Roles of natural zeolite (clinoptiolite) as a bed medium on growth and body composition of red tilapia (*Oreochromis* sp.) and lettuce (*Lactuca sativa var longifolia*) seedlings in a pisciponic system

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Abstract: Natural zeolite was used as a bed medium for plantation of lettuce seedlings and its effects on growth and chemical composition of red tilapia and lettuce were investigated in a pisciponic system. The place of study was the Aquatic Resources Technology Laboratory, Faculty of Agriculture, at the University Putra Malaysia, in 2002. The mean individual weight and biomass of fish in the treatment with zeolite were significantly higher ($P<0.05$) than the control at the end of experimental period. Use of zeoilte as bed media to plant lettuce seedlings significantly ($P<0.05$) increased the yield of lettuce. The yield of lettuce in zeolite bed medium and control treatments were 1507±83 and 275±48g, respectively at the end of the experiment. The percentage of protein, fiber and ash in the dry weight of fish were not significantly different ($P>0.05$) between treatments. The percentage of ash in the dry weight of lettuce in the control was significantly ($P<0.05$) higher than the zeolite bed medium group. It was concluded that the use of zeolite as bed medium to plant lettuce seedlings could improve culture system performance due to its positive effects in lettuce growth.

Keywords: Pisciponic system, Chemical composition, Lettuce, Red tilapia, Bed medium zeolite

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Introduction

Accumulation of suspended and dissolved solids (catabolic end products) originated both from uneaten and indigested feed are considered as restricting factors for more production of fish in a recirculating aquaculture system. Wastewater processing or purification by plants in greenhouses or specific treatment systems has also become increasingly popular in response to increasingly water demand and scarcity (Gloger *et al.*, 1995). Over the past three decades, aquaculture practices have focused on integrating the hydroponic(s) plant compartments to the aquaculture systems in both warm and moderate climates to alleviate the accumulation of nutrients especially, N-compounds (Naegle, 1977; Lewis *et al.*, 1978; Pierce, 1980; Sutton & Lewis, 1982). Closed recirculating systems appeared to be the most appropriate aquaculture system for integrating with hydroponics, because nutrients can be maintained at the sufficient concentrations for hydroponics plant culture (Nair *et al.*, 1985; Rakocy, 2000). On the other hand, reduction of aquaculture wastes through proper feeding practices and improvement of feed digestibility have been considered as another nutritional strategy. For example, zeolite has been replaced for carbohydrates in an energy-rich diet, in which ingredients with the high fiber content or indigestible carbohydrates could be reduced or eliminated to improve feed efficiency, as a result reducing aquaculture effluent discharges (Kaushik & Cowey, 1991; Cho & Cowey, 1991; Cho, 1993). Moreover, it has been reported that the addition of zeolite at low levels (2-5%) to fish diets improves weight gain and feed efficiency in fish (Smith., 1980; Lanari, 1996). Use of dietary zeolites and clays and their effects on biochemical composition of fish in relation to characteristics of input feed (total fat, protein, ash, and dry materials or nutrients) have also been investigated (Reinitz, 1984; Shiau & Huang, 1989; Edsall & Smith, 1989; Lanari, 1996; Dias *et al.*, 1998). Natural zeolite framework consists of 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 the appropriate materials for removing and exchanging ions (NH_4^+, Na^+, Ca^{2+} and K^+), and are relatively harmless (Curkovic, 1995). The effect of natural zeolite on the biochemical composition of red tilapia and lettuce in the same system has not been investigated. Therefore, investigating the effect of natural zeolite as a medium bed for planting the lettuce seedlings as well as on the biochemical composition of red tilapia and lettuce were the main objectives of this study.

Materials and methods

An experiment with two treatments, 1- an aquaponic system without use of zeolite as bed medium (control); 2- Use of zeolite with 42- small cotton bags, each containing 10g zeolite as a bed medium to plant lettuce seedlings in the hydroponic compartment of the system, in triplicates were conducted. The experimental system (unit) consisted of a fiberglass tank (110×84×100cm) equipped with three raft hydroponic troughs (110×30×5cm), and a submersible water pump (Model Aqua, 1500). The water pump was used for recycling the water from the fish tank through the hydroponic troughs then to the fish tank again (Fig. 1).

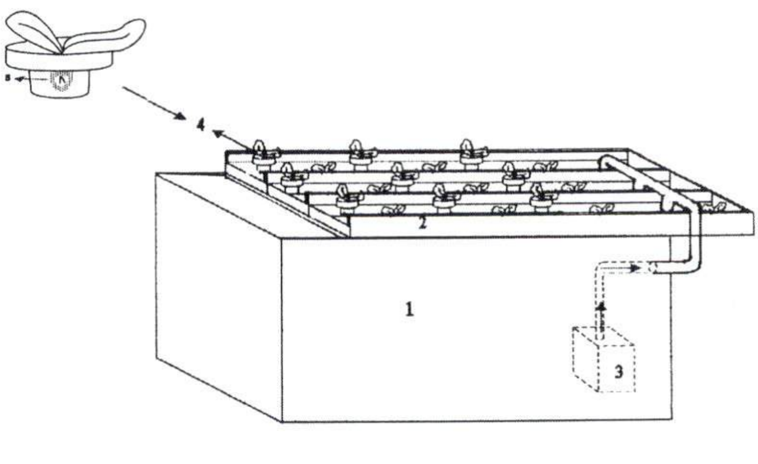

Figure 1: Schematic feature of the aquaponic system: 1- fish tank, 2- hydroponic troughs, 3- water pump, 4- lettuce cup, 5- a small cotton bag containing 10g zeolite.

Each tank was filled with 640 L of tap water and aerated continuously with two circular air stones (3L min^{-1}). The characteristics of water supply were as the following: Aged tap water: pH = 7.17; EC = 0.16mmhos; Ca = 5mg L^{-1}; Mg = 2.5mg L^{-1}; K = 0.00041mg L^{-1}; P = 0.00031mg L^{-1}; Fe = 0.578mg L^{-1}; Mn = 0.033mg L^{-1}; Zn = 0.00015mg L^{-1}, and Cu = 0.00013mg L^{-1}.

The feed was a commercial diet floating pellet (Car-gill Company), with 24% protein, 6% fat, 6% fiber and 11% moisture. The fish were fed twice a day *ad libitum* at 09.00 and at 13.30 h. The mineral content of feed was measured before initiation of the study. The characteristics of the feed are given in Table 1.

Table 1: The (mean±sd) percentage (%) of minerals[a] (nutrients) in dry experimental feed

Fe (%)	Mn (%)	Zn (%)	Cu (%)	Ca (%)	Mg (%)	N (%)	P (%)	K (%)
0.1094± 0.0574	0.003± 0.0014	0.0056± 0.00007	0.0024± 0.000005	1.74± 0.226	0.428± 0.037	3.40± 0.226	1.48± 0.091	0.53± 0.0014

Fe (ferrous), Mn (manganese), Zn (zinc), Cu (copper), Ca (calcium), Mg (magnesium), N (nitrogen), P (phosphorus) and K (potassium).

Dissolved oxygen (DO) and in fish rearing tanks were measured twice a week by YSI Model 57 DO meter electro conductivity (EC) and Ec meter model HANA instrument conductivity meter HI 8033. pH of water from fish tanks was determined using Orion model 410A pH meter. Total ammonia–nitrogen (NH_4+ NH_3) was measured weekly (taking two samples of water from the fish rearing tanks, diluted 10 times with distilled water) (Parsons *et al.*, 1984).

The individual and biomass of fish were measured at the beginning and end of the study, using gravimetery and correction for water values. Five fish from each five groups were sampled, weighed and dried for further proximate analysis before starting and after the termination of the experiment.

The process was done according to the methods explained in Standard Method Book (APHA, 1992).

The diet, whole fish and shoot of lettuce were dried at 75°C for 3 days; crude protein was determined with micro-Kejeldahal; Nx 6.25; fat by dichloromethane extraction (Soxhel) and ash by combustion at 550°C for 12h (APHA, 1992).

The experiment was run for a 7-week period. At the initiation of the experiment, each rearing tank was stocked with 50 red tilapia juveniles of 20g (20±0.34). Two weeks after the start of the experiment, the 42 cups, each containing a 1-week old seedling of lettuce 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 cultured for a 5-week period and both the fish and lettuce harvested simultaneously at the end of the experimental period.

Percent values were normalized by arc sin values transformation, then analyzed statistically. Data were subjected to paired-comparison t-test analysis at a 0.05 probability level (SPSS Microsoft version 10.0)(Zar, 1996).

Results

The mean body weight and biomass of fish between treatments at the end of the experiment were significantly different ($P<0.05$). This rate in the treatment with zeolite medium was higher compared to the control. The fish biomass was 1256.71 and 1458.60g in treatment 1 and 2, respectively. The survival rates of fish were not significantly different ($P>0.05$) between treatments. The yield of lettuce was significantly higher ($P<0.05$) in the treatment with zeolite medium compared to control. These values were 275 and 1507g in treatments 1 and 2, respectively (Table 2).

Table 2: Data of (mean±sd) individual fish weight (IFW), fish biomass (FB), fish survival (FS) and yield of lettuce (YL) in different treatments at the end of the experiment

Treatments	IFW (g)	FB (g)	YL (g)	FS (%)
1	32.50 ± 2.00^{a}	1256.71 ± 135.59^{a}	275 ± 83^{a}	79.76 ± 3.78^{a}
2	37.50 ± 2.01^{b}	1458.60 ± 143.31^{b}	1507 ± 48^{b}	77.70 ± 3.51^{a}

Values with the same superscript letters in a column are not significantly different at the 0.05 level (T:LSD: $P<0.05$).

The percentage of dry weight, crude protein, fiber, ash and total fat of fish were not significantly different (P>0.05) between treatments at the end of experimental period (Table 3).

Table 3: Dry weight (DW) and body composition of dry fish (mean ±sd) in different treatments at the end of the experimental period

Treatments	DW (%)	Protein (%)	Fat (%)	Fiber (%)	Ash (%)	NFE (%)
1	22.28±0.19	59.45±1.27	6.46±0.35	0.31±0.11	13.27±0.66	9.49±0.80
2	22.63±1.20	57.25±0.61	5.86±0.34	0.45±0.17	14.69±0.76	10.78±1.32

The percentage of ash in dry lettuce showed significant differences (P<0.05) between treatments at the end of the experimental period. The dry matter, crude protein, total fat and fiber of lettuce were not significantly different (P>0.05) between treatments at the end of the experimental period (Table 4).

Table 4: Data (mean ±sd) of dry matter (DM), yield (Y) and body composition of lettuce in different treatments at the end of the experimental period

Treatments	DM (%)	Protein (%)	Fat (%)	Fiber (%)	Ash (%)
1	5.59±0.3[a]	25.22±0.43[a]	10.78±0.00[a]	21.84±0.47[a]	28.62±1.17[b]
2	5.28±0.59[a]	26.14±0.31[a]	12.19±1.40[a]	24.19±1.61[a]	25.72±0.43[a]

Values with the same superscript letters in a column are not significantly different at the 0.05 level (T:LSD: P<0.05).

The concentration of total ammonia had a fluctuation during the experimental period, showing an increase for the first 4 weeks then decreased in the 5th week, after that continuously increased in all treatments by the end of experiment. The concentration of total ammonia was significantly lower (P<0.05) in zeolite treated system at the end of the experiment (Table 5).

Table 5: Variation in concentration of total ammonia (mean±sd, mg l^{-1}) in water in different treatments during the experimental period

T	2nd Week	3rd Week	4th Week	5th Week	6th Week	7th Week
1	0.68±0.71 ^{a}	2.65±0.82 ^{a}	4.02±1.08 ^{a}	0.87±0.29 ^{a}	4.65±0.62 ^{a}	9.19±0.69 ^{b}
2	0.59±0.62 ^{a}	1.61±0.92 ^{a}	2.72±1.23 ^{a}	1.17±0.41 ^{a}	3.90±0.68 ^{a}	7.27±0.21 ^{a}

Values with the same superscript letters in a column are not significantly different at the 0.05 level (T:LSD: $P<0.05$).

The concentration of total inorganic nitrogen (TIN) increased during the experimental period, which was significantly lower ($P<0.05$) in zeolite treated system at the end of the experimental period (within the 6 and 7th weeks (Table 6).

Table 6: Concentration of total inorganic nitrogen (mean±sd, mg l^{-1}) in water in different treatments during the experimental period

T	2nd Week	3rd Week	4th Week	5th Week	6th Week	7th Week
1	0.62±0.04 ^{a}	1.04±0.38 ^{a}	4.75±0.69 ^{a}	16.57±2.75 ^{a}	21.45±0.63 ^{b}	24.83±1.74 ^{b}
2	0.53±0.19 ^{a}	1.99±0.29 ^{a}	5.31±0.84 ^{a}	15.00±1.90 ^{a}	14.09±3.34 ^{a}	15.76±1.31 ^{a}

Values with the same superscript letters in a column are not significantly different at the 0.05 levels (T:LSD: $P<0.05$).

The Ec of water increased from 0.16 to 0.47mmhos/cm at the end of the experimental period. The pH of water decreased in rearing tanks and ranged from 6.57 to 7.21 during the experimental period. The concentration of oxygen in fish tanks was between 5.7-6.2mg L^{-1} during the experimental period.

Discussion

In the present study, it was well demonstrated that the use of natural zeolite as a bed medium to plant lettuce seedlings could efficiently increase the lettuce growth in an aquaponic system. These may be attributed to the possibility of filtering the macronutrient and ammonium by zeolites and more access of these cations to plant (Bergero *et al.*, 1996). The pH range of 5.5-7.5 reported as optimum range for zeolite activity, exchanging the cations, for example, replacement of ammonium with potassium (Bergero *et al.*, 1996). In this study, the pH ranged at optimum levels (6.57–7.21). The concentration of total ammonia in water among experimental units was between 0.59-9.19mg L^{-1}. When the ammonium level of water was reportedly below the threshold values (0.35–0.40mgL^{-1}), zeolites would preferentially capture other cations such as potassium, sodium, calcium and magnesium than ammonium (Wakatsuki *et al.*, 1993). However, the effective ability of zeolite in the captivation of cations like NH^{4+}, Cu^{2+}, Zn^{2+} and releasing amount of other cations such as: Na^{+}, Ca^{2+} and K^{+} from animal wastes, particularly from aquaculture wastewater have also been reported (Mumpton & Fishman, 1977; Watten & English, 1985; Miner,1993). Exposure of artificial zeolites as absorbents to the test materials containing NH^{4}, Mn, Zn, Cd and Pb has shown high reduction of these minerals in the test material solution as well (Curkovic, 1995). The removal of >50%, 85%, 95%, 95% and 96% for NH_4^{+}, Mn, Zn, Cd and Pb, respectively, has been reported (Lee, 1997). The highest removal efficiency values for NH_4-N achieved, using natural zeolite at concentrations lower than 100mgL^{-1}, resulting the changes in the bind of Na, K and other cations in the structure of zeolite and replacement of ammonium and H^{+} ions with these cations (Curkovic, 1995). In this study, concentration of total ammonia and inorganic nitrogen in fish rearing tank were significantly lower zeolite treated bed, than the control, showing higher removal of dissolved N-compounds from the water by plant than zeolite. A better protein conversion ratio reported with testing supplementary agar and zeolite at two dietary protein levels in the hybrid tilapia (Shiau & Huang, 1989). The effect of zeolite as bed medium did not significantly influence the biochemical composition of fish and lettuce body. However, its influence on the yield and, consequently, ash of lettuce was evident, indicating the higher access of lettuce to nitrogen resources due to more incorporation of these compounds, as body protein source, in lettuce body.

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