chemical water quality. The different level of water flow may give changes towards the crop growth. Besides that, growing substrate used may contribute another factor that influence physic-chemical water quality.

Therefore, this study is aimed to evaluate the physico-chemical water quality in fish tanks cultivation and planting trays during the experiments. This study provides useful information on managing recirculating water in aquaponic system besides providing information on the best growth media to be used with a good water quality monitoring especially for multi-layer planting tray aquaponic system.

**Materials And Method**

The study was conducted at Tissue Culture Nursery, Universiti Malaysia Kelantan, Jeli Campus, Malaysia (5°44'44.5" N and 101°51'57.2" E). This experiment was conducted under black netting shelter with 50% light penetrating in order to prevent direct sunlight and heavy rainfall. The floor of the nursery was laid with black silver shine layer to prevent the growth of weed. This area had an ambient temperature between the range of 24°C and 32°C. Prior to the experiment, potassium permanganate solution was sprayed to all aquaponic equipment for the purpose of washing and disinfecting. Double tier planting tray aquaponic system as shown in Figure 1 was set up at the study site which involved the area of 5.0 m wide and 6.5 m length respectively. In total, there were 9 aquaponic units in this system with 3 replications for each treatment. Each aquaponic unit consisted of 1 fish tank with the capacity of 105.0 L (approximately 49.0 cm in diameter and 65.0 cm in length). This system was designed as simple as possible so that it can be implemented for the limited space or area. Filtration of circulating water was combined with the growing substrate in order to treat the effluent from fish tank.

Figure 1: The diagram of the nine aquaponic units with nine culture tanks and 18 planting trays before starting the experiment (Figure 1a). The main components of this system are fish tank (1), first panting tray (2), second planting tray (3), syphon (4), overflow pipe (5) and shelf (6). Figure 1b shows the direction of the flowing water for single unit and black doted show the point of water sampling location.




All tanks and planting trays used opack container to prevent alga growth. Submersible pump (Aqua, 2000) with a maximum of 2.0 m static head was installed at the fish tank with continuously 24-hour of water supply through 25.0 cm diameter PVC pipe to the first planting tray at the height of 1.7 m. The flow rate of circulating water in this system was 3.6 litres per minute. The planting tray had a dimension of 48.5 cm in length, 37.5 cm in width and 14.5 cm in height. The water would flow gravitationally to the second planting tray through a syphon, which was installed at both planting trays. From the second planting tray, the water would flow back to the fish tank through a 34.5 cm diameter PVC pipeline. Every fish tank was closed with lids to prevent entry of predator, insects and rainfall. Overflow pipe was installed at each fish tank if the water level in fish tank exceeded 100.0 L. The water level inside the fish tank was monitored daily to keep the water at a constant level.

In this experiment, three treatments with different growing substrates were set up which were no growing substrate (T1) as control or treatment 1, gravel growing substrate (T2) as treatment 2 and a combination of coconut husk and charcoal (T3) as treatment 3. Tilapia (*Oreochromis niloticus*) was used in this study because it is commonly cultured in aquaponic system (Love et al., 2015; Bakiu & Shehu, 2014), third important dish after carp and salmon (Lee and Wendy, 2010) and has high commercial values (Jones, 2002). Water spinach (*Ipomoea aquatic*) was planted in this study because it grows in a short period of time (Endut et al., 2009). Tilapia fingerlings and water spinach seed were obtained from UMK Aquaculture Research Unit and agriculture shop input in Jeli respectively. Two weeks prior to the start of experiment, water spinach seeds were soaked in water overnight to enhance root growth. Later, the seeds were planted to the peat moss soil in planting tray (36.0 cm x 56.0 cm) with two seeds for each hole. Water spinach seedlings with the height of 15.23 ± 2.45 cm were transferred to the planting tray with 12 plants of 0.27 $m^2$ as suggested by Shete (2013). Ten tilapia fingerlings with the length and weight of 19.83 ± 0.27 cm and 36.10 ± 1.01 g respectively were put into each fish tank two weeks before the commencement of the experiment to prepare nutrient stock solution. The tilapia fingerlings were fed twice a day at 9.00 am and 6.00 pm. The fish food given contains 40% protein, 4% fat and 12% moisture. Protein level for tilapia fingerlings food was between 32% and 36% as recommended by Riche and Garling (2003).

Physico-chemical water quality in this system was evaluated using Portable Water Quality Multiparameter (YSI, 556 MPS, USA). The parameters observed were pH, temperature (T), dissolved oxygen (DO), electrical conductivity (EC), salinity (S), and total dissolved solid (TDS). The parameters were taken at the water inflow and water outflow end of the system for plant tray. For fish tank, the data was taken at the inflow and outflow of the system (surface and bottom of fish tank). Physico-chemical water quality parameters were taken and sampled at the interval of 7 days between 2.00 pm and 4.00 pm on each sampling date. The total solids of water were measured after the tilapia and water spinach were harvested at the end of the experiment. The water in each fish tank was stirred with a long stick before water sample was taken. The water sample was later placed in a 500 ml beaker for each replication of all treatments, each containing 300 ml of water and deposited into an oven at 70℃. Gravimetric method was used to measure the total dry solid as mentioned by Rafiee and Saad (2005). The graphical representation of data was conducted by using Microsoft Excel 2010. The data was subjected to One Way ANOVA ($\alpha = 0.05$) by using SPSS software. If ANOVA table shows significant difference, mean comparison by Tukey Method will be conducted.

## Results And Discussion

The pH value in aquaponic system varied among treatments. At the beginning of the experiment, the pH value of water increased for T1 and T3 but slightly declined for T2 (Figure 2a). At the end of the experiment, the pH gradually decreased on day 42 for T1. The highest pH value was observed on day 21 for T1 and T3. The changes in pH value were due to the presence of tilapia in each aquaponic system at the beginning of the experiment. The mean value of pH for T1 was the highest in each sampling location compared to other treatments followed by T3 and T2 (Figure 3a). The mean pH value for T2 was unchanged regardless of point locations.

To ensure the nutrients are available in the planting trays, the pH range should optimally be within the range of 5.0-6.0 (Gjesteland, 2013). To add to that, pH level that is up to 7.0 is also adequate for growth (Roosta, 2014). Nitrification is optimal within pH ranging from 7.5-9.0 (Tyson et al., 2008). An aquaponic system should maintain a pH range near 7 because nitrification efficiency decreases at lower pH values while nutrient solubility decreases at higher pH values (Rakocy et al., 2011). Over the course of the experiment, pH levels remained within acceptable range for treatment in all water sampling location for tilapia and water spinach (Table 2). There is no significant difference ($p < 0.05$) of pH value among treatments for all water sampling locations (Table 1). This showed that the different type of growth media did not give significant impact towards the pH value of the water.

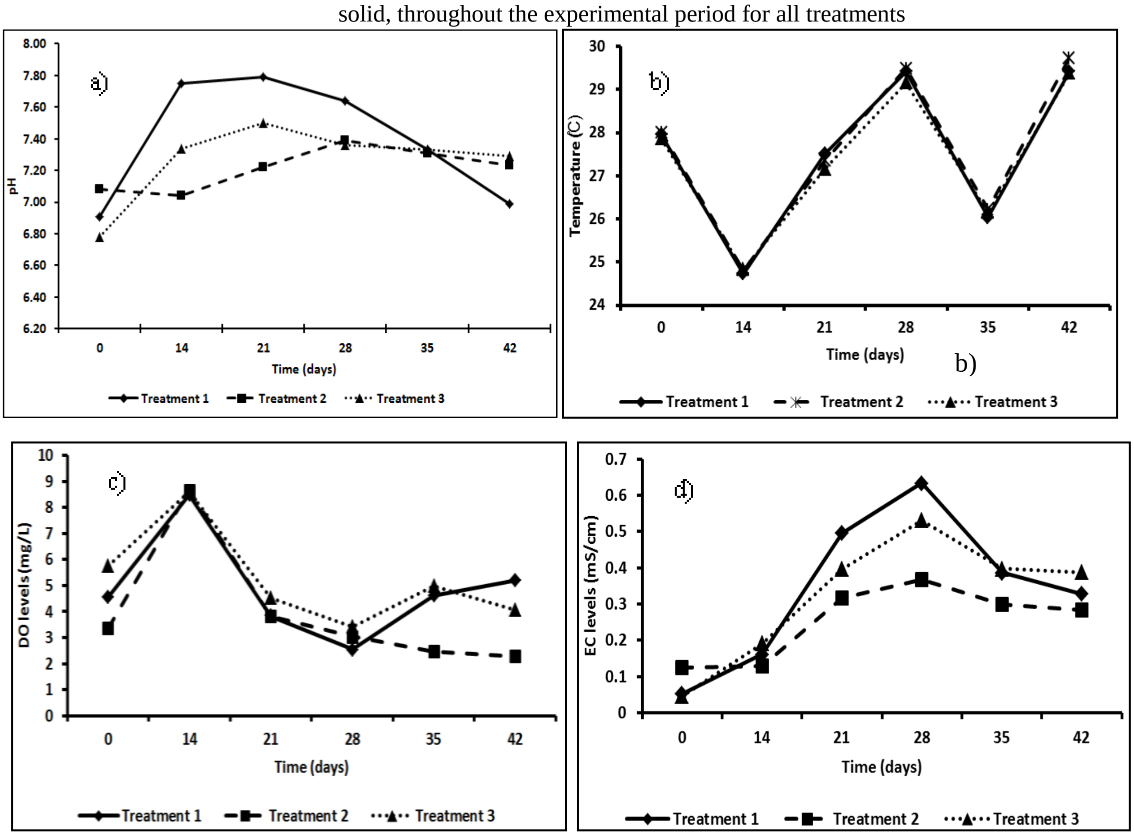
Figure 2b shows that there was a similar trend of water temperature among treatments. The temperature at the beginning, in the middle and at the end of the study was high (more than $28^0$C) but still in a preference range for water spinach and tilapia. Only on day 14 and day 35, the water temperature observed decreased as compared to other sampling time (Figure 2b). The temperature for T2 was high in each sampling location followed by T1 and then T3 (Figure 3b). The lowest temperature among all treatments and location of water sampling was at planting tray 2 for T3. The data of water temperature were varied between each experimental period due to the time of sampling. The temperature for water inflow and outflow for all treatments in all locations were within the same range and did not change much (Table 1). Over the course of the $42^{nd}$ day, water temperature remained within an acceptable range in all replicates (Table 2). To ensure maximum growth and minimize stress, the temperature needed to be kept in the optimal range of tilapia and water spinach. Depending on the species, water spinach has a high temperature tolerance (Endut et. al., 2009). No significant difference ($p < 0.05$) of water temperature among treatments of all water sampling location (Table 1). From the data analysis, using different growth media did not give significant impact towards water temperature.

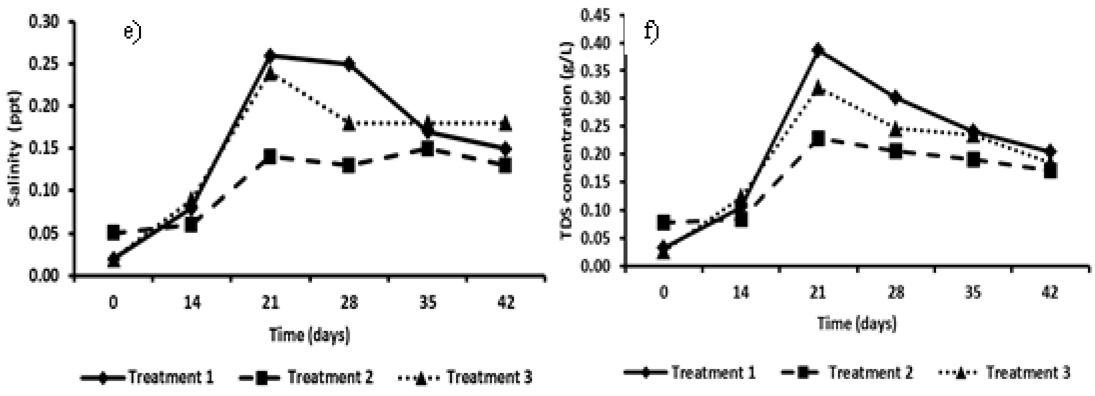
The pattern of dissolved oxygen levels in the water sampling among all treatments were almost the same but different throughout the experimental periods. The DO level was gradually increased at the beginning of the experiment until day 14 at all treatments and location (Figure 2c). The drastic changes of DO level on day 14 were parallel with the changes of pH values. Typically, oxygen levels dropped at night due to plants and animals respiration, which include fish. Day 14 was the interval of water sampling after two weeks the tilapias were added into the aquaponic system. Therefore, adding tilapia and plant at the beginning of experiment had caused the dissolved oxygen in the system increased. DO level for T1 decreased on day 21 and day 28 of the experimental period but increased on day 35 and day 42. The value of DO level for each treatment was almost the same in every sampling location as represent at Figure 3c. The observation found that T3 gave the highest value of DO level followed by T1 and T2. The mean value for DO at T3 was high at planting tray 2 and the lowest value of DO at planting tray 1 of T2. All the mean values of the DO level were fall within the preference value for tilapia (Table 2).

The parameters of DO level were related to temperature. In order to maintain a favourable condition for water spinach and tilapia growth, these two parameters in an aquaponic system should be in a stable condition. To achieve the stability of DO and temperature, water quality monitoring was needed. From the observed data, the DO level increases as the temperature decreases. From Table 1, DO level for T1 and T2 were the highest on planting tray 2 at water inflow and the lowest on planting tray 2 at water outflow. Meanwhile, DO level for T3 was the lowest at planting tray 1 of water outflow. The value of DO levels for all treatments were within a range of optimum value with the tilapia (3 – 5 mg/L) (Table 2). Even though the DO level exceeded optimum value for water spinach (< 3 mg/L), this species can withstand higher DO level. No significant differences were observed among all treatments in all water sampling locations ($p < 0.05$) (Table 1). DO levels is an important indicator when integrating the fish and plant. It is crucial that growth media does not affect the level of dissolved oxygen in the system.

The electrical conductivity in all treatments was different but the pattern throughout the experimental periods was similar (Figure 2d). In the beginning, the EC increased but at the end of experiment, EC level decreased but within an optimum value (Table 2). The highest EC was obtained for T1 and followed by T3 and T2 (Figure 3d). As the EC level decreased at the beginning of the experiment, the water content had more dissolved solids and ions. Therefore, the water was able to conduct more electrical current (Brinkop & Piedrahita, 1996). Besides, higher conductivity in the water resulted from the presence of various ions including nitrate, phosphate and sodium. Fish are very sensitive to EC value since conductivity is strictly related to the amount of osmotic pressure. Therefore, specific EC level must be maintained to prevent the fish from mortality. T2 showed the best condition for EC level in the system. During the experimental periods, the EC level for T1 at all sampling locations were higher and followed by T3 and T2 (Figure 3d). The EC value between T1 and T3 were different as compared to T2. As the growth media used in T2 was gravel, the ions contained in T2 were high due to the existing ions in the gravel itself. From the observation, the values of EC levels for all treatments were in a range of preference value for tilapia (0.25 - 0.75 mS/cm). The highest EC was obtained from the fish tank in water inflow and water outflow for T1 but the lowest EC was detected at water inflow on planting tray 2 at T2 (Table 1). Although the mean of observed EC was greater under the experiment conducted than preference value for water spinach, the EC had no significant differences among treatments over the course of the experiment.

Figure 2: Variation in a) pH, b) Temperature, c) Dissolved oxygen, d) Electrical conductivity, e) Salinity, and f) Total dissolved solid, throughout the experimental period for all treatments






The value of salinity for all treatments was increased gradually after day 14 and declined within the preference range (Figure 2e). For T1 at the time interval between day 0 and day 21, the salinity observed was increased drastically and then declined until day 42 of the experiment. While for T2, the salinity did not change much from the beginning and at the end of the experiment, but the value increased within day 14 and day 21 of the experiment. The fluctuation of salinity was caused by nutrient solution supplement from the feed (Khoda & Chopin, 2013). A comparison between T2 and T3, the salinity was higher for T1 most of the time. The salinity value in planting tray 1, tray 2 and fish tank were same among all treatments except for T2 at fish tank (0.12 ppt). Salinity value for T1 and T3 were 0.15 ppt in all sampling locations but salinity value for T2 at planting tray 1 and planting tray 2 were 0.11 ppt (Figure 3e). The same value of salinity between sampling location shows that, the water flows throughout a unit of aquaponic system carries the same amount of salts.  It is important to monitor the salinity level in the water because it can reduce the growth rate. This situation then result in smaller leaves, shorter stature, and sometimes fewer leaves. Uptake of water decreases as salinity increases, and this will dehydrated the water spinach and further inhibit growth (Chavez, 2005). Throughout the experimental periods, the salinity does not exceed the optimum value among treatments and also water sampling location of water inflow and outflow (Table 1).

As shown in Figure 2f, similar trends were found in TDS concentration among the three treatments. The result obtained shows that there was a relationship between TDS and salinity in the water. When the TDS concentration increases, the salinity content also increases and vice versa. The highest value for TDS was in T1 with 0.387 g/L followed by T3 (0.319 g/L) after day 21. In aquaculture, a constant level of minerals is necessary and parameter of TDS and pH should have the same levels as the fish original habitat. The changes in the TDS value will affect the growth performance of tilapia and water spinach. Too many dissolved salts in the water can dehydrate aquatic organisms while too few dissolved salts can limit the growth of aquatic organisms where dissolved salts act as a nutrient to the organisms (Sánchez, 2014).

After 24 days of experiment, the value of TDS for T1 was the highest followed by T3 and T2. There were no differences of TDS concentration between water inflow and water outflow except at planting tray 2. TDS value was slightly higher at water outflow compared to water inflow for all treatments (Table 1). However, no significant differences on TDS were observed among three treatments. From all the parameters observed, it could be summarized that all growing substrate gave positive effect to pH, temperature, dissolved oxygen, salinity, total dissolved solid and electrical conductivity. However, the value of electrical conductivity in irrigation water did not reach optimum range. This implied, nutrient concentration available at the planting tray was not enough or fish frequency in fish tank could be added in the system.

The total solid or material left after evaporation was different among treatments (Figure 4). T3 showed the highest percentage of total solid with 64.44 % as the growing substrate used was coconut husk with charcoal. The high content of total solid in the treatment was due to the coconut husk in the planting tray that moved along in the water which then deposited in the fish tank. The lowest percentage of total solid in the water was observed in T2 with gravel as growth media (51.39 %). Low percentage of total solid was believed due to the structure of gravel that was compact and prevents any residues or impurities in plant tray.

Small particulate matter from uneaten feed, fish faces and biological growth cause optimal water quality change if did not remove from the aquaponic system (Lennard, 2012). Apart from that, an increase in water flow during the experimental period can speed up the process of other particles to moves along and contribute to the levels of total solids in water. The mean comparison analysis showed that there was significant difference of total solids among treatments. The use of gravel as growing substrate significantly reduces the total solid in water compared to control and combination of coconut husk and charcoal treatment.

Figure 4: Total solid in water at the end of experimental period among treatments. Mean value with the same alphabet at the bar chart did not show any significant different ($p < 0.05$).

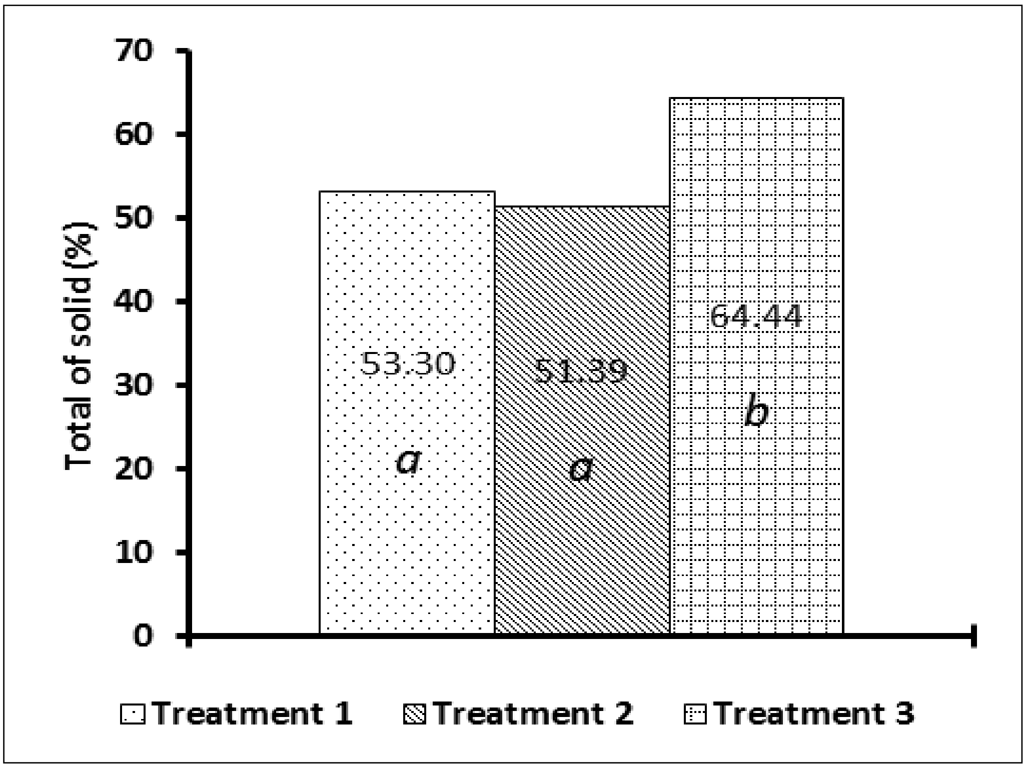

70
60
50
40
30
20
10
0
Total of solid (%)
53.30
a
51.39
a
64.44
b
Treatment 1
Treatment 2
Treatment 3

Table 1: Mean water quality parameters at water inflow and water outflow of the aquaponic system. Analysis of (ANOVA) showed that there were no significant different of parameters at different location on different treatments.

| Parameter | Treatment | Plant tray 1 | | Plant tray 2 | | Fish tank | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Water inflow | Water outflow | Water inflow | Water outflow | Water inflow | | Water outflow | |
| | | | | | | Surface of water | Bottom of water | Surface of water | Bottom of water |
| pH | T1 | 7.30±0.42[a] | 7.30±0.42 [a] | 7.39±0.56 [a] | 7.39±0.56 [a] | 7.40±0.56 [a] | 7.39±0.56 [a] | 7.40±0.56 [a] | 7.39±0.56 [a] |
| | T2 | 7.22±0.19 [a] | 7.21±0.19 [a] | 7.21±0.21 [a] | 7.22±0.21 [a] | 7.21±0.22 [a] | 7.21±0.21 [a] | 7.21±0.22 [a] | 7.21±0.23 [a] |
| | T3 | 7.26±0.30 [a] | 7.26±0.29 [a] | 7.28±0.30 [a] | 7.28±0.30 [a] | 7.27±0.29 [a] | 7.27±0.29 [a] | 7.27±0.29 [a] | 7.27±0.29 [a] |
| Temperature (ºC) | T1 | 27.48±1.73[b] | 27.48±1.74 [b] | 27.42±1.83 [b] | 27.41±1.83 [b] | 27.55±1.78 [b] | 27.57±1.78 [b] | 27.56±1.78 [b] | 27.58±1.78 [b] |
| | T2 | 27.57±1.78 [b] | 27.57±1.79 [b] | 27.54±1.83 [b] | 27.55±1.84 [b] | 27.63±1.79 [b] | 27.66±1.80 [b] | 27.64±1.79 [b] | 27.66±1.79 [b] |
| | T3 | 27.38±1.66 [b] | 27.38±1.66 [b] | 27.34±1.72 [b] | 27.34±1.73 [b] | 27.47±1.64 [b] | 27.49±1.64 [b] | 27.48±1.68 [b] | 27.50±1.64 [b] |
| Dissolved oxygen (mg/L) | T1 | 4.94±2.12[c] | 4.72±2.20 [c] | 5.03±1.89 [c] | 4.81±1.97 [c] | 4.86±2.06 [c] | 4.83±2.08 [c] | 4.88±2.10 [c] | 4.91±2.12 [c] |
| | T2 | 3.89±2.35 [c] | 3.75±2.41 [c] | 4.05±2.28 [c] | 3.83±2.40 [c] | 4.00±2.29 [c] | 3.98±2.29 [c] | 3.96±2.32 [c] | 4.00±2.31 [c] |
| | T3 | 5.26±2.05 [c] | 5.11±2.06 [c] | 5.46±1.85 [c] | 5.16±2.08 [c] | 5.17±1.97 [c] | 5.17±1.97 [c] | 5.17±1.95 [c] | 5.23±1.93 [c] |
| Electrical conductivity (mS/cm) | T1 | 0.341±0.20[d] | 0.337±0.21 [d] | 0.341±0.20 [d] | 0.343±0.20 [d] | 0.344±0.21 [d] | 0.345±0.21 [d] | 0.345±0.205 [d] | 0.345±0.21 [d] |
| | T2 | 0.242±0.12 [d] | 0.242±0.12 [d] | 0.236±0.12 [d] | 0.242±0.12 [d] | 0.266±0.13 [d] | 0.266±0.13 [d] | 0.266±0.13 [d] | 0.267±0.13 [d] |
| | T3 | 0.320±0.18 [d] | 0.325±0.18 [d] | 0.316±0.17 [d] | 0.325±0.18 [d] | 0.326±0.18 [d] | 0.327±0.18 [d] | 0.326±0.18 [d] | 0.327±0.18 [d] |
| Salinity (ppt) | T1 | 0.15±0.09[e] | 0.16±0.09 [e] | 0.15±0.09 [e] | 0.16±0.09 [e] | 0.16±0.09 [e] | 0.16±0.09 [e] | 0.15±0.09 [e] | 0.15±0.09 [e] |
| | T2 | 0.11±0.05 [e] | 0.11±0.05 [e] | 0.11±0.05 [e] | 0.11±0.05 [e] | 0.12±0.06 [e] | 0.12±0.06 [e] | 0.12±0.06 [e] | 0.12±0.06 [e] |
| | T3 | 0.15±0.08 [e] | 0.15±0.08 [e] | 0.15±0.08 [e] | 0.15±0.08 [e] | 0.15±0.08 [e] | 0.15±0.08 [e] | 0.15±0.08 [e] | 0.15±0.08 [e] |
| Total Dissolved Solid | T1 | 0.211±0.12[f] | 0.212±0.13 [f] | 0.210±0.12 [f] | 0.212±0.12 [f] | 0.212±0.12 [f] | 0.212±0.12 [f] | 0.212±0.12 [f] | 0.212±0.12 [f] |
| | T2 | 0.155±0.07 [f] | 0.155±0.07 [f] | 0.153±0.07 [f] | 0.156±0.07 [f] | 0.164±0.08 [f] | 0.164±0.08 [f] | 0.164±0.08 [f] | 0.164±0.08 [f] |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| (g/L) | T3 | 0.181±0.10 [f] | 0.189±0.10 [f] | 0.189±0.10 [f] | 0.191±0.10 [f] | 0.191±0.10 [f] | 0.191±0.10 [f] | 0.191±0.10 [f] | 0.191±0.10 [f] |

Table 2: Standard value of physical water quality parameters for fish and plant

| **Water Quality Parameters** | Optimum value and range | | Source |
|---|---|---|---|
| | Tilapia (In fish tank) | Water Spinach (In irrigation) | |
| pH | 6.0 – 9.0 | 6.4 – 8.0 | (Yamamoto & Brock, 2013; EPA, 2012) |
| Temperature **(°C)** | 27 - 29 | 20 - 30 | (Hambrey Consulting, 2013) |
| Dissolved oxygen (mg/liter) | 3 - 5 | <3 | (Khoda & Chopin, 2013) |
| Electrical conductivity (mS/cm) | 0.250 - 0.750 | 0.750 - 1.500 | (Rakocy *et al*., 2004) |
| Salinity (ppt) | 0.1 | 0.2 | (EPA, 2012) |
| Total dissolved solids (g/L) | < 0.400 | < 0.400 | (Rakocy *et al*., 2006) |

**Conclusion**

This study aimed to evaluate the physico-chemical water quality in fish tanks cultivation and planting trays during the experiments. Results of this study concluded that all treatments of different growing substrate were found to be effective in terms of physico-chemical water quality for the double tier planting tray aquaponic system. All parameters in the fish tank and planting trays were at the optimum rate for tilapia and water spinach growth. However, the range of EC in planting tray was low and did not meet the optimum growth for water spinach. Analysis of total solid revealed that the amount of solid in water could be reduced by using gravel as growing substrate compared to control treatment and combination of coconut husk and charcoal. Combination of coconut husk and charcoal as growing substrate could increase the level of dissolved oxygen in the water but there were no significant differences among the treatment. Gravel media was found to be the best growing substrate with optimum value of physico-chemical water quality and it can also reduce the total solid in water. The effect of parameters in water sampling location between inflow and outflow were the same. However, this study might be limited to the comparison of using gravel and coconut husk and charcoal combination as growing substrates. Further study on different types of growing substrates, fish densities, etc. must be carried out in order to observe it effect on the water quality as well as growth performance of plant and fish.

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