DEVELOPMENT AND UTILIZATION OF ENGINEERED AQUAPONICS RECIRCULATION SYSTEM FOR AQUACULTURES SPECIES

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DOCTOR OF PHILOSOPHY
UNIVERSITI MALAYSIA TERENGGANU

2011

1100084321

Perpustakaan Sultanah Nur Zahirah (UMT)
Universiti Malaysia Terengganu

PERPUSTAKAAN SULTANAH NUR ZAHIRAH UMT

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SH 135 .A9 2011

1100084321
Development and utilization of engineered aquaponics recirculation system for aquacultures species / Azizah Endut.

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Thesis Submitted in Fulfillment of the Requirement for the Degree of Doctor of Philosophy in the Faculty of Science and Technology
Universiti Malaysia Terengganu

August 2011

Abstract of thesis presented to the Senate of Universiti Malaysia Terengganu in fulfillment of the requirement for the degree of Doctor of Philosophy

DEVELOPMENT AND UTILIZATION OF ENGINEERED AQUAPONICS RECIRCULATING SYSTEM FOR AQUACULTURES SPECIES

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AUGUST 2011

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The integration of hydroponics plant production into recirculating aquaculture system namely aquaponics appears to be an excellent way of saving water, improve waste management as well as the production of a commercially useful hydroponics by products. The emergence of the self contained food production systems based on aquaponics is a fairly new concept and remains relatively undeveloped in Malaysia. This study was conducted to develop and utilize a pilot scale of aquaponics recirculation system (ARS) as the design protocol for the development of an economically feasible and environmentally sustainable aquaculture industry in Malaysia.

The first part of this study is to evaluate the effect of hydraulic conditions on growth performance of the African catfish (*Clarias gariepinus*) and water

spinach (*Ipomoea aquatica*) as well as nutrients removal. Six hydraulic loading rates (HLR) such as 0.64, 0.96, 1.28, 1.92, 2.56, and 3.20 m/day were used in this evaluation. The determination of HLR was based on ammonia removal mass balance. The experiments were conducted with the same stocking density of African catfish for 35 days. The result showed that fish production performance did not differ significantly between HLR. In contrast, the water spinach production was significantly higher in the lower HLR. The nutrients removal was found to be strongly dependent on HLR. The effect of HLR on removal rate constant was further examined by linear regression. Strong correlations were found between rate constant and HLR. The optimum HLR in terms of plant growth and nutrients removal of nitrate-N and orthophosphate was at 1.28 m/day.

The second experiment was conducted to evaluate the effectiveness of crops in removing nutrients of aquaculture wastewater. The treatment efficiencies of ARS containing water spinach (*Ipomoea aquatica*) and mustard green (*Brassica juncea)* were evaluated using the optimum HLR obtained from the first experiment. The effects of seed density (15, 20 and 25 g) on nutrient removal such as total ammonia nitrogen (TAN), nitrite-N (NO_2-N), nitrate-N (NO_3-N) and orthophosphate (PO_4^{3-}), fish and plant growth were also investigated. Water spinach showed higher removal in TAN, NO_2-N, NO_3-N and PO_4^{3-} (85.5%, 92.2%, 87.1% and 84.9%, respectively) than Mustard green (75.9%, 79.3%, 80.7% and 77.9%, respectively). Statistically, there were significant differences in nutrient percent removal and plant production between seed density of the water spinach and mustard green.

The last part of this study was conducted to assess the relationship of the optimum ratio of plant to fish. The ratio is expressed as the weight of feed given to fish on a daily basis relative to the plant growing area. Seven ratios of plant to fish (2, 4, 6, 7, 8, 9, and 10) have been determined to balance nutrient generation from fish with nutrient removal by plants. The result showed that the optimum ratio was about 27-90 gram in fish feed per square meter of plant growing area per day, which was equivalent to one fish to eight plants. This relationship was used to develop and predict mathematical model of fish growth and ingested feed. The specific growth rate (SGR) and the daily feeding rate (DFR) both depend on the average weight, W (g), of the fish: $Y = aW^b$, where Y may be SGR or DFR, and a and b are empirical constants. The result revealed that the growth rate of fish followed the exponential rate at the early stage and declining rate at the later stage. The ingested feed relationship showed that daily feeding rate was significantly decreased with increasing average fish weight.

Development of the optimum conditions, e.g., HLR, crops, and plants to fish ratio, operation in ARS is vital in order to maximize fish and plant productions and nutrient recovery. At the same time utilization of ARS minimizes water exchange and nutrient accumulation as well as beneficial environmental impact.

Abstrak tesis yang dikemukakan kepada Senat Universiti Malaysia Terengganu sebagai syarat memenuhi keperluan Ijazah Doktor Falsafah

PEMBANGUNAN DAN PENGGUNAAN SISTEM KITARAN SEMULA AKUAPONIK YANG DIREKABINA UNTUK SPESIS AKUAKULTUR

AZIZAH ENDUT

OGOS 2011

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Integrasi pengeluaran sayuran hidroponik dalam sistem kitaran semula akuakultur yang di kenali sebagai akuaponik merupakan cara terbaik mengurangkan penggunaan air, mempertingkatkan pengurusan sisa dan juga penghasilan produk secara komersil. Penggunaan sistem ini masih baru dan belum dimajukan di Malaysia. Kajian ini dijalankan untuk membangun sistem kitaran semula akuaponik dan menilai keupayaan sistem kitaran semula akuaponik yang dibangunkan dalam penghasilan produk pertanian dan kelestarian alam sekitar dalam industri akuakultur di Malaysia.

Bahagian pertama kajian ini adalah untuk mengkaji kesan hidraulik ke atas prestasi tumbesaran ikan keli Afrika (*Clarias gariepinus*) dan kangkung (*Ipomoea aquatica*) serta penyingkiran nutrien. Enam kadar muatan hidraulik (KMH) yang berbeza iaitu pada 0.64, 0.96, 1.28, 1.92, 2.56 dan 3.20 m/hari.

Penentuan KMH adalah berasaskan kepada keseimbangan jisim penyingkiran ammonia. Hasil kajian menunjukkan KMH tidak memberi kesan yang signifikan terhadap penghasilan ikan. Sebaliknya, KMH memberi kesan yang signifikan terhadap penghasilan sayur kangkung dan penyingkiran nutrien. Penghasilan kangkung secara signifikan adalah lebih tinggi pada KMH yang rendah. Penyingkiran nutrien di dapati berkadaran kepada KMH. Penghasilan dan tumbesaran sayuran serta penyingkiran nutrien memberikan hasil yang optimum pada KMH 1.28 m/hari.

Eksperimen yang kedua dijalankan untuk menilai keberkesanan jenis sayuran yang memberikan prestasi yang optimum dalam penghasilan ikan dan penyingkiran nutrient. Keberkesanan sistem yang dibangunkan diuji menggunakan dua jenis sayuran iaitu kangkung (*Ipomoea aquatica*) dan sawi (*Brassica juncea)* menggunakan KMH pada 1.28 m/hari. Kesan berat benih (15, 20, 25 g) ke atas penyingkiran nutrien seperti jumlah ammonia nitrogen (TAN), nitrit-N (NO_2-N), nitrat-N (NO_3-N) dan ortofosfat (PO_4^{3-}) serta tumbesaran ikan dan sayuran juga di kaji. Hasil kajian menunjukkan bahawa kangkung mempunyai keupayaan yang lebih tinggi dalam menyingkir TAN, NO_2-N, NO_3-N dan PO_4^{3-} (masing-masing adalah sebanyak 85.5%, 92.2%, 87.1% and 84.9%) berbanding sawi (masing-masing adalah sebanyak 75.9%, 79.3%, 80.6% and 77.9%). Secara statistiknya, terdapat perbezaan yang signifikan dalam penyingkiran nutrien dan penghasilan sayuran di antara berat benih kedua-dua sayuran.

Bahagian yang terakhir kajian ini dijalankan untuk menilai pertalian nisbah optima di antara ikan dan sayuran. Nisbah dinyatakan sebagai berat makanan ikan yang diberi setiap hari relatif kepada keluasan tanaman sayuran, di mana tujuh nilai nisbah ikan dan sayuran (2, 4, 6, 7, 8, 9 dan 10) telah digunakan. Keputusan menunjukkan nisbah optima adalah dalam julat di antara 27-90 gram makanan ikan bagi setiap meter kuasa dua keluasan tanaman sayuran sehari, yang setara dengan nisbah satu ekor ikan dan lapan sayuran. Nilai ini telah digunakan untuk membangun dan meramal pertalian matematik bagi tumbesaran ikan dan kadar pengambilan makanan harian. Kedua-dua kadar spesifik tumbesaran dan kadar pengambilan makanan harian mempunyai perkadaran dengan purata berat ikan, W (g): $Y = aW^b$, di mana Y adalah SGR atau DFR dan a dan b adalah pemalar. Hasil kajian juga menunjukkan yang kadar tumbesaran ikan mengikut kadar eksponen pada peringkat awal dan kadar penurunan pada peringkat akhir. Pertalian matematik pengambilan makanan ikan harian pula secara signifikan menurun dengan kenaikan berat ikan.

Pembangunan keadaan yang optimum seperti KMH, jenis tanaman dan nisbah sayuran kepada ikan adalah penting bagi memaksimumkan penghasilan ikan, sayuran dan penyingkiran nutrien. Pada masa yang sama penggunaan sistem kitaran semula akuaponik berupaya meminimumkan penggunaan air, mengurangkan pengumpulan nutrien dan memanafaatkan impak alam sekitar