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The Production of Catfish and Vegetables in an Aquaponic System

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Abstract

Aquaponic is a system that mutually integrates aquaculture and plant cultivation (by means of hydroponic). Both crops are combined in a recirculating system that utilizes less water than the traditional farming. Nutrients contained in fish tanks are recycled into plant biomass with the presence of nitrifying bacteria that convert the excreted ammonia to nitrite and then to nitrate. In this study, fifteen sets of aquaponic system were developed to study the growth of African catfish (*Clarias gariepinus*) and three types of plants; the red and green-red amaranth (*Amaranthus spp.*) and water spinach (*Ipomoea aquatica*). The combination of aquaculture and hydroponic gives a new insight into increasing the efficiency of food production which respects principles of sustainable agriculture.

Keywords: Aquaponic; Aquaculture; Integration; Sustainable; Integrated aquaculture

Introduction

The development of aquaculture industry has become a major economic importance worldwide. Aquaculture continues to show increasing production at an average annual growth rate of 6.1% between 2002 and 2012. The production increased from 36.8 million tons in 2002 to 66.6 million tons in 2012. Major aquaculture producers in 2012 were China (41.1 million tons), India (4.2 million tons), Vietnam (3.1 million tons), Indonesia (3.1 million tons), Bangladesh, Norway, Thailand, Chile, Egypt and Myanmar. These producers contributed 88% of the total aquaculture production worldwide [1].

Aquaculture in Malaysia started in the 1920's with multiple carp species reared in ex-mining pools. Since then, the industry has developed into a lucrative and sustainable industry. Freshwater pond culture has been the greatest contributor to local aquaculture production. A total production of 14,162 tons with estimated value of MYR 97.6 million was achieved in 1992 [2]. The main fish species cultured are red tilapia hybrid (*Oreochromis sp.*), catfish (*Clarias sp.*) and climbing perch (*Anabas testudineus*) [3]. However, it is noticeable that the development of aquaculture worldwide is slowing. The growth of aquaculture for land-based and near-shore systems has peaked due to political, environmental, economic and resource constraints. Therefore, the development of aquaculture is currently on going, driven by new ideas and innovations [4].

Integrated aquaculture has gained attention as an innovated system to add value to water, recycle nutrients and wastes in the system to produce more crops. Integration of crops is also regarded as an environmentally friendly practice which intensifies the use of land [5,6]. Integration of aquaculture and hydroponic is known as aquaponic. It combines the rearing of aquatic organisms (mainly fish) and plant production in a recirculating water system [7,8].

The concept of aquaponic is to reuse the nutrient-enriched water from the fish rearing tank for the growth of plants in hydroponic system. In addition, aquaponic is a productive method of producing fish and vegetables in a green, sustainable and energy efficient system. Aquaponic presents opportunities to increase economical operations because spaces, nutrients and water are optimized. This contributes to lower infrastructural costs, production of inexpensive food and consequently poverty reduction.

The objective of the present study is to assess the growth of African catfish (*Clarias gariepinus*) and three vegetable types; red amaranth, green-red amaranth and water spinach in an aquaponic system.

Materials and Methods

Fifteen aquaponic sets were installed in an aquaculture setting at Kuala Sungai Baru, Perlis, Malaysia. Each set consisted of a 150 gallon polyethylene tank and four rows of hydroponic trays. Water was circulated from the rearing tank to the trays with a 15 watt submersible water pump. Fifty juveniles of African catfish (*C. gariepinus*) were assigned to each tank filled with 80 gallons of water. They were fed twice daily (at 0830 and 1600 hrs.) with commercial pellets at 6% of their total body weight (wet weight).

Seeds of the vegetables (red amaranth, green-red amaranth and water spinach) were sown and sprouted in the sowing trays before being transferred to the hydroponic system. The fish were reared for 60 days while the vegetables were grown twice within the period. The fish were weighed weekly and the vegetables were weighed at the end of the cultivation period.

Data on average length and weight of the fish were assessed at the end of the experimental period. In addition, plants were weighed and number of leaves were determined in this study. One-way analysis of variance (ANOVA) tests were conducted to determine significant difference in growth of fish with different plant types.

Student's T-tests were carried out to assess significant difference of plant growth between the two cycles. All significant differences were accepted at $p<0.05$. All statistical tests were determined using SPSS Statistics (version 17.0).

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Results

Results on fish growth performance (total length and weight) are presented in Figures 1 and 2. The highest average length and weight of catfish was obtained with the green-red amaranth (20.22 ± 0.19 cm/fish; 55.42 ± 1.34 g/fish), followed by fish co-cultured with red amaranth and water spinach (19.58 ± 0.95 cm/fish; 49.17 ± 5.45 g/fish and 19.39 ± 0.17 cm/fish; 48.13 ± 1.17 g/fish, accordingly). However, there was no significant difference in average length and weight of catfish co-cultured with any of the three plant types (one-way ANOVA, $p>0.05$).

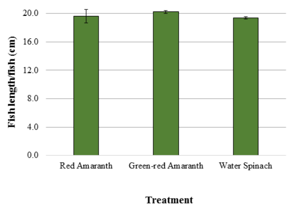

Figure 1: Average length per fish (cm) integrated with hydroponic cultivations of red amaranth, green-red amaranth and water spinach. No significant difference in fish length with different plant types ($p>0.05$).

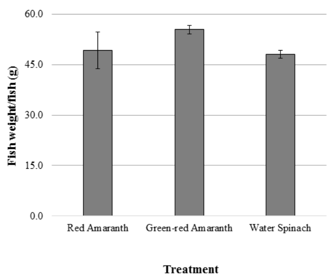

Figure 2: Average weight per fish (g) integrated with hydroponic cultivations of red amaranth, green-red amaranth and water spinach. No significant difference in fish weight with different plant types ($p>0.05$).

The plants were grown in two cycles within the eight weeks of culture period (Figure 3). The wet weight (g) and number of leaves of the plants are shown in Figure 4. Results show that both amaranth plant types grew better in the second cycle. The red amaranth produced an average wet weight of only 43.67 g/plant in the first cycle. However, the growth reached 92.38 g/plant in the second cycle.

There was a significant difference in the wet weight of red amaranth between the first and the second cycle (T-test, $p<0.05$). Similarly, growth of the green-red amaranth showed significant improvement in the later cycle. The plant weighed 72.63 g/plant in the first cycle and it grew to 103.71 g/plant in the second cycle. However, the growth of water spinach in the first and second cycles was significantly similar (72.01 g/plant and 70.75 g/plant, accordingly) (T-test, $p>0.05$).

Figure 3: Cultivation of plants with African catfish in an aquaponic system. (A) the green-red amaranth (B) the red amaranth (C) the water spinach (D) the aquaponic system.

Discussion

Results of this study suggest that none of the three types of plants had a deleterious effect on the growth of catfish. The catfish is a hardy, robust fish species. They can thrive in turbid and low-oxygen water, and sometimes be found in drying rivers [9].

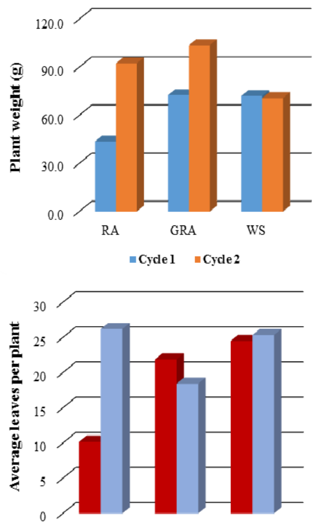

Figure 4: Wet weight (left) and average number of leaves (right) of plants cultivated in the aquaponic system (RA: Red Amaranth; GRA: Green-red Amaranth; WS: Water Spinach).

Therefore, catfish has been considered as a good candidate for aquaculture [10,11]. The present study also shows significant differences in growth of the red and green-red amaranth between the two crop cycles. Vegetable amaranth require high medium fertility, particularly potassium and nitrogen [12,13]. Previous studies have indicated that levels of nutrients in water increased with culture time [14,15]. Therefore, the lower plant weight in cycle 1 for both amaranth types could be associated with the lower nitrogen content in the water.

The two most common species of nitrifying bacteria are *Nitrosomonas sp.* and *Nitrobacter sp. Nitrosomonas sp.* converts ammonia (NH_3) to nitrite (NO_2) while *Nitrobacter sp.* use nitrites for their energy source during its conversion to nitrate (NO_3). Nitrogen in nitrate form is absorbed and used as a nutrient by plants. It can take a significant amount of time for these bacteria to grow in a system. This might have contributed to lower nitrogen content in the first few weeks.

Integration of fish farming (aquaculture) and plants has the potential to be environmentally friendly and sound because water use is minimized, less water discharge and the water form fish tank is reused to produce vegetables. In addition, the recirculating water keeps the water quality adequately safe for the fish. In the common aquaculture practices, water is changed regularly to reduce the accumulation of nitrogenous compounds [16]. These compounds mainly come from the faecal materials of the fish and uneaten feeds. The discharge of nutrient-enriched water creates environmental problems such as sedimentation and eutrophication [17,18]. This eventually will pollute the waterways and we may run out of clean water we depend on. It is very imperative to sustain the production of food sources without increasing pressure on the environment. Advances in knowledge can have significant benefits towards improving the living of people and protecting the natural environment [19].

This study shows that aquaponic practice is an effective way to raise fish and vegetables in one system. It utilizes the existing water containing nutrient from the fish tanks to water plants in the hydroponic system. The culture of catfish seemed to be positively co-exist with amaranth plants and water spinach. The aquaponic system is an efficient way to not only produce food crops, but also a successful system to recycle wastewater in aquaculture.

Acknowledgements

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