

The Effect of Natural Zeolite (Clinoptiolite) on Aquaponic Production of Red Tilapia (*Oreochromis* sp.) and Lettuce (*Lactuca sativa* var. *longifolia*), and Improvement of Water Quality

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ABSTRACT

The effects of natural zeolite as a bed medium in increasing lettuce and red tilapia growth as well as improvement of water quality parameters in an aquaponic system were investigated. An experiment with a completely randomized design was run with two treatments in triplicates, 1) an aquaponic system without use of zeolite as a control group and 2) use of a small cotton bag, containing 10 g zeolite as a bed medium for planting a lettuce seedling. In each experimental unit, 42 seedlings of lettuce were introduced. The individual weight of fish and lettuce yield in treatment 2 was significantly higher ($P < 0.05$) than treatment 1 at the end of experiment. The initial mean individual weight of red tilapia juveniles was 6.23 ± 0.06 g and increased to 32.50 ± 2.00 and 37.50 ± 2.20 in treatments 1 and 2, respectively by the end of experiment. The yield of lettuce was higher in treatment 2 (1507 ± 445.00 g/unit) compared to the control (275 ± 83 g/unit). The concentration of total ammonia-N in the water was significantly lower ($P < 0.05$) in treatment 2 compared to treatment 1 at the end of experiment. The concentration of phosphorous and potassium in the fish rearing tanks was significantly lower ($P < 0.05$) in treatment 2. These results indicated that the use of zeolite, as a bed medium to plant lettuce seedlings in a recirculating aquaponic system could increase the growth of lettuce seedlings as well as improving water quality parameters.

Keywords: Aquaponic system, Diet, Lettuce, Red tilapia, Water quality, Zeolite.

INTRODUCTION

Nitrous oxide, nitric oxide, nitrate, nitrite or ammonia/ammonium are all soluble forms of nitrogen in water, causing eutrophication of estuaries and coastal seas (Mander and Forsberg, 2000). Excess nitrogen is formed from the catabolism of N-compounds in aquatic animals and a large amount of these compounds are produced in aquatic animal farms and released as wastewater in the environment and have a consid-

erable environmental impact. Therefore, control of wastewaters must be considered an essential factor in the management of any intensive fish culture system with the aim of achieving a reduction of wastewater and a high production of fish, particularly while sustainable aquaculture is the target (Mump-ton and Fisherman, 1997; Bergero *et al.*, 1996). Various methods of ammonia-nitrogen removal from waters have been developed, but the main aim of worldwide investigators has been the presentation of new possibilities for ammonia-nitrogen re-

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removal in waters. Wastewater processing or purification by plants in greenhouses or specific treatment systems has become increasingly popular in response to water shortages and increasingly its demands (Gloger *et al.*, 1995). Over the past three decades, in aquaculture practices, hydroponic(s) plant compartments with different experimental design have been integrated into aquaculture systems in both warm and moderate climates to alleviate the accumulation of nutrients, especially N-compounds in the culture system (Nair *et al.*, 1985; Rakocy, 1995). The natural zeolite framework consists of a symmetrically stacked alumina and silica tetrahedral which results in an open and stable three dimensional honey comb structure with a negative charge. The negative charge within the pores is neutralized by positively charged ions (cations) such as sodium. These cations are exchangeable with certain cations in solutions such as ammonium ions. Therefore, zeolites represent an appropriate material for removing and exchanging ions (Na^+ , Ca^{2+} and K^+) that are relatively harmless (Curkovic 1995). As a result, it would be possible to reduce further the nutrient solution produced in the fish culture system using a plant compartment, while natural zeolite integrates as a bed medium of lettuce seedling plantation. Thus, the main objective of this study was to evaluate the use of natural zeolite as a bed medium for planting lettuce seedlings and as an ion exchangeable medium associated with plant roots with regard to N-compounds, the removal of other cations from water and the improvement of water quality efficiency due to higher lettuce growth in an aquaponic system.

MATERIALS AND METHODS

The System and Experimental Design

The effects of natural zeolite as a bed medium in increasing the lettuce growth and improvement of water quality parameters in an aquaponic system were investigated. An

experiment with a completely randomized design was run with two treatments in triplicates, 1) an aquaponic system without use of zeolite as a control and 2) use of a small cotton bag, containing 10 g zeolite as a bed medium for planting a lettuce seedling in the hydroponic compartment of the system. The system consisted of a fiberglass tank (110 W×84 L×100 H cm) equipped with three hydroponic troughs (110L×30W×5 D cm) and a submersible pump (Model Aqua, 1500) for recycling the water from the rearing tank through the hydroponics troughs then to fish tank again (Figure 1).

Feed and Feeding

The supplemental feed was a commercial diet of floating pellets (Car-gill company), containing 24% protein, 6% fat, 6% fiber and 11% moisture. The fish were fed twice a day at a rate of 5% of daily fish biomass at 09.00 and 13.00 hrs.

Production of Lettuce Seedlings

One week prior to the start of experiment, lettuce seeds were sowed in some sponge sheets (3×40×60cm), which were already cut into small pieces (a sponge cube 3 ×3×3 cm); each had a shallow slit in one side made as a seed germination bed. The seeds were irrigated daily until germination. Then each new seedling (followed with a small sponge cube) was put separately inside a perforated plastic cup. The cups containing seedlings were introduced to the experimental trials at the initiation of the experiment.

Water Quality Parameter Measurements

Dissolved oxygen (DO) and Temperature (T) were measured (using YSI Model 57, oxygen and temperature meter). Electro Conductivity (EC) was determined twice a week (with an EC meter model HANNA instrument conductivity meter HI 8033). The pH was determined twice a week (with an

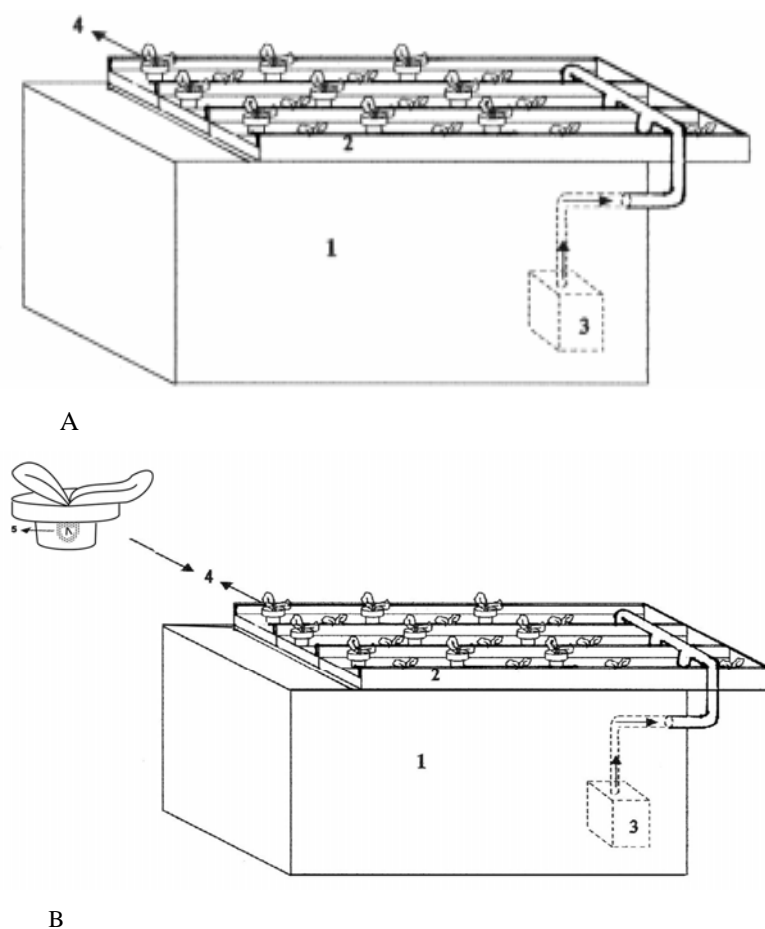


Figure 1. Schematic feature of the aquaponic system used for culture of fish and vegetables, 1. Fish tank, 2. Hydroponic troughs, 3. Water pump, 4. Lettuce cup, 5. A small cotton bag containing 10 g zeolite.

Orion model 410A pH meter). Total ammonia ($\text{NH}_3\text{-N}$) were measured (after 10 times dilution of the samples) weekly in rearing tanks (using the indophenols method) (APHA, Standard Methods book, 1992). The concentration of dissolved nutrient in the rearing tanks was recorded weekly, taking two samples, each containing 100 ml of water. The concentration of total nitrogen (modified Bertholet method) and phosphorous (orthophosphate reacts with molybdate to form phosphomolybdic acid then reduced by ascorbic acid to intensively colored Molybdenum blue complex which can be measured at 660 nm.) were measured by an Auto

analyzer by Chemlab-system 4. The concentration of K, Fe, Ca, Mg, Zn and Cu were measured with an atomic absorption spectrophotometer, model Perkin Eliner AAS 3110.

Analytical Methods

A proximate analysis of the diet, fish body and lettuce shoot was made, using the following procedures; dry matter by drying at 75 °C for 3 days; crude protein with micro-Kjeldahal; $\text{N} \times 6.25$; fat by dichloromethane extraction (Soxhel) and ash by combustion at 550 °C for 12 h (APHA, 1992).



Protocol

The experiment was conducted over a 7-week period. At the start of the experiment, each rearing tank was stocked with 50 red tilapia juveniles with a mean weight of 6.23 ± 0.06 g (mean \pm SD) and filled with 640 L of aged tap water. Water continuously aerated through two circular air stones (five cm dimension) during the experimental period. Two weeks after the initiation of the experiment, 42 cups, each containing a 1-week old lettuce seedling was placed into the 42 holes of polystyrene sheets that already were fixed inside all NFT (Nutrient Film Technique) troughs in each experimental unit. The lettuce seedlings were cultured for a 5-week period and both the fish and lettuce were harvested simultaneously at the end of the experimental period.

Statistical Analysis

Percent values were transferred to arc sin values and analyzed statistically. Data of variables were subjected to paired-comparison t-test analysis at a 0.05 probability level (SPSS Microsoft version 10.0).

RESULTS

Fish and Lettuce Growth

The amount of feed consumed by the fish in all the experimental units was the same during the experimental period (1050g). Individual body weight was significantly different ($P < 0.05$) between treatments and

reached mean individual weights of 32.5, and 37.5 g in treatments without zeolite (1), and with zeolite (2), respectively by the end of experiment. The biomass of the fish increased during the experimental period and was not significantly different ($P > 0.05$) between treatments at the end of experiment. These amounts were 1235 and 1349 g for treatments 1 and 2, respectively. The fish survival rate was not significantly different ($P > 0.05$) between treatments (Table 1).

Water Quality Parameters

Total ammonia

The concentration of total ammonia fluctuated during the experimental period. The concentration of ammonia in water increased within the first three weeks of the experiment then, in the 4th week, decreased and later on continuously increased in treatments by the end of experiment. The concentration of total ammonia was significantly different ($P < 0.05$) between the treatments by the end of the experiment. These rates were 9.19 and 7.27 mg L⁻¹ in treatments 1 and 2, respectively (Table 2).

Total inorganic nitrogen (TIN)

The concentration of TIN increased during the experimental period. The concentration of TIN was significantly higher ($P < 0.05$) in treatment 1 than 2, these rates were 24.83 and 15.76 mg L⁻¹ for treatments 1 and 2, respectively at the end of experimental period (Table 3).

Table 1. Data (Mean \pm SD) of Dried fish body (DFB), Fish protein (FP), Fish Biomass (FB), Fish survival (FS), Individual fish weight (IFW), Yield of lettuce (YL) and Lettuce protein (LP) in different treatments (T_{1,2} without zeolite and with zeolite, respectively) at the end of experiment.

T	DFB (%)	FP (%)	FB (g)	FS (%)	IFW (g)	YL (g)	LP (%)
1	22.28 \pm 0.19 ^a	59.48 \pm 2.27 ^a	1249 \pm 107 ^a	79.00 \pm 4.00 ^a	32.50 \pm 2.00 ^a	275 \pm 83 ^a	25.22 \pm 0.43 ^a
2	22.63 \pm 1.20 ^a	57.25 \pm 0.61 ^a	1275 \pm 144 ^a	77.00 \pm 3.00 ^a	37.50 \pm 2.20 ^b	1507 \pm 448 ^b	26.14 \pm 0.31 ^a

The same superscript letters in a column are not significantly different at the 0.05 level.

Table 2. Variation in concentration of total ammonia (Mean \pm SD) in treatments (T) during the experimental period.

T	Week 2 mg L ⁻¹	Week 3 mg L ⁻¹	Week 4 mg L ⁻¹	Week 5 mg L ⁻¹	Week 6 mg L ⁻¹	Week 7 mg L ⁻¹
1	0.68 \pm 0.71 ^a	2.65 \pm 0.82 ^a	4.02 \pm 1.08 ^a	1.87 \pm 0.29 ^a	4.65 \pm 0.62 ^a	9.19 \pm 0.69 ^b
2	0.59 \pm 0.62 ^a	1.61 \pm 0.92 ^a	2.72 \pm 1.23 ^a	1.17 \pm 0.41 ^a	3.90 \pm 0.68 ^a	7.27 \pm 0.21 ^a

The same superscript letters in a column are not significantly different at the 0.05 levels.

Table 3. The concentration of total inorganic nitrogen (Mean \pm SD) in treatments (T) during the experimental period.

T	Week 2 mg L ⁻¹	Week 3 mg L ⁻¹	Week 4 mg L ⁻¹	Week 5 mg L ⁻¹	Week 6 mg L ⁻¹	Week 7 mg L ⁻¹
1	0.62 \pm 0.04 ^a	1.04 \pm 0.38 ^a	4.75 \pm 0.69 ^a	16.57 \pm 2.75 ^b	21.45 \pm 0.63 ^b	24.83 \pm 1.74 ^b
2	0.53 \pm 0.19 ^a	1.99 \pm 0.29 ^a	5.31 \pm 0.84 ^a	15.00 \pm 1.90 ^b	14.09 \pm 3.34 ^a	15.76 \pm 1.31 ^a

The same superscript letters in a column are not significantly different at the 0.05 level.

Electro-conductivity (EC)

The EC of water increased in both treatments during the experimental period. The Ec of water was significantly different ($P < 0.05$) after three weeks (Table 4). These rates were 0.43 and 0.46 mmhos/cm for treatments 1 and 2, respectively at the end of experimental period.

The pH and oxygen

The pH of water decreased in the rearing

tanks during the experiment. These rates were 6.5 and 6.53 in treatments 1 and 2, respectively at the end of experiment (Table 5). The concentration of oxygen in the fish tanks was between 5.70-6.20 during the experimental period.

Phosphorus (P)

The concentration rate of P increased in the fish rearing tanks during the experimental period. The P concentration was significantly ($P < 0.05$) lower in treatment 2 than

Table 4. Electro-conductivity (EC) (mmhos/cm) (Mean \pm SD) of water in rearing tanks in treatments during the experimental period.

T	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7
1	0.16 \pm 0.00 ^a	0.18 \pm 0.02 ^a	0.33 \pm 0.01 ^a	0.27 \pm 0.02 ^a	0.35 \pm 0.02 ^a	0.43 \pm 0.03 ^a
2	0.16 \pm 0.00 ^a	0.22 \pm 0.01 ^b	0.32 \pm 0.03 ^a	0.32 \pm 0.07 ^a	0.37 \pm 0.04 ^a	0.46 \pm 0.01 ^a

The same superscript letters in a column are not significantly different at the 0.05 level.

Table 5. The pH of water in fish tanks between treatments during the experimental period.

T	Week 1	Week 2	Week 3	Week 4	Week 5	Week 7
1	7.21	6.40	6.30	6.08	6.62	6.50
2	7.21	6.45	5.91	5.49	6.40	6.53

**Table 6.** Variation in concentration of Phosphorus (P) in water (Mean \pm SD) in treatments (T) during the experimental period.

T	Week 2 mg L ⁻¹	Week 3 mg L ⁻¹	Week 4 mg L ⁻¹	Week 5 mg L ⁻¹	Week 6 mg L ⁻¹	Week 7 mg L ⁻¹
1	1.70 \pm 0.03 ^a	1.86 \pm 0.18 ^a	5.57 \pm 0.45 ^a	11.4 \pm 0.62 ^a	12.7 \pm 0.43 ^b	19.73 \pm 0.12 ^b
2	1.70 \pm 0.11 ^a	2.16 \pm 0.03 ^b	5.34 \pm 0.49 ^a	12.50 \pm 0.53 ^a	11.57 \pm 0.55 ^a	16.20 \pm 0.26 ^a

The same subscript letters in a column are not significantly different at the 0.05 levels.

Table 7. Concentration of Calcium (Ca) in water (Mean \pm SD) in treatments during the experimental period.

T	Week 2 mg L ⁻¹	Week 3 mg L ⁻¹	Week 4 mg L ⁻¹	Week 5 mg L ⁻¹	Week 6 mg L ⁻¹	Week 7 mg L ⁻¹
1	13.57 \pm 1.40 ^a	23.33 \pm 2.90 ^a	23.50 \pm 4.44 ^a	44.00 \pm 7.00 ^a	38.33 \pm 1.26 ^b	33.17 \pm 3.00 ^a
2	15.80 \pm 0.53 ^b	24.5 \pm 0.09 ^a	21.83 \pm 1.53 ^a	38.67 \pm 0.90 ^a	26.70 \pm 0.26 ^a	34.70 \pm 4.93 ^a

The same subscript letters in a column are not significantly different at the 0.05 levels.

treatment 1 by the last two weeks of the experiment. These rates were 19.73 and 16.20 mg L⁻¹ for experiments 1 and 2, respectively at the end of experiment (Table 6).

Calcium (Ca)

The concentration of Ca increased in the fish rearing tanks during the experimental period. The Ca concentration was significantly different ($P < 0.05$) two weeks after initiating the experiment; afterwards it did not show any significant differences ($P > 0.05$). These rates were 33.17 and 34.70 mg L⁻¹ for experiments 1 and 2, respectively, at the end of experiment (Table 7).

Magnesium (Mg)

The concentration of Mg in the fish tanks

was not significantly ($P > 0.05$) different between treatments during the experimental period. However, it was lower in treatment 2 compared to treatment 1 at the end of experiment. These rates were 5.37 and 4.60 mg L⁻¹ for experiments 1 and 2, respectively (Table 8).

Zinc (Zn)

The concentration of Zn in the fish rearing tanks was significantly ($P < 0.05$) different between treatments at the end of experimental period. It was lower in treatment 1 compared to treatment 2 at the end of experiment. These rates were 0.13 and 0.14 mg L⁻¹ for experiments 1 and 2, respectively (Table 9).

Table 8. Concentration of Mg in water (Mean \pm SD) in treatments during the experimental period.

T	Week 2 mg L ⁻¹	Week 3 mg L ⁻¹	Week 4 mg L ⁻¹	Week 5 mg L ⁻¹	Week 6 mg L ⁻¹	Week 7 mg L ⁻¹
1	0.60 \pm 0.00 ^a	1.93 \pm 0.02 ^a	1.97 \pm 0.13 ^a	4.70 \pm 0.42 ^a	4.95 \pm 0.52 ^a	5.37 \pm 0.62 ^a
3	0.60 \pm 0.00 ^a	2.35 \pm 2.38 ^a	2.40 \pm 0.20 ^a	4.42 \pm 0.23 ^a	4.02 \pm 0.30 ^a	4.60 \pm 0.55 ^a

The same superscript letters in a column are not significantly different at the 0.05 levels.

Table 9. Concentrations of Zinc (Zn) in water (Mean \pm SD) in treatments during the experimental period.

T	Week 2 mg L ⁻¹	Week 3 mg L ⁻¹	Week 4 mg L ⁻¹	Week 5 mg L ⁻¹	Week 6 mg L ⁻¹	Week 7 mg L ⁻¹
1	0.00 \pm 0.00 ^a	0.00 \pm 0.00 ^a	0.013 \pm 0.006 ^a	0.047 \pm 0.006 ^a	0.08 \pm 0.006 ^a	0.13 \pm 0.01 ^a
2	0.00 \pm 0.00 ^a	0.00 \pm 0.00 ^a	0.013 \pm 0.006 ^a	0.05 \pm 0.001 ^a	0.10 \pm 0.030 ^a	0.14 \pm 0.02 ^b

The same superscript letters in a column are not significantly different at the 0.05 levels.

Potassium (K)

The concentration of K increased in the fish rearing tanks during the experimental period. The K concentration was significantly ($P < 0.05$) lower in treatment 2 compared to treatment 1 in the last two weeks of the experimental period. These rates were 12.33 and 5.70 mg L⁻¹ for experiments 1 and 2, respectively, at the end of experiment (Table 10).

Manganese (Mn)

The concentration of Mn increased in the rearing fish tank during the experimental period. The Mn concentration was significantly ($P < 0.05$) lower in treatment 2 than in

treatment 1 in the last two weeks of the experimental period. These rates were 0.14 and 0.4 mg L⁻¹ for experiments 1 and 2, respectively, at the end of experiment (Table 11).

DISCUSSION

In present study, it was well demonstrated that the use of natural zeolite as a bed medium to plant lettuce seedlings could efficiently increase lettuce growth in an aquaponic system. This may be attributed to the possibility of filtering the macronutrient and ammonium by zeolites and more access of these cations to the plants (Bergero *et al.*, 1996). The optimum pH value for water between 5.5-7.5 has been reported for the re-

Table 10. Concentration (mg L⁻¹) of Potassium (K) in water (Mean \pm SD) in treatments during the experimental period.

T	Week 2 mg L ⁻¹	Week 3 mg L ⁻¹	Week 4 mg L ⁻¹	Week 5 mg L ⁻¹	Week 6 mg L ⁻¹	Week 7 mg L ⁻¹
1	4.00 \pm 0.00 ^a	5.50 \pm 0.87 ^a	5.70 \pm 0.27 ^a	10.17 \pm 1.04 ^a	12.00 \pm 1.32 ^b	12.33 \pm 1.26 ^b
3	4.50 \pm 0.29 ^b	5.80 \pm 0.29 ^a	5.70 \pm 0.78 ^a	8.83 \pm 2.47 ^a	4.17 \pm 1.52 ^a	5.70 \pm 2.06 ^a

The same superscript letters in a column are not significantly different at the 0.05 levels.

Table 11. Concentration of Manganese (Mn) in water (Mean \pm SD) in different treatments during the experimental period.

T	Week 2 mg L ⁻¹	Week 3 mg L ⁻¹	Week 4 mg L ⁻¹	Week 5 mg L ⁻¹	Week 6 mg L ⁻¹	Week 7 mg L ⁻¹
1	0.03 \pm 0.00 ^a	0.03 \pm 0.00 ^a	0.04 \pm 0.00 ^a	0.07 \pm 0.00 ^a	0.08 \pm 0.00 ^b	0.14 \pm 0.01 ^b
3	0.03 \pm 0.00 ^a	0.03 \pm 0.00 ^a	0.04 \pm 0.00 ^a	0.07 \pm 0.00 ^a	0.04 \pm 0.01 ^a	0.04 \pm 0.01 ^b

The same superscript letters in a column are not significantly different at the 0.05 levels.



removal of ammonium and exchange of other cations between zeolite and waterborn (Bergero *et al.*, 1996). In this study, the pH was in the optimum range for the exchange of cations (5.31-7.21). It has been reported that, while the ammonium level is below the threshold values (0.35-0.40 mg L⁻¹), the zeolite will preferentially capture other cations such as potassium, sodium, calcium and magnesium than ammonium (Wakatsuki *et al.*, 1993). However, the effective ability of zeolites in the captivation of cations like NH⁴⁺, Cu²⁺, Zn²⁺ and releasing the amount of other cations such as Na⁺, Ca²⁺ and K⁺ from animal wastes, particularly from aquaculture wastewater, have been reported (Mumpton and Fishman, 1977; Miner, 1993; Watten and English, 1985). Exposure of artificial zeolites as absorbents to the test materials containing NH⁴⁺, Mn, Zn, Cd and Pb has shown a high reduction in the concentration of these minerals in the test material solution as well. The removal of >50%, 85%, 95%, 95% and 96% for NH⁴⁺, Mn, Zn, Cd and Pb, respectively has been reported (Lee, 1997). The highest removal efficiency values for NH⁴-N was achieved with the natural zeolite at concentrations lower than 100 mg L⁻¹ (Cerjan-Stefanovich *et al.*, 1997). These can be related to a weakly bound structure of Na, K and other cations in zeolite and the replacement of ammonium and H⁺ ions with these cations (Cerjan-Stefanovich *et al.*, 1997). In this study, the concentration of total ammonia and inorganic nitrogen in fish rearing tanks decreased significantly in treatment with the use of zeolite as a bed medium for lettuce planting, compared to the control. This emphasized the higher removal of dissolved N-compounds from the water by the plant than zeolite. The value of Ec was higher in treatment 2 than 1 and this could be related to the use of zeolite and ion exchanges with water in the fish rearing tank. The highest absorption of P by lettuce from the fish rearing tank in treatment 2, resulted in a high concentration of Ca in the water. These phenomena pointed to a reduction of phosphorous precipitation under the low concentration of Fe (Wild *et al.*, 1998).

After four weeks by the end of experiment, the concentration of K in the fish rearing tank continuously decreased in treatment 2. Significant depletion in the concentration of K in treatment 2 compared to 1 was recorded at the end of experiment. Considering the lettuce yield harvested in treatments 1 and 2 at the end of experiment, these differences were due to differences in the amounts of potassium incorporated in the body of lettuce yields. The concentration of Mn in the fish rearing tank increased in both treatments within the first five weeks of experimental period and this could be attributed to the continuous addition of feed to the fish rearing tank and bio-degradation of organic matter to inorganic matter as a result of releasing a higher level of Mn than assimilation rates. A decrease in the concentration of Mn after five weeks and by the end of experiment emphasized the higher absorption of Mn by plants than excretion due to bacterial activities (Saad *et al.*, 2002).

CONCLUSIONS

This study was a preliminary work to evaluate the effective use of natural zeolite as a bed medium for planting lettuce seedlings and enhancing lettuce and red tilapia growth in an aquaponic system. Results of this study have concluded that use of zeolite as bed medium could improve the environmental conditions for growing lettuce and that this may be due to more access of nutrients, as a result of the improvement in water quality and better conditions for fish growth. Total ammonia and total inorganic nitrogen concentrations reduced in the rearing tank and a greater incorporation of nitrogen in the body of lettuce occurred. These were the main results of this experiment. To fully evaluate the use of zeolite as a medium for planting lettuce seedlings in the retention of nutrients in the bodies of fish, lettuce and in supplied water deserve further investigations.

REFERENCES

1. APHA. 1992. Standard Method for the Examination of Water and Wastewater (18th ed.), American Public Health Association, Washington, DC.
2. Bergero, D., Boccignone, M., Di Natale, F., Forneris, G. Palmegiano, G. B. and Zoccarato, I. 1996. Intensive Fish Culture and its Impact on the Environment: the Role of Natural Zeolite in the Reduction of the Ammonium Content in the Effluents. In: "Proceedings of the Second World Fisheries Congress" (Eds.) Hancock, D.A. and Beumer, J.P. Brisbane, Australia, pp. 101–102.
3. Curkovic, L. 1995. Natural Zeolites as Ion Exchangers. M.Sc. Thesis, Faculty of Chemical Engineering and Technology, University of Zagreb.
4. Forsberg, C. 1998. Which policies Can Stop Large Scale Eutrophication? *Water Sci. Technol.*, 37, P. 193.
5. Gerjan-Stefanovich. and Curkovic, L. 1997. Selectivity of Natural Zeolites for Toxic Ions. *Natural zeolites-Sofia* 95: 121.
6. Gloger, C. K., Cotner, B. J., Cole, M. W. M., Rakocy, J. E., Baily, D. S. and Shultz, K. 1995. A Contribution of Lettuce to Waste Water Treatment Capacity of Raft Hydroponics in a Closed Recirculating Fish Culture System. *Aquaculture Engineering and Waste Management*, Proc. Aquaculture in the Mid-Atlantic Conference. Washington, D.C. June 24-28, 1995.
7. Lee, J. H. 1997. Treatment of Municipal Landfill Leakages Using Artificial Zeolite. *J. Fuel Energ.*, 36(6): PP445
8. Mander, L. and Forsberg, C. 2000. Nonpoint Pollution in Agricultural Watersheds of Endangered Coastal Sea, *J. Ecol. Eng.*, 14(4): 317-324.
9. Miner, J. R. 1983. Use of Natural Zeolites in the Treatment of Animal Wastes. Journal paper no. 6402, Oregon Agricultural Experiment Station, Corvallis, Oregon, USA, pp. 257–262.
10. Mumpton, F. A. and Fishman P. H. 1977. The Application of Natural Zeolites in Animal Science and Aquaculture *J. American Sci.*, 45: 1188-1203.
11. Nair, A., Rakocy, J. E. and Hargreaves, J. A. 1985. Water Quality Characteristics of a Closed Recirculating System for Tilapia Culture and Tomato Hydroponics. *Proc. Second International Conference on Warm Water Aquaculture Finfish*. 223-254 pp.
12. NRC (National Research Council), *Nutrition Requirements of Fish*, National Academy Press, Washington, DC, USA, 1993, 114 pp.
13. Oenema, O. and Roest, C.W. J. 1998. Nitrogen and Phosphorus Losses from Agriculture into Surface Waters; the Effects of Policies and Measures in the Netherlands. *Water Sci. Technol.*, 37: 19.
14. Rakocy, J. E. 1995. The roles of plant crop production in aquacultural waste water, Aquacultural Engineering and waste management, proceedings from the aquaculture Expo VIII and Aquaculture in the Mid-Atlantic Conference, Washington, D.C. June 24-28, 1995.
15. Saad, C. R., Rafiee G. R., Kamarudin, M. S., Sijam, K. and Ismail, M. R. 2002. Use of Lettuce (*Lactuca sativa* var. *longifolia*) for Purification of Aquaculture Wastewater, *Proc. Second International Conference on Sustainable Agriculture for Food, Energy and Industry*, Beijing, 8-12 September 2002. Volume 2. pp.1511-1517.
16. Wakatsuki, H, Esumi. and Omura S. 1993. High Performance and N&P Removable On-site Domestic Waste Water Treatment System by Multi-soil-layering Method. *Water Sci. Technol.*, 27(1): 31–40.
17. Wild, D. Kislakove, A. and Siegrist. 1999. P-fixation by Mg, Ca and Zeolite a during Stabilization of Excess Sludge from Enhanced Biological P-removal. *J. Water Sci. Technol.*, 34(1-2): 391-398
18. Watten, T. and English. M. J. 1985. Effects of Organic Matter in Aquaculture Waste on the Ammonium Exchange Capacity of Clinoptilolite. *Aquaculture* 46: 221–235.
19. Zar J. H. *Biostatistical Analysis*, 3rd ed., Prentice Hall, New Jersey, 1996, 662 pp.



اثر زئولیت طبیعی (کلینوپتیولیت) بر میزان رشد ماهی تیلاپای قرمز (*Oreochromis sp.*) و کاهو (*Lactuca sativa*) و بهبود کیفیت

غ. رفیعی و چ. ر. سعد

چکیده

اثر زئولیت طبیعی (کلینوپتیولیت) به عنوان بستر کشت بر روی رشد ماهی تیلاپا و کاهو و بهبود کیفیت آب محیط پرورش در یک سازگان توام پرورش ماهی و گیاه مورد بررسی قرار گرفت. وجود یا عدم وجود زئولیت طبیعی (کلینوپتیولیت) به عنوان بستر کشت، تیمارهای آزمایش را تشکیل داد. در تیمار اول یا شاهد زئولیت به عنوان بستر کشت کاهو وجود نداشت و در تیمار دوم یا مورد آزمایش ۱۰ گرم زئولیت در کیسه هایی از جنس کتان قرار داده شد و به عنوان بستر کشت هر نشاء کاهو به کار گرفته شد. هر تیمار شامل سه تکرار بود. مدت انجام آزمایش ۷ هفته بود. در شروع آزمایش، هر حوضچه پرورش ماهی با ۶۴۰ لیتر آب پر شد و در آن ۵۰ قطعه ماهی تیلاپا قرمز به وزن تقریبی 0.06 ± 0.23 گرم ریخته شد و هر حوضچه از طریق ۲ سنگ هوا که به شبکه هواده مرکزی وصل بودند هوادهی شدند. دو هفته بعد از شروع آزمایش تعداد ۴۲ نشاء کاهو به سینی های پرورش گیاه در هر واحد آزمایش وارد شد. در پایان آزمایش میانگین وزن انفرادی ماهی اختلاف معنی داری ($P > 0.05$) را در بین تیمارها نشان داد. میانگین وزن انفرادی ماهی در تیمار حاوی زئولیت و شاهد به ترتیب 2.20 ± 0.37 و 2.20 ± 0.50 گرم بود. مقدار محصول کاهو در تیمار حاوی زئولیت بطور معنی داری ($P < 0.05$) در مقایسه با شاهد بیشتر بود. مقدار محصول در تیمار حاوی زئولیت و شاهد به ترتیب 44.5 ± 15.7 و 8.3 ± 27.5 گرم بود. مقدار غلظت آمونیاک کل در تیمار حاوی زئولیت به طور معنی داری ($P > 0.05$) کمتر از تیمار شاهد بود. مقدار غلظت پتاسیم و فسفر در تیمار حاوی زئولیت به طور معنی داری ($P > 0.05$) کمتر از تیمار شاهد بود. نتایج این تحقیق نشان داد که وجود زئولیت به عنوان بستر کشت کاهو اثر چشمگیری را در افزایش رشد و تولید کاهو و بهبود کیفیت آب در یک سازگان توام کاهو و ماهی دارد.