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Experimental Investigation of Plant Bio-Filter on Water Quality and Growth of Iridescent Shark in a Pilot Scale Aquaponic System

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Abstract: ***An aquaponic system is a recirculating aquaculture system (RAS) that incorporate the production of plants without soil. These systems raise large quantities of fish in relatively small volumes of water by treating the water to remove waste products. System reuses the water many times for the production of plants. The system has two components: hydroponics and aquaculture in which it converts the food as excreta of the fish. The excreta dissolved in water fulfill the nutrient requirement of plants. The experiment is conducted to test the survival and growth of the iridescent shark and balsam plants in an aquaponic system. A pilot aquaponic system is developed to examine such possibility and sustainability with 1.08 m3 area of water in aquaponic component and 1 m2 for plant growth. The hydroponic component is used as a plant bio-filter. In the hydroponic component, the coarse aggregate of 0.01m is selected to support the plants. Coconut husk and sand particle layers of 0.03m and 0.06m are used for the growth and development of nitrifying bacteria. The aim of the experiment is to test the success of the aquaponic system in adverse conditions like the unavailability of fresh water for replacement, poor sunlight, drastic temperature variations, and minimum D.O. condition. The system is examined with only 25% of water replacement after 45 days and without maintenance of the biofilter. The recirculation period of water is varied for every 20 days of the span. The impact on environmental factors like D.O., Ammonia, Nitrogen, Nitrates, TDS, and pH are studied in experimental investigations. The growth of fish is steady, and no death is observed during the experimentation. The experimental investigation proves that water can successfully be recirculated and reused for the growth of iridescent shark and balsam plants with a minimum replacement of water for once in 70 days.***

Index Terms: Aquaponics, ANOVA,recirculation,TAN.

I. INTRODUCTION

India has a coastline of 7,517 km and offers a huge potential for aquaculture development. The country has an extensive river and canal system which consists of 14 major, 44 medium and numerous small rivers along with the streams. Pond and tank resources are estimated at 2.36 million ha[1]. The 73% of the Indian Sunderbans population is directly or indirectly depends on aquaculture [2]. The river Ganga flows through the Bay of Bengal and formed the Indian Sunderban Mangrove ecosystem. It is the UNESCO World Heritage site and spans an area of 9630 sq. km comprising 56 islands [2]. It is mentioned by World bank that 16% of animal protein is consumed globally and this hunger will go up with per capita income in rise [3]. India ranks second with 4.2 million out of 66 million tonnes of global fish production [4]. It is evident that the need of sustainable food production is constantly expanding in India and hence a cost effective food production technology like aquaponics need to be adopted. An aquaponic system combines aquaculture and hydroponics is a recirculating production technique and a promising solution to the emerging problems of limiting water source ad the consequent effects [5],[6]. It's an integrated system of aquaculture and plant production [7]. A systematic and dynamic interaction of fish, nitrifying bacteria and plant takes place in aquaponic systems [8]. It minimizes the need of micronutrients and macronutrients needed for the growth of plants [8]. The basic principal behind a successful aquaponic system is the nutrient rich water with enough dissolved oxygen for fish health and the cost effective water quality maintanance [10], [6]. Several experimental methods were carried out to optimize the AP systems for sustainable fish and crop production [7]. Three most common methods are nutrient film method (NFT), media based method and deep water culture (DWC) method [13].

A. Effect of ammonia in aquaponic system.

The mechanism of aquaponic system is to recycle the nutrient rich effluent generated from an aquaculture unit in the hydroponic unit where, the essential nutrients are taken up by the plants for the growth. By absorbing the nutrients, plants prevent their accumulation by acting as a natural biofilter and extending the use of water returning to aquaculture unit [11]. Nitrogen is one of the major nutrient required for plant growth and living organisms because it is a component of deoxyribonucleic acid (DNA), ribonucleic acid (RNA), amino acids and proteins. The fish feed in aquaponic system is the major source of nitrogen which is excreted by fish in the form of ammonia nitrogen [12]. Ammonia (NH3) is produced by fish in the liver and excreted into the water by gills, which consists of two components NH3 and NH4+ [13]. They are called as total ammonia nitrogen (TAN) in aquaculture. Being very soluble in water and can diffuse easily in cell membranes, it is converted to NH4+ in cell membranes at lower pH [14]. NH3 is toxic to fish when high in concentrations, but it is oxidized by nitrifying bacteria (Nitrosomonas) into nitrite (NO2-) and again into nitrate (NO3) by a second type of bacteria (Nitrobacter) which can be easily absorbed by

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plants [15]. With an accumulation of these elements in RAS, the health and development of the species under culture are at risk. The increased levels of ammonia mainly affect the central nervous system which is further followed by ammonia intoxication and death [13]. The excessive ammonia can cause extensive damage to tissues, damage to gills and kidney, decreased resistance to disease, impared growth and death. Therefor to reduce these wastes, the main component in RAS is a biofilter [16].

B. Significance of Biofilter and plants in aquaponics.

A biofilter is in simple words, is a place for the bacteria to colonize and in RAS it is a vital part as the water runs through it and ammonia is converted to nitrite and nitrates [17]. Biofilters were successfully used in air, water and wastewater treatment since their first introduction in 1893 in England, as trickling filters to treat wastewater [31]. Since then, they have been successfully used for the treatment of domestic and industrial wastewater. For contaminant removal in wastewater treatment, plant uptake is one of the widely recognized and practiced biological process. [20]. In constructed wetland systems, Ammonia nitrogen removal efficiencies of 86% to 98% were reported [21]. In hydroponic plant production systems, the nutrient removal rates of nitrogen are depending on the effluent flow rate and plant numbers [22]. For ammonium, plant roots were found more competitive than the ammonia oxidizing bacterial species Nitrosomonas europaea [23]. When sufficient plants are present in aquaponic systems, there will be less reliance on biofilters for ammonia removal. More work needs to be done to understand the relationships between biological and hydrological factors for optimization of aquaponic systems [24]. Nile Tilapia (Oreochromis niloticus) is a common fish species in aquaponics all across the world as it has a faster growth, good meat flavor and a huge market demand [25]. There are a variety of plants that can be grown as a part of biofilter in aquaponics. Out of those, basil (Ocimum basilicum), peppermint (Mentha piperita) and spearmint (Mentha spicata) are the most recommended herbaceous plants as they grow fast, their adaptability and their utilities in the field of medicinal and aromatic purposes [26]. Research findings of basil production integrated to grow tilapia and prawn were reported by Rakocy, Shultz, Bailey and Thoman (2004). Similarly, mint integrated to tilapia was reported by Wahap, Estim, Seok-Kiang and Mustafa (2010). Many research findings were reported on the integration of various plants to fish species. However, all these research activities were mainly carried out with a focus on plant production parameters. Aquaponics, which use nitrogen-rich wastes as organic fertilizer proved efficient than hydroponics, which entirely depends on nutrient supplements [7]. Apart from the availability of commercial aquaponic systems, the high investments and operation costs of RAS is a significant constraint in developing countries. [30],[9]. Aquaponic needs low operational costs and high profitability to get adopted as an economical food production system. [28],[29]. One of the solutions for reducing operational cost can be the reduction in the water recirculation period. However, a limited research done on how water recirculation time affects plant growth and water quality parameters. [18].

This paper represents the results of the experimental investigation carried to test the effect of minimum recirculation timings and their variations on water quality and growth of fish and plant species in a laboratory scale aquaponic system.

II. MATERIALS AND METHOD

A. Aquaponic system components.

The experiments were conducted in a pilot scale aquaponic system in the laboratory of K. J. College of Engineering and Management Rearch, Pune, in Maharashtra district, India. The system comprised of two components: 1) The fish tank of 1.2m (L) × 1m (B) × 0.9m (H) resulting in $1.08m^3$ of volume and 1000 lit capacity, 2) The hydroponic component with inbuilt biofilter 0.9m length, 0.26m depth and 0.55m diameter. The biofilter is assembled with 5 layers. The layer at the bottom with coarse aggregates = 0.1m, coconut husk layer above bottom layer = 0.03 m, third layer of sand particles = 0.06 m, again coconut husk layer as fourth layer = 0.03 m, and cocopit layer as firth layer = 0.03 m. To achieve the full cycle of recirculation in 90 minutes, a water pump of 18 watts and 2000 rpm capacity was provided to aquaponic system. The water travels through the biofilter layers of coconut coir and filter media. Coconut coir is used in prefilters as an effective medium for the removal of sewage and lechate impurities from highly turbid waters [32]. For the removal of diverse type of pollutants from water, the coconut tree parts such as shell, pith and coir are extensively studied as biosorbants [33]. A plastic bottle with micropores is fitted at the bottom of the hydroponic component for carrying the filtered water back to the fish tank through a 20mm PVC pipe.

B. Iridescent shark.

Iridescent shark (Pangasianodon hypophthalmus) was selected as fish species for aquaculture component. This fish is introduced into the habitat of many countries due to its commercial trade and economic value. In the USA, Russia and in some European Economic areas, it is popular in food fish trade [35]. This fish is known to produce large numbers of larvae. It is a popular species in aquaculture trade due to its large body size, with a maximum standard length 1300 mm and 44kg weight [35]. The aquaponic system implemented for 70 days to investigate the production of balsam plant with iridescent shark aquaculture.

C. Hydroponic plant: Balsam.

Balsam, (Impatiens balsamina) is selected as plant in hydroponic component. The plant contains mainly naphthoquinones, coumarins, phenolic acid, flavonoids, anthocyanidins and steroids, which can be useful in the development of new drug and to treat various diseases with their different pharmacological characteristics [34]. Being the impatiens native of India, this species has a rich flora widely distributed all over the country. Impatiens balsamina is commonly known as Gul Mehendi in Hindi language and Rose balsam in English. In Kerala, it is locally known as

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balsam and belongs to the family Balsaminaceae [34]. Herbal medicines based drugs are commonly used in India. A combination of balsam plant with other herbs is popularly used in a bath after childbirth for general health. The decoction mixed with onion and fennel flower is consumed for aching joints and coughs. The decoction of the leaves is antiarrhythmic, expectorant, antispasmodic, astringent, antigastralgic and anthelmintic [34]. Therefor balsam plant is selected for hydroponic component.

D. Experimental method.

The experiment was conducted for 70 days from November 1, 2018 to January 10, 2019. The main objective of this experiment was to test the success of the system in water scarce areas with a poor electricity supply. Therefor the experiment was carried to examine the survival and growth of fish under low DO conditions and low water circulation periods for 70 days. The recirculation period was varied once in 20days. For the first 20 days, the period was kept 2.5 hr/day (6.6 lit/min). For the next 20 days, it was kept 3 hr/day (5.5 lit/min), and for last 20 days, it was kept 2 hr/day (8.3 lit/min). The hydraulic loading rates (HLR) were, 5.5 m/d, 4.5 m/d and 6.9 m/d respectively. The levels of pH, TAN, ammonia, Nitrogen, DO and TDS along with temperature were recorded once at 10 a.m. every day. The activity of fish was observed and recorded as surface respirations for the first 14 days of the experiment. Total 20 fishes present in the tank reacted to the decreasing oxygen levels. The fish periodically appeared on the surface level for consuming oxygen. The appearances were recorded every day and the data was used for statistical analysis between circulation periods and surface respiration activity of fish. After 14 days, the recirculation was resumed according to the planned schedule for further investigations. The experiment started with 20 fish of 5cm length. The fish were fed with a commercial floating pellet manually twice a day at around 9:30 am and 4:30 pm each day. These diets contained 32% crude protein, 4% crude fat and 10% moisture.The effect of recirculation period on TAN levels was tested using one way ANOVA and differences of means were evaluated for significance (p=0.05) by a range test of Tukey for variences using Minitab statistical software.

III. RESULTS AND DISCUSSION

For first five days of experimentation, there was no water circulation and the pH, TAN, NH4 levels were recorded. The levels increased rapidly and crossed their acceptable limits when the circulation was completely stopped. TAN level recorded 2.9 ppm. NH4 recorded as 4.3 ppm, DO was zero and nitrate concentration was 97 ppm at the end of the 5th day. The recirculation period was gradually increased till the 14th day of the experiment. The system was tested for the hypoxic conditions and all the water quality parameters were recorded for further analysis. For next 60 days it was scheduled to test with variation in recirculation period for each 20 days of span. The figure 1 indicates that for first 20 days, with recirculation period 2.5 hr/day, the TAN levels decreased as pH levels raised beyond 7 pH. TAN level dropped around 1 ppm when pH level raised around 7.5. And the level increased beyond 2 ppm when pH dropped below 7. From 21st day, recirculation period was changed to 3 hr/day and the records were noted. Fig 2 shows the progression of TAN curve where it gradually increases for 2 days and then gradually decreases till 40th day. It indicates that the biofilter worked efficiently within that particular period. Fig. 3 indicates that, the TAN curve gradually increased from 41st day till 60th day. It indicates the decreasing efficiency of biofilter during the last 20 days. The experiment started with 20 iridescent sharks of 50mm (5 cm) lengths. The fish were fed 2% of their body weight. The fish grown to 17cm from 5cm length in three months. They gain an average body weight of 102 gm and no mortality was observed during their growth. The system was tested with hypoxic conditions and DO level was below ppm most of the time. The ammonia level was above 2 ppm most of the time. Under such conditions iridescent survived and proved its adoptive strength of surface respiration. Low water circulation period didn't affect the growth of fish. However the fish activity was observed to be decreased with low DO conditions.

Table 1 pH and TAN levels with recirculation periods

Day	pH	DO (ppm)	TAN (ppm)	Ammonia (ppm)	Recirculation period (hr/day)
01	7.2	00	1.2	3.3	00
07	6.7	00	2.6	3.5	00
10	6.6	1	2.3	2.5	2.5
30	7.4	1.5	1.5	3.7	2.5
31	7.4	1.2	1.5	3.5	3
50	7.5	1.5	1	2	3
51	7.5	1.5	1	2.1	2
70	7.5	1	1	3	2

Table 2. Fish growth

Day	Avg.length (cm)	Avg.weight (gm)
01	5	1.5
07	5	2.1
10	5	2.3
30	8	40
50	12	70
70	17	102

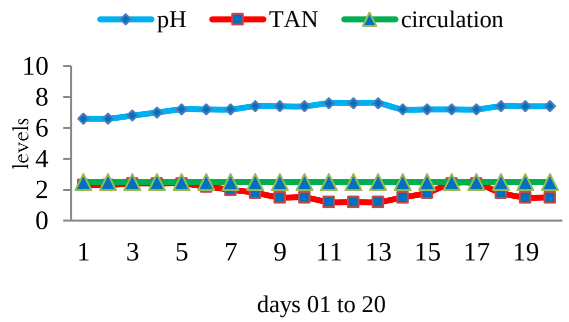

Figure 1 variations in pH, TAN and recirculation period in first 20 days

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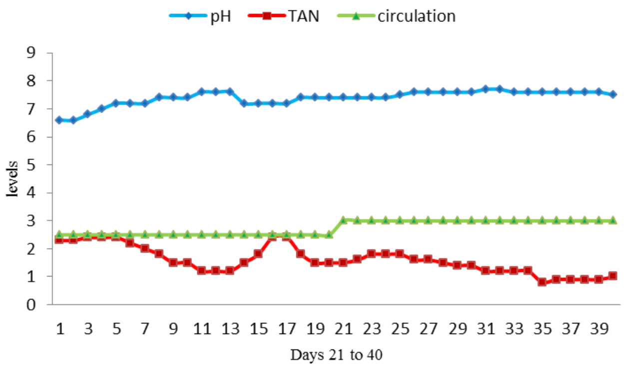

Figure 2 variations in pH, TAN and recirculation periods from 1st to 40th day.

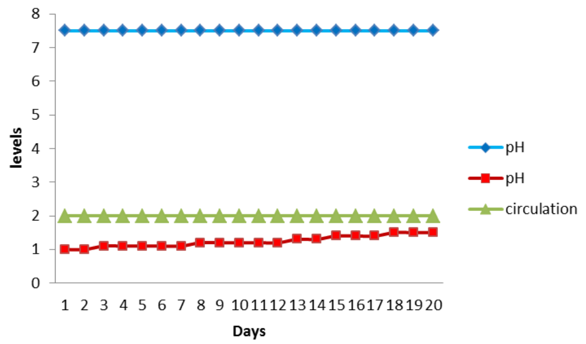

Figure 3 Variations in pH, TAN and recirculation periods from 41st to 60th day

Table 3. ANOVA for TAN

Sr. No.	Source	DF	Adj ss	Adj ms	F-Value	P-Value
	Circulation	4	8.151	2.0379	11.73	0.000
	Error	64	11.117	0.1737		
	Total	68	19.268			

The p-value in the table 1 is not more than significance level. Therefor there is enough evidence to reject the null hypothesis and that there are some of the points having different means. Confidence intervals are used to determine likely ranges for the differences and to determine whether the differences are practically significant. In table 2, the results show that circulation no. 1, 3 an 5 do not share a letter. It indicates that circulation 1 has significantly higher means than 3 and 5. While, circulations 2 and 4 do not share a letter and are not statistically significant. Tukey method was used for grouping information.

Table 4. Tukey Simultaneous Tests for Differences of Means

Difference of Levels	Difference of Means	SE of Difference	95% CI	T-Value	Adjusted P-Value
0.5 - 0.0	1.000	0.349	(0.021, 1.979)	2.87	0.043
2.0 - 0.0	-0.541	0.206	(-1.121, 0.039)	-2.62	0.079
2.5 - 0.0	-0.035	0.208	(-0.620, 0.550)	-0.17	1.000
3.0 - 0.0	-0.590	0.208	(-1.175, -0.005)	-2.83	0.047
2.0 - 0.5	-1.541	0.308	(-2.405, -0.677)	-5.01	0.000
2.5 - 0.5	-1.035	0.309	(-1.903, -0.167)	-3.35	0.012
3.0 - 0.5	-1.590	0.309	(-2.458, -0.722)	-5.14	0.000
2.5 - 2.0	0.506	0.129	(0.144, 0.867)	3.93	0.002
3.0 - 2.0	-0.049	0.129	(-0.411, 0.312)	-0.38	0.995
3.0 - 2.5	-0.555	0.132	(-0.925, -0.185)	-4.21	0.001

Table 5. Grouping Information Using the Tukey Method and 95% Confidence

Circulation	N	Mean	Grouping			
0.5	2	2.900	A			
0.0	5	1.900		B	C	
2.5	20	1.865		B		
2.0	22	1.3591			C	D
3.0	20	1.3100				D

The pairs except 2.0 – 0.0, 2.5 – 0.0 and 3.0 – 2.0 have a P-value more than the adjusted P value ($P > 0.05$). Therefore, these pairs are not statistically significant. And all the pairs except the above mentioned pairs are statistically significant ($P < 0.05$).

Table 6. Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.416771	42.31%	38.70%	32.97%

Table 4 shows, model summery where the s-value indicates the data values of response variables are falling far by 0.416771 from the fitted values. This lower value of S indicates that the model has a better response. The percentage of variation in the response (R^{2}) is 42.31%, which is not a bigger one and indicates that this model just fits the data but cannot give a better performance. However to check how well the model respond the new observations, predicted R^2 value is checked from table 4. The value is not substantially less than the R^2 value which indicates that the model is not over-fit and can respond better to new observations.

IV. CONCLUSION

The experimental results indicated that the system can be a solution to the water scarce areas where the unavailability of fresh water and poor electricity has badly affected the food production. Iridescent shark fish might be the aquaculture, which can support plant production in hypoxic conditions and survive for longer times. More research is needed on iridescent shark aquaculture with different vegetable plants which are locally popular as food in India. More experimental investigations needed to achieve the optimum combination of iridescent shark, Indian vegetable plant and low, low rates to test efficiency and cost effectiveness of the system.

REFERENCES

1. Kumar, Sujit. 2016. Fisheries India. Commissioned by the Netherlands Embassy to India, p. 1; FAO. 2014 National Aquaculture Sector Overview India, pp. 11.
2. Chandra, Ganesh & L. Sagar, R. (2003). Fisheries in Sundarbans:
3. Problems and Prospects. 10.2139/ssrn electronic journal. 2084014.
4. World Bank, “Fish to 2030: Prospects for fisheries and aquaculture”. Agriculture and Environmental Services Discussion Paper. 2013; 3 (83177-GLB): 1-102. www.fao.org/docrep/019/i3640e/i3640e.pdf
5. FAO. 2014 National Aquaculture Sector Overview India, p. 1; Ministry of Agriculture, Department of Animal Husbandry, Dairying and Fisheries. 2014. Handbook on Fisheries Statistics 2014, p. 5.
6. Rakocy, J.E. and Bailey, D.S., “Initial economic analyses of aquaponic systems. In: Aquaculture Europe”, Beyond Monoculture, European Aquaculture Society, 2003,58-64.
7. Nuwansi, Tharaka & Verma, A & Prakash, Chandra & Tiwari, Virendra Kumar & M H Chandrakant, bullet & Shete, Amruta & Prabhath, Amil (a 2015), “Effect of water flow rate on polyculture of koi carp (Cyprinus carpio var. koi) and goldfish (Carassius auratus) with water spinach (Ipomoea aquatica) in recirculating aquaponic system”, Aquaculture International, 24.
8. D. C. Love, M. S. Uhl, and L. Genello (2015), Energy and water use of a small-scale raft aquaponics system in Baltimore, Maryland, United States. Aquac. Eng., vol. 68, pp. 19–27.
9. E. Okemwa (2015), Challenges and Opportunities to Sustainability in Aquaponic and Hydroponics Systems, International Journal of Scientific Research and Innovative Technology, vol. 2, no. 11, pp. 54–76.
10. C. I. M. Martins et al (2010), Aquacultural Engineering New developments in recirculating aquaculture systems in Europe : A perspective on environmental sustainability. Aquac. *Eng.*, vol. 43, no. 3, pp. 83–93
11. Reebs, S.G., Whoriskey, F.G., and Fitzgerald, G.J.(1984), Diel patterns of farming activity, egg respiration, and the nocturnal behavior of male three-spined sticklebacks, Gasterosteus aculeatus L. (f. Trachurus), *Canadian Journal of Zoology*, Vol. 62, pp. 329-334.
12. Rakocy, J.E., Masser, M.P., and Losordo, T.M.(2006.),Recirculating Aquaculture Tank Production System: Aquaponic-Integrating Fish and Plant Culture. SRAC Publication No. 454, Texas, USA, pp.16.
13. Timmons, Michael & Ebeling, James & Wheaton, F.W. & Summerfelt, Steven & Vinci, Brian. (2002). Recirculating Aquaculture System.
14. Randall, D. J., & IP, Y. K. (2006). Ammonia as a respiratory gas in water and air-breathing fishes. Elsevier, 154 (1): 216-225.
15. Evans, D. H. (1998). The physiology of fishes (2nd ed.). New York: CRS press.
16. Somerville C., Cohen M., Pantanella E., Stankus A. & Lovatelli, A.(2014), Small-scale aquaponic food production. Integrated fish and plant farming. *FAO Fisheries and Aquaculture Technical Paper*. Rome, FAO, paper no. 11, 262 pp.
17. Hall, A.G., 1999. A comparative analysis of three biofilter types treating wastewater produced in recirculating aquaculture systems. Master’s Thesis. Virginia Polytechnic Institute and State University, Blacksburg, Virginia, p. 67.
18. Nelson Rebecca 2008,Aquaponic Equipment The Biofilter, Aquaponic journal,48.
19. Committee, N.N., Martins, M.Q., Bremenkamp, C.A. and Nunes, J.A. 2011. Nitrate concentrations in lettuce leaves depending on photosynthetic photon flux and nitrate concentration in the nutrient solution. Horticulture Brasileira, 29: 548-533.
20. Liu, K.W. and Yang, Q.C. 2012. Effect of short-term treatment with various light intensities and hydroponic solution on nitrate concentration of lettuce. Acta Agriculturae Scandinavica, Section BSoil & Plant Science, 62(2): 109-113. doi: 10.1080/09064710.2011.580366
21. Mitsch, W.J. and J.G. Gosselink. 2000. Wetlands. 3rd Ed. John Wiley & Sons, Inc., New York, NY. Papen, H. and R. von Berg. 1998. A most probable number method (MPN) for the estimation of cell numbers of heterotrophic nitrifying bacteria in soil. Plant Soil 199:123–130.
22. Lin, Y.F., S.R. Jing, D.Y. Lee, and T.W. Wang. 2002. Nutrient removal from aquaculture wastewater using a constructed wetlands system. Aquaculture 209:169–184.
23. Adler, P.R., F. Takeda, D.M. Glenn, and S.T. Summerfelt. 1996. Utilizing byproducts to enhance aquaculture sustainability. World Aquaculture 27:24–26.
24. Verhagen, F.J.M., P.E.J. Hageman, J.W. Woldendorp, and H.J. Laanbroek. 1994. Competition for ammonium between nitrifying bacteria and plant roots in soil pots; effects of grazing flagellates and fertilization. Soil Biol. Bioch. 26:89–96.
25. Richard V. Tyson, James M. White, Amarat Simonne (2008), Reconciling pH for Ammonia Biofiltration and Cucumber Yield in a Recirculating Aquaponic System with Perlite Biofilters, HORTSCIENCE 43(3):719–724.
26. Nelson R.L. (2004) Tilapia. Fast growing, hardy and tasty. Aquaponics Journal 35, 16-17.
27. Kintzios S. & Makri O. (2007) Ocimum sp. (Basil): botany, cultivation, pharmaceutical properties, and biotechnology. Journal of Herbs, Spices & Medicinal Plants 13, 123–150.
28. Rains J. (2007) Plants that grow well in aquaponics. Backyard Aquaponics Magazine 1, 20.
29. Klinger, D. and Naylor, R., (2012). Searching for solutions in aquaculture: Charting sustainable course. Annual Review of Environment and Resources, 37: 247-276.
30. Goada, A.M.A., Essa, M.A., Hassaan, M.S. and Sharawy, Z. (2015). Bio economic features for aquaponic systems in Egypt. Turkish Journal of Fisheries and Aquatic Sicences, 15 (3): 525-532.
31. Rakocy J., Shultz R.C., Bailey D.S. & Thoman E.S. (2004). Aquaponic production of tilapia and basil: comparing a batch and staggered cropping system. ISHS Acta Horticulturae 648: South Pacific Soilless Culture Conference – SPSCC.
32. Metcalf and Eddy Inc(1991)., “Wastewater Engineering: Treatment, Disposal and Reuse,” 3rd edition, Revised by Tchobanoglous, G. and Burton, F., McGraw-Hill, Inc., Singapore.
33. Durgananda Singh Chaudhary, Saravanamuthu Vigneswaran†, Huu-Hao Ngo, Wang Geun Shim* and Hee Moon*(2003), Biofilter in water and wastewater treatment, Korean J. Chem. Eng.,**20**(6), 1054-1065.
34. Ratnoji Shilpa S and Singh, Nimisha, 2014, A study of coconut shell - activated carbon for filtration and its

comparison with sand filtration. International Journal of Renewable Energy and Environmental Engineering,2 (3), 201-204.
35. B. Meenu, E. D. Neeraja, G. Rejimon, and A. Varghese (2015), Review Article Impatiens balsamina : An overview, Journal of Chemical and Pharmaceutical Research, vol. 7, no. 9, pp. 16–21
36. FAO Fisheries and Aquaculture Department 2011, Technical Paper. No. 500/1. Rome, FAO,105 pp.

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