Greenhouse tilapia culture in aquaponic system

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Abstract

The aquaponics system is the integration of a hydroponic system with aquaculture in a recirculating system that removes wastes and metabolites produced by farmed fish through nitration and their uptake by plants. Bacteria associated with plant roots are involved in the transfer of nutrients. Red hybrid tilapia *Oreochromis* sp. was used for intensive production in the aquaponics system with stocking density 120/m^3 in round polyethylene tanks. Cultivation of vegetables including basil, common mint, peppermint, pennyroyal, lettuce, beets, Swiss chard, water cress, celery and okra in the floating beds led to proper production.Given the large number of dormant greenhouses in Iran and the limitation of water resources in these regions and the need to strengthen production and employment, commercial production in aquaponic system seems a very appropriate program for aquaculture and agriculture improvement.

Keywords: Tilapia, Greenhouse, aquaponic, Iran

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Introduction

The aquaponic system is the integration of the hydroponic system with aquaculture in a recycling system in which the wastes and metabolites produced by farmed fish are removed by nitration and absorption by plants. Bacteria in food particles plant roots are involved in the transfer of nutrients. In this system, plants as biological filters improve water quality and the discharge of effluents and toxins from fish farming and plant production into the environment is greatly reduced (El-Sayed, 2006; Karlsdottir, 2012).

In aquaponic agriculture, in addition to the protection and optimal use of agricultural water and soil, healthy food products are produced. Aquaponic system based on optimal water consumption, no need for agricultural lands and soil, the possibility of implementation in farms with non-permanent water, reducing the use of fertilizers and pesticides, aquaculture/agriculture with environmental considerations, intensive production of healthy fish/plant products and increasing diversity farm production is a favorable response to the current needs of the agricultural sector and a good way to increase per capita aquatic consumption.

With the development of tilapia studies in Iran in recent years, the production of the fish has been studied in different systems and the production of tilapia in the aquaponic system has been followed (Rafiee *et al*., 2005a&b; Rajabipour *et al*., 2017).

In the present study, the intensive production of tilapia with vegetables and cucurbits in the aquaponic system was investigated.

Materials and methods

This project was carried out in a 300m^2 greenhouse. The space inside the greenhouse was separated by a polycarbonate plate into two separate salons for fish farming and plant cultivation.

Round polyethylene tanks with a total volume of 15m^3 were considered for fish culture. Clarifier tanks were zucchini-shaped with a vertical wall in the middle of cylindrical section a bottom drain valve to separate solid particles and a water outlet pipe at the top to transfer water to the filtration pool. The filtration pond with a volume of 4m^3 with media net was considered to create a suitable bacterial coating for nitrogen fixation activities. The degassing pool had a volume of 4m^3 cubic meters and was equipped with a strong aeration hose to remove undesirable gases. Hydroponic canals consisted of 3 canals with dimensions of 15 x 2 meters and a depth of 45cm. The surface of the ponds was covered with ionolithic sheets with a thickness of 5cm with a total area of about 70m^2. To cultivate the plant, pores with a diameter of 5 cm were created in the number of 24/m^2. A 1m^3 septic tank equipped with a float was buried in the ground at the end of the water flow path to collect cycled water from the system. A 0.5hp pump pushed water from the

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septic tank to the fish tanks. The water moves in all other parts of the system by gravity and. Blue was used. A heat furnace was used to provide water heating in winter and a water cooler was used to cool the plant cultivation salon in the warm season.

Daily water temperature of fish farming and plant cultivation salons were recorded by maximum-minimum thermometer and water temperature was recorded by mercury thermometer. Dissolved oxygen, pH, salinity and EC were measured by portable Hatch system, ammonium, nitrite, nitrate, iron and calcium by calorimetric method. Sodium, potassium, magnesium and TDS ions were measured by electrolyte analyzer.

Juveniles of the red hybrid tilapia, *Oreochromis* sp. with an average weight of 47-61 g and a density of 120/ m^3 were stored in June and July 2019 in 6 tanks 501-506. The fish were fed with32% crude protein pellet food three times a day. The average daily nutrition of fish was $80 g/m^2$/day. Fish weight and length of 25 fish from each tank were measured monthly. Fish culture period continued until February 2019. The amount of feed consumed was recorded and finally the feed conversion ratio was calculated (Paul and Reynolds, 1999).

Seeds and seedlings were used to grow the plants, which were placed in ionolite sheets in a disposable glass containing straw, in a disposable glass containing straw. The common green basil *Ocium basilium*, common mint *Mentha sativa*, peppermint *Mentha piperita*, pennyroyal *Menthum pulegium*, comon lettuce *Lettuce sativa*, fodder beet *Beta vulgaris*, Swiss chard *Beta vulgaris cicla*, water cress *Nasturtium officinale*, celery *Apium graveolens*, okra *Abelmoschus esculentus*and tomatoe *Solanum lycopersicum* were grown. Cultivation density was considered for leafy vegetables 20, celery 8 and cucurbits 6 plants/m^2. Cultivation area for any plant was at least $2m^2$. Chelate iron was added to the culture medium once a month. Harvesting of plants was done at appropriate intervals according to their type.

In general, the system was designed based on the aquaponic UVI model. Storage, culture, and measurements were consistent with conventional FAO-approved methods (Rakocy *et al*., 2004, 2010, and 2015; Somerville *et al*., 2014).

Results

The monthly water temperature ranged from 24.6±2.8°C to 32.1±2.3°C. The mean values of minimum and maximum daily air temperature in fish farming salon was 19-27°C and in plant salon 19-22°C. The highest temperature was recorded in fish and plant breeding salons in June to August, the minimum temperature in December to February. Changes of water temperature, minimum and maximum of air temperature in fish and plant breeding salons are shown in Figures 1 to 3, respectively.

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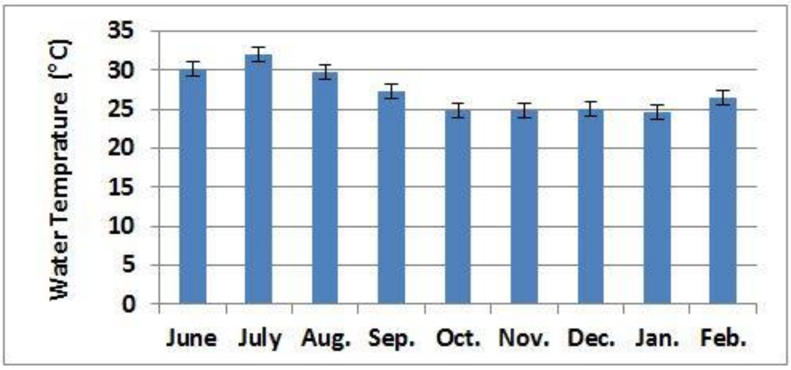

Figure 1: Monthly water temperature in fish farming tanks.

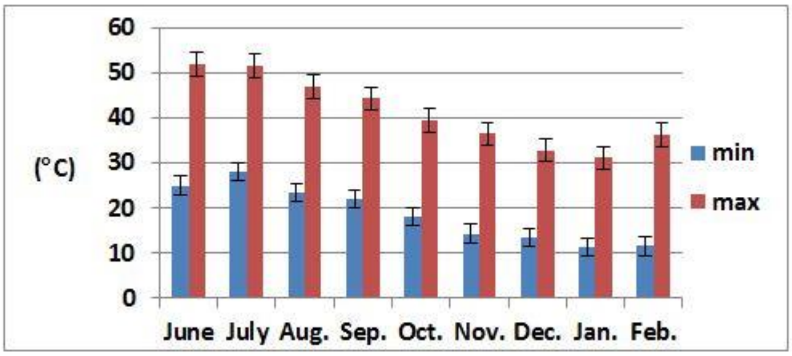

Figure 2: Minimum and maximum monthly average in the air temperature of the fish culture salon.

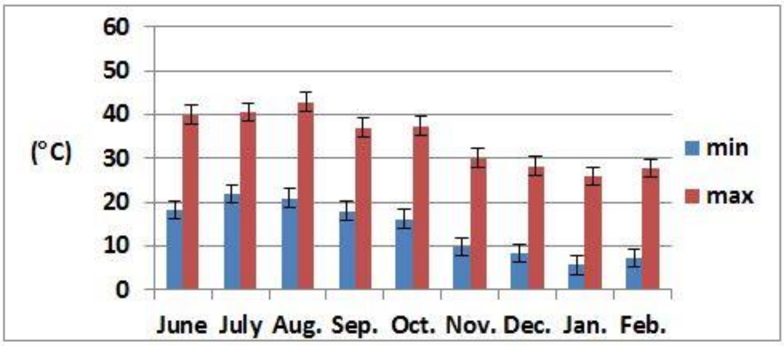

Figure 3: Minimum and maximum monthly average in the air temperature of the plant cultivation salon.

The monthly values of salinity, electrical conductivity (EC) and total dissolved solids (TDS) are given in Table 1. The trend of changes in electrical conductivity and water TDS has been increasing during the breeding period.

The monthly mean changes of dissolved oxygen and pH of fish ponds and hydroponic channels are listed in Table 2. The density of water-soluble oxygen has been declining until the last months of the study. The pH of water also tended to acidify and decrease.

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The concentrations of ammonium, nitrite and nitrate in the water of fish tanks and hydroponic channels are shown in Table 3. Ammonium concentrations were often lower in hydroponic channels than in fish farms. The concentrations of Fe, Ca, Na, K and Mg ions in the water of hydroponic channels are shown in Table 4.

Table 1: Monthly values of water salinity (ppt), EC (µmho/cm) and TDS (ppm).

Month	Salinity	EC	TDS
June	1.05	2271	859
July	1.23	2740	980
August	1.18	2470	1153
September	1.11	2310	1211
October	1.11	2211	1252
November	1.15	2225	1172
December	1.08	2173	1051
January	0.94	1814	1278
February	1.00	2096	1302

Table 2: Monthly averages of dissolved oxygen (mg/L) and pH in fish tanks and hydroponic channels

	DO		pH	
Month	Fish Tank	Hyd. Ch.	Fish Tank	Hyd. Ch.
June	6.99	6.68	8.00	7.98
July	5.47	5.20	7.33	7.49
August	4.40	4.77	6.97	7.28
September	5.11	4.85	7.32	7.44
October	5.85	5.01	7.24	7.23
November	4.14	5.25	6.44	6.38
December	4.49	7.11	6.24	6.21
January	6.28	7.77	6.67	6.56
February	5.44	6.66	6.47	5.92

Table 3: Monthly averages of ammonium, nitrite and nitrate concentrations in fish tank and hydroponic channels (mg/L).

	NH4+		NO2-		NO3-	
Month	Fish Tank	Hyd. Ch.	Fish Tank	Hyd. Ch.	Fish Tank	Hyd. Ch.
June	0.3	0.13	0.1	0.08	20	20
July	0.25	0.32	0.25	0.27	44.7	31
August	0.7	0.35	0.21	0.25	36.7	40
September	0.7	0.48	0.16	0.25	110	75
October	0.75	0.45	0.13	0.15	150	125
November	0.75	0.48	0.14	0.18	137.5	137.5
December	1.3	1	0.15	0.2	125	110
January	0.2	0.15	0.1	0.1	60	90
February	1.2	1	0.1<	0.1<	125	125

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Table 4: Monthly averages of Fe, Ca, Na, K and Mg in hydroponic channels (mg/L).

Month	Fe	Ca	Na	K	Mg
June	0.06	77	729.1	128.7	32
July	0.01>	78	520	62	35
August	0.05	89	485	25	34
September	0.07	77	391	36.6	41
October	0.11	89	487.8	22.0	36.5
November	0.09	89	365.7	46.0	23
December	0.15	86.5	406.2	50.7	34
January	0.01>	80	519.8	41.0	32
February	0.1	86	485.3	39.8	35

The monthly changes of the mean length and weight of farmed tilapia showed a monthly increase (Figs. 4 and 5). The average length and weight is higher in the 504 to 506 tanks that were stored before the other three tanks, in June. FCR was obtained 1.7 during the period.

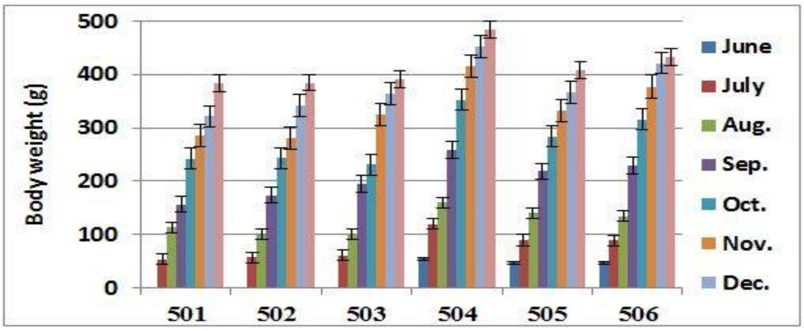

Figure 4: Average monthly body weight of farmed tilapia in tanks 501 to 506.

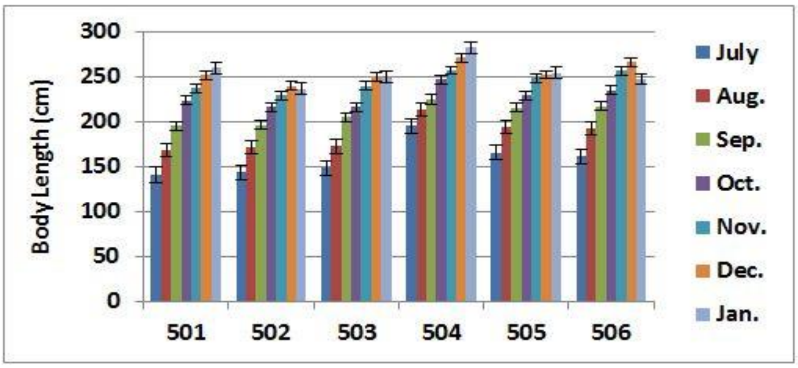

Figure 5: Average monthly length of farmed tilapia in tanks 501 to 506.

The average monthly yield of the plants per unit areawas acquiredfor basil 1.3, common mint 1.5, peppermint 3.9, pennyroyal 1.2, lettuce 1.3, beet leaf 4, Swiss chard 1.5, water Leek 4, okra 1, tomato 4.5 kg/ m^2. Celery was harvested at a rate of 11 kg/m^2 after 3 months of cultivation.

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Discussion

The minimum and maximum temperatures were 19-27°C in the fish breeding salon and 19-22°C in the plant breeding salon, and this difference between day and night temperatures is due to the climatic conditions of the region. The water temperature in the hot season was 27-32°C, which is favorable for growing tilapia, because of very hot summers. With decreasing air temperature in winter, water temperature decreased and reached below 25°C in November, the water temperature was maintained above 25°C within the desired range for growing tilapia using a heating system (Nandlal and Pickering, 2004; El-Sayed, 2006; Rakocy *et al*., 2010).

In order to produce plants properly during the cultivation period, the maximum temperature of the culture salon did not rise above 32°C and the lowest did not fall below 10°C. Types of mint had a more suitable crop at higher temperatures. Lettuce cultivation was suitable in the cold season and at temperatures above 25°C, the quality of the crop was not good. Plant production intervals vary depending on the type of plant and temperature conditions have a direct effect on it. Adequate lighting is important, especially in winter, when the day length is shorter.

The amount of dissolved oxygen and pH decreased due to the growth of fish and plants with the progress of the period, which was expected, meanwhile these values were within the desired range (Nandlal and Pickering, 2004; Rakocy *et al*., 2004; El-Sayed, 2006).

The amount of ammonium in the water of hydroponic canals was less than that of fish farming tanks, which is expected due to nitrogen fixation reactions. Nitrate concentration was in the appropriate range and changes in nitrate concentration with the progress of the incremental period and indicates the favorable conditions of nitrogen fixation performance.

The concentration of Na (729-366 mg/L), Ca (77-89 mg/L) and Mg (32-31 mg/L) in water is relatively high, which can explain the amount of electrical conductivity of water (1814-2740µmho/cm). The concentration of Fe in water was very low, from less than 0.01 to 0.15 mg/L. For this reason, iron chelates were added to the culture medium once every three weeks. (Rakocy *et al*., 2004; Somerville *et al*., 2014).

The average weight of fish in the tanks stored in June in a period of 6 months was in the range of 484-408 grams and in the tanks stored in July was 391-384 grams. The amount of fish production per unit volume in a period of 6 months was about 53.3kg/m^3.

Monthly yield of plants per unit area for basil 1/3, common mint 1.5, peppermint 3.9, pennyroyal 1.2, lettuce 1.3, beet leaf 4, Swiss chard 1.5, water cress 4, okra 1, tomatoes 4.5 kg andcelery 11kg/ m^{2}after 3 months of cultivation, are suitable and their cultivation in aquaponic system is recommended. Intensive cultivation of tilapia and the amount of plant production per unit area has been favorable compared to the results of other researchers (Losordo, *et al*., 1999; Masser, 1992; Rakocy *et al*., 2004 and 2006; Rakocy *et al*., 2011; Pantanella and Colla, 2013). However, in order to save energy and achieve a better yield of the plant product, lettuce is more suitable for lower indoor temperature conditions and types of mint for warm season.

In order to properly profit the aquaponic production system and considering the health of the fish and plant products produced, identifying the target market, introducing these products to applicants in terms of quality and health, packaging and how to supply these products is very important. Due to the non-use of chemical toxins and fertilizers, it is recommended that these products be introduced and offered to consumers and applicants of healthy and organic products. Proper packaging as well as processing of plant products such as drying and sweating is effective in the added value of production.

The results of this study showed that by implementing the aquaponic UVI model at a scale of 500 square meters of land, which includes 30 cubic meters of aquaculture space and 220 square meters of plant cultivation (Rakocy *et al*., 2010), more than 3000kgculture tilapia and 2000-12000 kg edible plants would be produced.

Given the large number of dormant greenhouses in Iran especially in the central regions of the country, and the limitation of water resources in these regions and the need to strengthen production and employment, the implementation of aquaponic projects seems a very appropriate program for aquaculture and agriculture improvement.

References

El-Sayed, A.M. 2006. *Tilapia culture*. CABI Pub.277P.

Karlsdottir, S.K., 2012. Aquaponics – Grønn vekst, Funded by Nordisk Atlantsamarbejde (NORA) 2011-2012, Project No 510-072, Final report from the project, September 2012.

Losordo, T.M., Masser, M.P. and Rakocy, J.E., 1999. Recirculating aquaculture tank production systems: A review of component options. Southern Regional Aquaculture Center Pub.

Masser, M.P., 1992. Hydroponic integration with aquaculture. Lecture, Dept of Wildlife and Fisheries Sciences, TAMU (In: Rakocy, James E., Thomas M. Losordo, and Michael P. Masser., 1992. Recirculating Aquaculture Tank Production Systems: Integrating Fish and Plant Culture.SRAC Publication No. 454.Southern Region Aquaculture Center, Mississippi State University. 6P.

Nandlal, S. and Pickering, T., 2004. Tilapia fish farming in Pacific Island countries. V: 1-2. Copyright Secretariat of the Pacific Community and Marine Studies Program, the

University of the South Pacific, Oceania.

Pantanella, E. and Colla, G., 2013. Advance in freshwater aquaponic research. International Aquaponic Conference, Aquaponic and Global Food Security, University of Wisconsin.

Paul, J.B.H. and Reynolds, J.D., 1999. Handbook of fish biology and fisheries. V: 1. Blackwell Science Pub. 413.

Rafiee, G., Saad, C., Kamarudin M.H., Ismail, M.R and Sijam, K., 2005a. Usage of Aquaculture Wastewater Produced in A Recirculating Aquaculture System as A Medium for Lettuce (Lactuca sativa Var Longifolia) Production. *Iranian J.Natural Res*., 58, 3, pp.???

Rafiee, Gh.R., Kamarudin, M.H. and Farahmand, H., 2005b. Design of a Simple Closed Aquaponic System and Production of Red Tilapia (Oreochromis sp.) and lettuce (Lactuca sativa var longifolia). *Iranian J. Natural Res*., 58, 4.

Rajabipour, F., Mashaii, N., Sarsangi, H., Mohammadi, M. and Matinfar, A., 2017. An Investigation on Tilapia Culture in Aquaponic System in Iran. *Modern Agricultural Science and Technology*, ISSN 2375-9402, USA December 2017, 3, 5-6, pp. 12-17.

Rakocy, J.E., Bailey, D.S., Shultz, R.C. and Thoman, E.S., 2004. Update on Tilapia and vegetable production in the UVI aquaponic system. p.676–690, In Blivar, R. B., Mair, G. C., Fitzsimmons, K., eds, *Proceedings from the Sixth International Symposium on Tilapia in Aquaculture*, Manila, Philippines.

Rakocy, J.E., Masser, M.P. and Losordo, T.M., 2006. Recirculating aquaculture Tank Production Systems: Aquaponics-Integrating Fish and Plant Culture, SRAC Publication, N 454.

Rakocy, J.E., Bailey, D., Shultz, C. and Danaher, J., 2010. The Status of Aquaponics - University of the Virgin Islands Agricultural Experiment Station.

Rakocy, J.E., Bailey, D., Shultz, C. and Danaher, J., 2011. The International Aquaponics and Tilapia Aquaculture Course at the University of the Virgin Islands, Agricultural Experiment Station, University of the Virgin Islands, U.S.A.

Rakocy, J., Baily, D., Shultz, C. and Danaher J., 2015. Design and Operation of the UVI Aquaponic System. University of the Virgin Islands

Somerville, C., Cohen, M., Pantanella, E., Stankus, A. and Lovatelli, A., 2014. Small-scale aquaponic food production, integrated fish and plant farming. FAO Fisheries and Aquaculture Technical Paper 589. Food and Agriculture Organization of the United Nations, Rome.

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