ASSESSMENT OF WATER QUALITY REMEDIATION THROUGH AQUAPONIC SYSTEMS

Nguyen Van Quang[1], Nguyen The Hung[1], Jerry J Wu[2]
[1]*Thainguyen University of Agriculture and Forestry*
[2]*College Science, Fengchia University, Taiwan, China*

SUMMARY

Research records data related to small-scale aquaponic systems were applied using two pilot models, Floating bed systems (FBS) and Media Filled Systems (MFS), for effective testing as well as assessment. Aquaponic is a sort of bioreactor that combines the process of fish farming and use of plants to recycle wastewater, which is the combination of aquaculture and hydroponics. The physics chemical parameters, such as DO, pH, temperature, COD, BOD_5, NO_2-N, NO_3-N, NH_3-N and PO_4-P, were evaluated in each system over a period of 75 days. In the Media filled systems (MFS) water quality parameters were reduced for 75 days DO, pH, BOD, COD, NO_2-N, NO_3-N, NH_3-N, and PO_4-P is 7.0 mg/L, 7.31, 4.66 mg/L, 6.86 mg/L 1.31 mg/L, 1.1 mg/L, 1.42 mg/L, and 0.41 mg/L and Floating bed systems (FBS) were also shown DO, pH, BOD, COD, NO_2-N, NO_3-N, NH_3-N, and PO_4-P were 6.88 mg/l, 7.46, 4.81 mg/L, 6.88 mg/L, 1.95 mg/L, 1.47 mg/L, 1.48 mg/L, 0.48 mg/L. The average weight of fish is 30 grams which is 40% higher than the original weight, average yield of 45.5 grams per plants showed that the system yielded satisfactory results. Two systems are effective in improving water quality. However, in MFS system is more efficient than the FBS system.

Keywords: Aquaculture, Hydroponics, Aquaponic systems, Media Filled Systems (MFS), Floating Bed Systems (FBS).

1. INTRODUCTION

According to statistics provided by economic and social organizations, world population has reached 7 billion in May 2018. The top three countries include China, India and the United States, accounting for 41 percent of the total population in the world. The problem of food security is facing great challenges due to the increasing demand, which has led us to create new cropping methods to provide clean and environmentally friendly products.

Although there have been successful studied on feasibility of the Aquaponic systems, further studies are needed to help to clarify some following issues such as experience in aquaculture. Availability of land, drought, soil erosion and pollution have created a demand for scientists to also examine the world's terrestrial food production techniques. Aquaponics is a closed recirculation system that combines fish farming and tree planting to improve water quality through root absorption. Water-rich nutrients from the process of raising fish after metabolism from toxic substances into harmless substances by nitrate bacteria. These harmless substances are a good source of natural fertilizers for plants to absorb (S.A. Castine et al., 2012; M. Connolly et al., 2015).

Currently, instead of raising fish alone, integrated aquaculture is a method of rubbing and scaling which not only helps to save costs such as labor and irrigation but also income from the water which will also increase significantly (S. A. Castine et al., 2012; P. Chen et al., 2012; M. Connolly et al., 2014). From the perspective of an environmentalist, Aquaponics systems are a system that provides green space to the user, saves water and especially does not use the soil that has caused the infestation of soil resources. Land in many developed countries due to agricultural land uses too much fertilizer, pesticides, and growth stimulants for trees (H.J.E. Beaumont et al., 2004; A. Buhmann, J. Papenbrock, 2013; K.M. Buzby, L.-S. Lin, 2014). Food that is grown in the Aquaponics system can be considered a green food source because it does not use chemical fertilizers. It provides a nutritious food source, and its wastewater can be recycled without concern to water pollution, eutrophication and the proliferation of toxic algae due to the abundance of nutrients (H.J.E. Beaumont et al., 2004; Y.S. Al-Hafedh et al., 2008). This problem not only affects quality of the water but also affects the aquatic ecosystem. This is my research because has been conducted to evaluate effect of catfish farming associated with water spinach on two systems, Media filled systems (MFS) and Floating bed systems (FBS). The results are evaluated as the water quality development ability of this tree will be a good signal to farmers as the basis for applied life sciences.

2. RESEARCH METHODOLOGY

2.1. Aquaponic systems design and operation

Setting of aquaponics was operated side by side at the College of Science, Feng Chia University Taichung, Taiwan (Figure 1), from March 15, 2018 to May 31, 2018. In each system, fish tank in which water was kept at 240 L, and Floating Bed Systems (FBS) 120 L, were both made of plastic containers. Media Filed Systems (MFS) tanks were kept 30 L and all the tanks were made in Taiwan. A cover was used in all the fish tanks to prevent sunlight which could stimulate algae growth. An air pump was used to provide more oxygen (made in Taiwan) to fish growth and then the tank fish water with (DO) dissolved oxygen concentrations were kept above 5 mg/L.

Figure 1. Aquaponics sub-system at the designated Aquaponic research area college of science at Fengchia University

Table 1. Filter materials used in the experimental model

Time	Models	Materials
1	Floating raft	Plastic tanks
2		Plastic thickness floading is 3 cm
3	Media filled	Small gravel Φ 5 mm to 10 mm (30 percent)
4		Clay soil (30 percent)
		Charcoal (40 percent)

- Input capacity: 100 L/h = 2400 L/day.
- Aquaponics model:
  + Aquarium: V = 250 L.
  + Vegetation basin: Length x width x height = 70 x 40 x 40 (cm).
  + Stocking density: 120 fish/m^3.
  + Drop of fish: 30 fish/tank

2.2. Fish and plant in experiments

Loach fish (***Mastacembelidae***) and water spinach which is a very popular aquaculture and vegetable in Taiwan was used to be cultured in this research. Fish with an initial weight of 14 g to 18 g was distributed into each fish tank with stocked density around 10 kg/m^3, feeding artificial fish was used in present studies. At the beginning of study, fish feed was added into the fish tank twice per day then the unconsumed fish feed was taken out 15 minutes later to prevent the water from being polluted. In apre-experiment it was proceeded with present aquaponic systems before the study began. The present study was carried on for 75 days, and aquaponic systems were continued. There are three pH such as 6.5, 7.0 and 8.5 were contained in three replicates and we used vinegar to keep the pH in the desired range. Plants were harvested during the end of the experiment.

Figure 2. Initial and final fish from the fish tanks

2.3. Research Methods

The experiments designed on nutrient-rich water will be pumped from the aquarium tank into two systems is FBS and MFS to provide nutrients for plants while reducing the amount of nutrients which can be toxic to fish and the water will be brought back to the aquarium tanks with a closed circulation cycle in the system. Additionally, systems are equipped with aeration machine to provide oxygen to the fish.

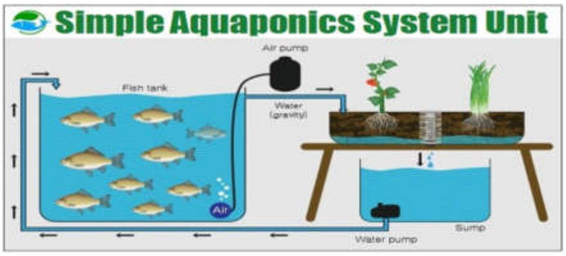

Figure 3. Experimental model

(Source: internet)

2.4. Sampling and analytical methods

Water samples were taken out every day at 9.00 to 10.00 a.m., the pH was measured daily. pH and DO concentrations were analyzed by using pH meter and DO meter, the water temperature was analyzed by a DO meter and conductivity (TDS) meter simultaneously. 50 ml of water sample was collected into bottles and kept in the refrigerator where are four-degree C. COD, NH_3-N and NO_2-N, NO_3-N, PO_4-P were accomplished in 12 hours according to the methods described in APHA (2005). BOD_5- test period for BOD is 5 days at 20 degrees Celsius after using DO meter.

* Monitoring indicators

- Physical indicators: turbidity - color, odor, EC.

- Chemical index: COD, NH_3-N and NO_2-, NO_3-, PO_4-, BOD_5

- Biomass of plants in Aquaponics:

+ Total weight (kg);

+ Productivity (kg/m^2).

- Biomass of fish in the model:

+ Total weight (kg);

+ Productivity (kg/m^3).

2.5. Statistics analysis

- Synthesize, measure, calculate the research data.

- Demonstrate, statistical results, parameters by graph, chart.

- Analyze, evaluate and comment on experimental parameters.

- Analysis and evaluation of available data, data collected, analyzed. Integrate these data into Excel software (Microsoft, 2013,) and the SAS 9.1 to make comments and assessments in full.

3. RESULTS AND DISCUSSIONS

3.1. Fish production

The selection of same fish and same weight and size. Table 2 and figure 4 shows the fish growth indexes as follows: Feed conversion ratio (FCR) (g) BWG (g) Final weight g) Initial weight (g) Initial biomass (g) Initial length (cm) Final length (cm) The results showed that the growth rate of fish after 75 days was 30.5 grams, 15 grams higher than initial weight, where the feed conversion ratio was 1.01 and survival rate of 82%. This indicates that for every 100 fish released into the system results show that 30 dead fish accounted for 30 percent of total fish. Whereas, with a starting point of about 11 cm and 75 days, length of the fish was approximately 16 cm, an increase of 5 cm compared to the original, indicating that the results were satisfactory. It's true to the original study intentions.

Table 2. Performance of Fish Growth in means (± SD) Aquaponic Sub-systems, ($p < 0.05$)

Parameters	Eels fish
Feed Conversion Ratio (g)	1.01 ± 0.20
BWG (g)	2000.085 ± 12.9
Initial Weight (g)	16 ± 7.5
Final Weight (g)	30 ± 12.9
Survival Rate (%)	0.70 ± 0.01
Final Biomass (g)	2100 ± 132.9
Initial Length (cm)	12 ± 1.5
Final Length (cm)	16 ± 2.3

Figure 4. Initial and final fish from the fish tanks

3.2. Plants (vegetables) growth performance

During the first 15 days of experimentation, there was no difference in the rate of growth of the plants in both systems, but after about 30 days there was an obvious difference in the differences between the two systems, namely growth rate in MFS systems, grow faster than their average length FBS systems and increased their biomass indicating their positive growth efficiency. Data on water spinach and growth parameters related to water spinach have the average length of roots shown in table 3 we can see the plant biomass wet weight of MFS system is four times higher than the volume of FBS, which is a proof that the ability to grow and absorb and remove nutrients in the MFS system is better than FBS.

Table 3. Growth performance of water spinach in means (± SD) two systems FBS and MFS, ($p < 0.05$)

Parameters	FBS	MFS
Total Final Weight (g)	60.9 ± 1.9	273 ± 74.9
Weight Per Plants (g)	10.2 ± 7.2	45.5 ± 27.0
Plant Length (cm)	15 ± 1.6	23 ± 2.3
Roots Length (cm)	12 ± 6.1	14 ± 6.6

In table 3 the final weight in both experiments were the MFS model was higher than the FBS, this is shown in figure 4 so the difference in the two systems can be explained the following. The FBS model grows well in the tank. However, in the last days of May, the average temperature is quite high at about 35 degrees Celsius for plants stop absorption of nutrients, so water temperature can be a factor in reducing the plant's ability to absorb nutrients.

3.3. Water quality physical parameters

The mean values of the four indicators, respectively, temperature, DO, pH, BOD, respectively, are shown in table 4, with data showing that the average temperature in the three systems were fish tanks at 25.8°C, MFS 27.8 degrees Celsius, FBS 28 degrees Celsius, DO ranges from 6.88 mg/L to 7.13 mg/L in all three systems, pH ranged from 7.31 to 7.64 while the final BOD in water. It is good to be in the bracket allowing aquaculture 3.12 mg/L to 9 mg/L. All four indicators are favorable for the development of eel.

Figure 5 show changes in the concentration of the physical parameters of water during the experiment, with above pH is an ideal condition for ammonia to convert to nitrite it should be noted that ammonia is a nutrient for plants but is also readily available to fish if concentration is too high in water. Therefore, it is important to select an appropriate crop to help the absorption process eliminate the concentration of ammonia. As well as the conversion of ammonia to nitrite (M. Connolly et al., 2015; V. Díaz et al., 2012). Important elements in water that need to be monitored throughout the experiment are DO, Temperature, pH, which is the key to the success of this experiment. It not only brings life to fish and plants; it is also the decisive factor for the absorption and improvement of water quality. Concentration of total nitrogen (ammonia, nitrite and nitrate) within the aquaponic systems generally states that the objective of the study is to be able to improve water sources as well as use of extra water to ensure not only the survival of beneficial plants (B. L. Ho, 2000) but also for fish.

Table 4. Water parameter in means (± SD) temperature (°C), Dissolved oxygen (DO) and pH, Ec, BOD, COD in Floating Bed Systems (FBS), Media Filled System (MFS), ($p < 0.05$)

Parameters	Fish tanks	FBS	MFS
Temperature (°C)	25.82 a ± 1.9		27.89 a ± 2.4
Dissolved oxygen (mg/L)	7.13a ± 0.8	6.88 a ± 0.8	7.0 a ± 0.8
pH	7.64 a ± 0.1	7.46 b ± 0.1	7.31 a ± 0.1
Ec (µs cm)	606 a ± 88.3	613 a ± 40.7	588 a ± 87.0
BOD (mg/L)	3.41 a ± 8.9	4.81 b ± 8.4	4.66 a ± 8.2
COD (mg/L)	6.47 a ± 5.73	6.88 a ± 4.9	6.86 a ± 4.8

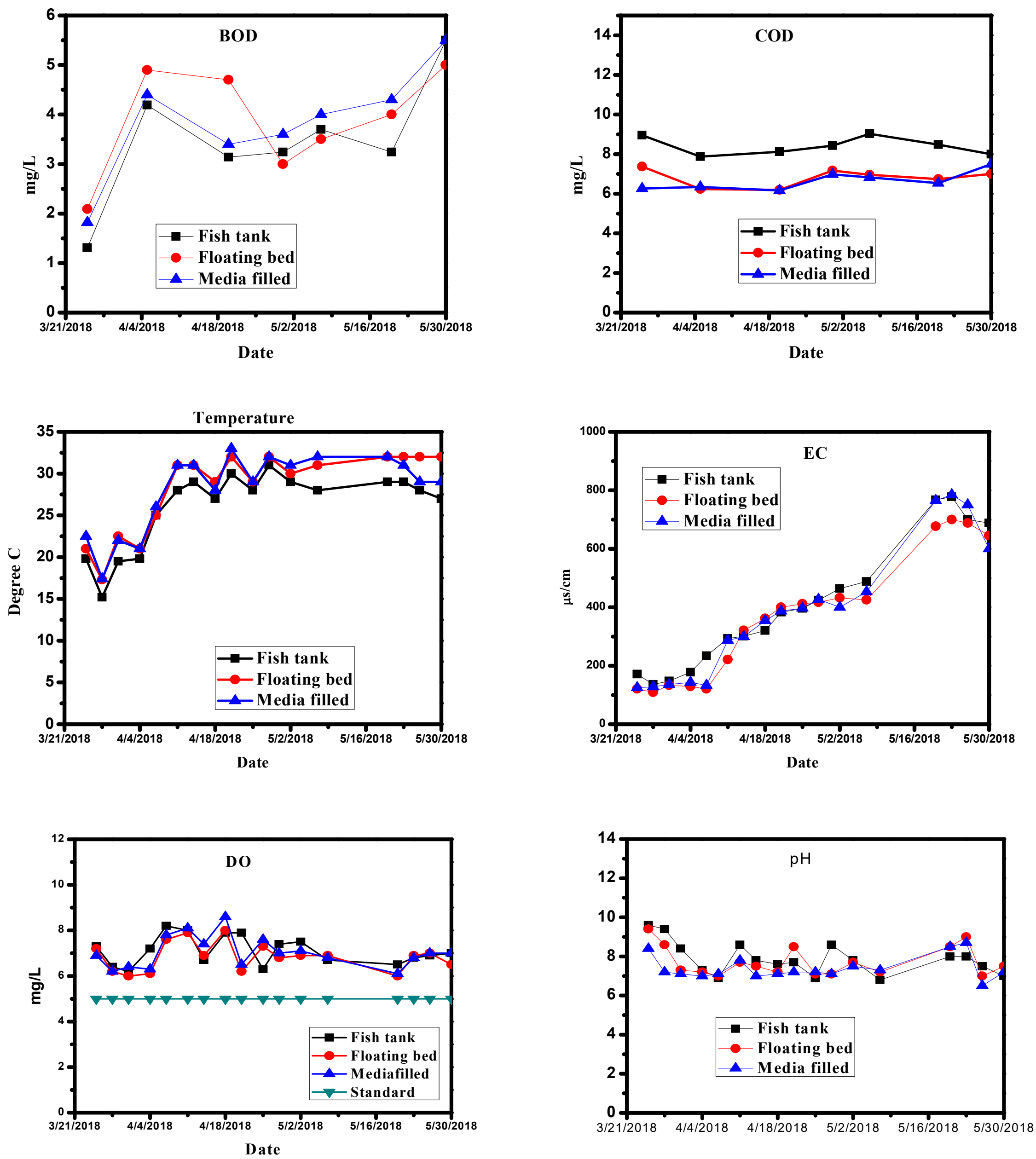

Figure 5. Concentration of COD, BOD, EC, DO, pH, Temperature in The Media Filled System (MFS), Floating Bed Systems (FBS) and Fish Tanks

pH, DO, Temperature is one of the factors that affect nitrification. In previous experiments, typically, experiments of two (Salama et al., 2006; Daudpota et al., 2014) with the best water quality for fish farming is an average temperature of 22 degrees Celsius to 30 degrees Celsius. This is an ideal temperature for fish farming. In this study, the average temperature of fish tanks was 25.8 degrees Celsius and was within the allowable range of previous studied. The previous test as well as conditions at the site where eels are a suitable fish species and meet requirements.

DO concentrations in water are always maintained at a high level above 7 mg/L compared to permitted standard of not less than 5 mg/L as allowed by an aquaponics system. Through the roots (C.R. Engle, 2015), high DO concentrations in water are also a factor to evaluate the freshness of plants. One of the reasons explained here is that the process of circulating water brings more oxygen to the system.

The pH of this study ranged from 7.3 to 7.6 and this was within the allowable range for plants and fish during experiment with pH being comparable to previous studies being perfectly reasonable. Typically, research (L. Silva et al., 2015) indicated that the previous hydroponic farming environment was the ideal setting over the pH ranged from 5.5 to 7.5. Some further studies indicated that pH 5.5 to 6.5 is acceptable. This study with the above pH is perfectly feasible. In general, we maintained the pH of 5.5 and below 9, which is most appropriate because water is characterized by mild alkalinity. All of the indicators mentioned above are suitable for fish development. One of the earlier studies, such as the study of water spinach combined with tilapia culture (S. Mustafa, R. Shapawi (Eds.), 2015) where the results of this study (pH, DO, Temperature) did not differ significantly from this study.

3.4. Water nutrients concentrations

Table 5 shows the concentration of nutrients in water such as NO_2-N, NO_3-N, NH_3-N, and PO_4-P in three aquaponic systems. The nutrient concentrations of NO_2-N, NO_3-N, NH_3-N, and PO_4-P in each system (MFS, FBS, Fish tanks) decreased with the length of the experiment. This is proven in the graph down here as mutual (Sheet et al., 2014). Overall, the nutritional value of overall head achieves satisfactory results and is within control and standard of aquaponic systems, but salient features of all three systems are nutrients. All nutrients are added to mid-stage and reduced to final stage due to absorption of nutrients by plant. However, there is a point where phosphorus concentration does not decrease but increases at the end of the stage. The average values of nutrient concentrations of NO_2-N, NO_3-N, NH_3-N, and PO_4-P at fish tanks were 2.15 mg/L, 1.97 mg/L, 2.08 mg/L and 0.6 mg/L. These values, although slightly higher than those of fish tanks in some previous studies (A.M. Daudpota et al., 2014), remained good for fish development and were within acceptable limits, although in the FBS and MFS models, levels of nutrients were lower than those which demonstrated that there was an uptake of plants as well as of bacteria.

Table 5. Water Nutrient Concentrations of NH_3-N, NO_2N, NO_3-N and PO_4-P in three tanks, Fish tanks, Floating Bed Systems (FBS), Media Filled Systems (MFS)

Parameters	Fish tanks	FBS	MFS
NH_3-N (mg/L)	2.08 ± 0.11	1.48 ± 0.02	1.42 ± 0.02
NO_2-N (mg/L)	2.15 ± 0.19	1.85 ± 0.22	1.85 ± 0.20
NO_3-N (mg/L)	1.97 ± 0.12	1.47 ± 0.37	1.4 2± 0.39
PO_4-P (mg/L)	0.6 ± 0.20	0.48 ± 0.04	0.41 ± 0.50

3.5. Economic Efficiency Assessment of small-scale Aquaponics sub-systems

Table 6 illustrates surveys and assesses economic viability of the models, as seen in the aquaponic systems, which is more efficient than the effective combination of the other two models.

- Expenditure for systems construction: 7500 TW

- Cost of maintaining systems:

+ Electricity: To maintain stable operation, each formula uses 01 pumps of 25W (1.5 - 2.5 m high) and 01 aeration pumps in 3W tanks, of which:

Pumped water twice a day, each time running continuously 6h (from: 10h - 16h and from 23h - 5h the next morning).

Aeration tank operating 24/24h.

Total electricity consumption:

25*2*6 + 3*24 = 300 + 72 = 372 Wh/day = 11.16 KWh/month.

So, the total electricity cost spent in 3 months running the model for each formula: 11.16 * 5 * 3 = 167.4 (TW/3 months/formula)

Total invest cost: 7500 + 167.4 = 7667.4 TW.

Table 6. Economic analysis of production through conventional aquaculture and hydroponic and Aquaponics for 1m^2 area

Parameters	Aquaculture	Hydroponic	Aquaponics
fish (eels) Production = 2.5 kg Sales = TW 120.28/kg	TW 300.7	–	TW 300.7
vegetables (water spinach)	–	3kg × TW 72.54 = TW 217.62	3kg × TW 72.54 = TW 217.62
1 system have plants Production = 3 kg			
Sales = TW 217.62			
Total sales in one cycle = 3kg × TW 72.54 = TW 217.62			
Total sales	TW 300.7	TW 217.62	TW 518.32

4. CONCLUSIONS

4.1. Conclusions

The objective of this study was to assess the physical and chemical properties of water in aquaponic systems through two types of filtration. Firstly, media filled systems (MFS) and secondly, floating bed systems (FBS). Nutrient concentrations in water also compared by the absorption of plants in both types and the water quality of the aquarium are also reviewed and assessed. In order to assess feasibility of systems in outdoor conditions. The results showed that

It can be concluded that Aquaponics is a useful system and partly benefits from the improvement of the parameters of nutrient-rich water. However, more research in future is needed to make the system more useful.

4.2. Suggestions

It is suggested to continuously expand the research into various experiments with different concentration levels, different load levels, different plant systems, etc., comprehensive evaluate processing capacity of systems. The adaptation ability of plants and animals and economic efficiency should be evaluated.

Guidance for farming knows how to use and bring the highest processing efficiency.

Suggestion: Do not use fertilizer when operating this model

Studying can apply systems in urban areas: ensure efficiency of treatment and protection of environment, contribution to create landscapes and raise incomes, ensuring sources clean and fresh food. Systems can apply in high mountainous areas often lack water, drought.

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ĐÁNH GIÁ XỬ LÝ CHẤT LƯỢNG NƯỚC THÔNG QUA HỆ THỐNG AQUAPONIC

Nguyễn Văn Quảng[1], Nguyễn Thế Hùng[1], Jerry J Wu[2]
[1]*Trường Đại học Nông Lâm Thái Nguyên*
[2]*Trường Đại học Phùng Giáp, Đài Loan*

TÓM TẮT

Nghiên cứu dữ liệu liên quan đến hệ thống aquaponic quy mô nhỏ đã được áp dụng bằng hai mô hình thí điểm, hệ thống giường nổi (FBS) và hệ thống giá thể lọc (MFS), để thử nghiệm cũng như đánh giá hiệu quả. Aquaponic là một loại hình mới nó là sự kết hợp giữa nuôi cá và sử dụng thực vật để tái chế nước thải, là sự kết hợp giữa nuôi trồng thủy sản và thủy canh. Các thông số hóa học vật lý, như DO, pH, nhiệt độ, COD, BOD_5, NO_2-N, NO_3-N, NH_3-N và PO_4-P, được đánh giá trong mỗi hệ thống trong khoảng thời gian 75 ngày. Trong đó các thông số chất lượng nước của hệ giá thể màng lọc (MFS) đã giảm trong 75 ngày DO, pH, BOD_5, COD, NO_2-N, NO_3-N, NH_3-N và PO_4-P là 7,0 mg/L, 7,31, 4,66 mg/L, 6,86 mg/L 1,31 mg/L, 1,1 mg/L, 1,42 mg/L và 0,41 mg/L và hệ thống giường nổi (FBS) cũng được hiển thị DO, pH, BOD_5, COD, NO_2-N, NO_3 -N, NH_3-N và PO_4-P là 6,88 mg/l, 7,46, 4,81 mg/L, 6,88 mg/L, 1,95 mg/L, 1,47 mg/L, 1,48 mg/L, 0,48 mg/L. Trọng lượng trung bình của cá là 30 gram, cao hơn 40% so với trọng lượng ban đầu, năng suất trung bình 45,5 gram mỗi cây cho thấy hệ thống mang lại kết quả khả quan. Hai hệ thống có hiệu quả trong việc cải thiện chất lượng nước. Tuy nhiên, trong hệ thống MFS hiệu quả hơn hệ thống FBS.

Từ khóa: Hệ thống Aquaponic, hệ thống giá thể màng lọc (MFS), hệ thống giường nổi (FBS), nuôi trồng thủy sản, thủy canh.

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