UNIVERSITI PUTRA MALAYSIA

DYNAMIC OF NUTRIENTS IN A RECIRCULATING AQUAPONIC SYSTEM USING RED TILAPIA (OREOCHROMIS SP.) AND LETTUCE (LACTUCA SATIVA VARLONGIFOLIA)

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BY

GHOLAM REZA RAFIEE

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia in the Fulfillment of the Requirements for the Degree of Doctor of Philosophy

March 2003

IN THE NAME OF GOD

DEDICATION

To my family for their helps and financial supports, especially to my father who passed away without sharing in the results of this study, to my wife, to my teachers, to my friends and students.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirements for the degree of Doctor of Philosophy.

DYNAMIC OF NUTRIENTS IN A RECIRCULATING AQUAPONIC SYSTEM USING RED TILAPIA (*Oreochromis* sp.) AND LETTUCE (*Lactuca sativa* var *Longifolia*)

By

Gholamreza Rafiee

March 2003

Chairman: Dr. Che Roos Saad

Faculty: Agriculture

A series of experiments were conducted to evaluate the fish and vegetable production in a recirculating aquaponic system. In the first experiment, the efficiency of three recirculating aquaculture systems (plant as a biofilter, a simple handmade- biofilter and combination of both plant and biofilter) in the production of fish and removal of N-compounds were evaluated. It was concluded that all the systems were efficient both in the removal of N-compounds as well as giving high red tilapia (*Oreochromis* sp.) and lettuce (*lactuca sativa* var *longifolia*) production. Within a period of fish culture (15 weeks), and a period of lettuce culture (5 weeks), the yield of red tilapia and lettuce ranged from 13.61 to 19.41 kg/m^3 and from 0.851 to 2.87 kg/m^2 in the hydroponic area, respectively. Based on the results of the first experiment, the system with the use of plant as a biofilter was selected as a model for investigation of the nutrient removal and reabsorption in an aquaponic system. The main parts of the system consisted of a black fiberglass tank (110 L x 84 W x 100 H cm) equipped with three hydroponics troughs

(110L x 30 W x 5 cm Depth), and a submersible pump (Model Aqua, 1500) for recirculating the water through the culture system.

In the second, third and fourth experiments, the total ammonia excretion by red tilapia (the endogenous ammonia excretion related to catabolism of body protein and exogenous ammonia excretion related to metabolism of feed protein), as well as gaseous ammonia escape rate during different stages of its growth from the culture system were evaluated. It was found that the weight of fish significantly affected ammonia excretion. The rate of total N content of feed excreted by red tilapia ranged from 31.10 to 54.20% for 20 –200g red tilapia. On average, 39.54% of the nitrogen content of fish feed was excreted as ammonia-N by red tilapia. Water recycling influenced the escape of ammonia due to ventilation an in the culture system. However, the rate of ammonia escaping from the system, decreased inversely with an increase in the fish weight. The percentage of escaped ammonia ranged from 7 – 72% of total ammonia excreted by fed fish.

In the fifth experiment, the ability of red tilapia in absorbing the nutrient contents of supplementary feed in the different stages of its growth in the culture system were investigated. It was found that the red tilapia could assimilate 11.46% Fe, 13.43% Zn, 6.81% Mn, 3.55% Cu, 26.81% Ca, 20.29% Mg, 32.53% N, 7.16% K and 15.98% P of the mineral content of the feed supply during a culture period. It means that 88.54% Fe, 93.19% Mn, 86.57% Zn, 96.44% Cu, 73.19% Ca, 79.71% Mg, 67.47% N, 92.84 % K and 84.02% P content of fish feed were released in the forms of faecal materials, urine and ammonia gas excretion in the culture system. It was calculated that after three weeks of initial introduction of fish in the culture system, the total concentration of minerals in the solid faecal materials were comprised of 23.93 % Fe, 86.05 % Mn, 46.17 % Zn, 21.49 %

Cu, 15.71 % Ca, 88.87 % Mg, 5.55 % N, 5.85 % K and 17.90 % P of total mineral content of given feed. In the sixth experiment, the production of hydroponic lettuce associated with natural flora of microorganisms (bacteria) in the purification of aquaculture wastewater was determined. On average, 2,124 g (wet weight/ m^2) lettuce was harvested during each lettuce plantation period (5 weeks). The nutrient assimilation rates by lettuce averaged 3.2, 73.8, 8.0, 3.5, 5.0, 4.7, 1.5, 9.0 and 0.3% for Fe, Mn, Zn, Cu, Ca, Mg, P, N and K from the content of feed supply, respectively. The concentration of nutrient content of the wastewater at the end of experiment [Total Dissolved Solids (TDS) and Total Suspended Solids (TSS)] indicated that the concentrations of nutrients were enough for growing a new crop of lettuce.

On average, the sum of dried TDS and TSS in the water decreased from 231.26 to 185.56 g after 5 weeks. The diversity of the bacteria increased during the experimental period and 19 types of bacteria were responsible for degradation of organic materials to inorganic nutrient just within 3-week of fish culture period only.

These results indicated that in the current system with regards to the hydroponic area (with 45 seedlings of lettuce), the assimilation of nutrient content in the recycling wastewater was not in equilibrium between the rate of nutrient excreted by fish and rate of recovery by microorganisms and plants. Thus, a larger hydroponic area most probably will increase the efficiency of the system performance in the production of fish and vegetable.

Abstrak tesis dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi syarat untuk mendapatkan Ijazah Doktor Falsafah.

DINAMIK NUTRIEN DALAM KITARAN SEMULA SISTEM AKUAPONIK MENGGUNAKAN IKAN TILAPIA MERAH (*Oreochromis* sp.) DAN SAYUR SALAD (*Lactuca sativa* var *Longifolia*)

Oleh

Gholamreza Rafiee

Mac 2003

Pengerusi: **Dr. Che Roos Saad**

Fakulti: **Pertanian**

Satu siri kajian telah dijalankan untuk menilai pengeluaran ikan dan sayuran di dalam sistem kitaran semula akuaponik. Dalam kajian pertama, kecekapan tiga system kitaran semula akuakultur (tumbuhan sebagai penapis biologi, penapis buatan yang mudah dan gabungan tumbuhan serta penapis buatan) dalam pengeluaran ikan serta pembuangan sebatian-N telah dinilaikan. Adalah didapati ketiga-tiga sistem ini berkesan dalam pembuangan sebatian-N dan meningkatkan pengeluaran ikan tilapia merah (*Oreochromis sp*) serta sayuran salad (*Lactuca sativa* var *longifolia*). Sepanjang pengkulturan ikan (15 minggu) dan penanaman salad (5 minggu untuk setiap pusingan), hasil dari ikan tilapia merah dan sayur salad berjulat dari 13.61 hingga 19.41 kg/m^3 dan dari 0.851 hingga 2.87 kg/m^2 untuk kawasan hidroponik masing-masing. Berdasarkan hasil dari kajian pertama, sistem yang menggunakan tumbuhan sebagai penapis biologi telah dipilih sebagai model untuk mengkaji pembuangan dan penyerapan semula nutrien dalam sistem akuaponik. Bahagian utama dalam sistem ialah sebuah tangki gentian kaca berwarna hitam (110 P x 84 L x 100 T cm), dan sebuah pam tenggelam (Model Aqua 1500) untuk pengitaran air

serta dilengkapi dengan 3 takungan hidroponik yang bersalur (110 P x 30 L x 5 cm dalam) dalam sistem tersebut.

Dalam kajian kedua, ketiga dan keempat, jumlah perkumuhan ammonia oleh ikan tilapia merah (secara dalaman yang berkaitan dengan katabolisma protein dalam badan dan secara luaran iaitu hasil dari metabolisma protein dalam makanan) dan kadar gas ammonia yang keluar dari sistem telah dikaji disepanjang peringkat pertumbuhan saiz ikan yang berbeza. Adalah didapati berat badan ikan memberi kesan yang bererti terhadap perkumuhan ammonia. Banyaknya nitrogen yang di kumuhkan oleh ikan tilapia merah berjulat dari 31.10 hingga 54.20 % dari jumlah kandungan N dalam makanan bagi ikan tilapia merah bersaiz 20 – 200 g. Purata, 39.54 % dari kandungan N dalam makanan dikumuhkan sebagai ammonia-N oleh ikan tilapia merah. Pengitaran air semula memberi kesan terhadap gas ammonia yang keluar dari sistem dan ia mempunyai kaitan berbalik dengan pertambahan berat badan ikan. Peratusan ammonia yang keluar dari sistem berjulat dari 7 – 72% dari jumlah ammonia yang dikumuh oleh ikan.

Dalam kajian kelima, keupayaan ikan tilapia merah untuk menyerap kandungan nutrien dalam makanan semasa pertumbuhan berbagai peringkat saiz ikan telah dikaji. Adalah didapati ikan tilapia merah boleh menyerap 11.46 % Fe, 13.43 % Zn, 6.81 % Mn, 3.55 % Cu, 26.81 % Ca, 20.29 % Mg, 32.53 % N, 7.16 % K dan 15.98 % P dari jumlah kandungan zat galian dalam makanan. Ini bermakna 88.54 % Fe, 93.19 % Mn, 86.57 % Zn, 96.44 % Cu, 73.19 % Ca, 79.71 % Mg, 67.47 % N, 92.84 % K dan 84.02 % P dalam makanan ikan telah dikeluarkan dalam bentuk najis, air kencing gas ammonia oleh ikan dalam sistem penternakan ini. Adalah ditaksirkan selepas tiga minggu ikan di masukkan kedalam sistem pengkulturan, jumlah kepekatan zat galian dalam bentuk pepejal najis

mengandungi 23.93 % Fe, 86.05 % Mn, 46.17 % Zn, 21.49 % Cu, 15.71 % Ca, 88.87 % Mg, 5.55 % N, 5.85 % K and 17.90 % P dari jumlah kandungan zat galian dalam makanan.

Dalam kajian keenam, pengeluaran salad hidroponik telah dilakukan. Purata, 2,124 g (berat basah/m^2) salad telah dituai untuk setiap pusingan tanaman sayuran salad ini (5 minggu). Purata penyerapan nutrien oleh sayur salad ialah 3.2, 73.8, 8.0, 3.5, 5.0, 4.7 1.5, 9.0 dan 0.3 % untuk Fe, Mn, Zn, Cu, Ca, Mg, P, N, dan K masing-masing dari jumlah kandungan zat galian dalam makanan ikan. Kepekatan kandungan nutrien (Jumlah Pepejal Terlarut (TDS) dan Jumlah Pepejal Terampai (TSS)) dalam air buangan dipenghujung kajian menunjukkan kandungan bahan-bahan ini mencukupi untuk satu pusingan tanaman sayur salad yang baru.

Secara purata, jumlah bahan TDS dan TSS yang kering dalam air berkurangan dari 231.26 g ke 185.56 g selepas 5 minggu kajian berjalan. Diversiti bakteria bertambah semasa pengkulturan ikan dimana didapati 19 jenis bakteria terlibat dalam degradasi bahan organan kepada nutrien bukan organan didalam masa hanya 3 minggu sahaja.

Kesimpulannya, kajian ini menunjukkan nisbah ruang hidroponik (45 biji benih daun salad) kepada kapasiti pemeliharaan ikan adalah masih kecil untuk mencapai keseimbangan antara kadar perkumuhan nutrien oleh ikan dan mikroorganisma dan kadar pengambilan oleh tumbuhan. Oleh itu, dengan memperluaskan ruang hidroponik kecekapan system ini boleh ditingkatkan dalam pengeluaran ikan tilapia dan sayuran,

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I certify that an Examination committee met on 5th March 2003 to conduct the final examination of Gholamreza Rafiee on his Doctor of Philosophy thesis entitled "Dynamic of Nutrients in a Recirculating Aquaponic System Using Red Tilapia (*Oreochromis* sp.) and Lettuce (*Lactuca sativa* var *Longifolia*)" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulation 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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This thesis submitted to the Senate of Universiti Putra Malaysia and it has been accepted as fulfillment of the requirement for the degree of Doctor of Philosophy. The members of Supervisory Committee are as followes:

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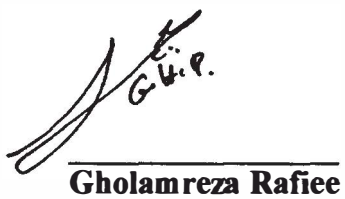
DECLARATION

I hereby declare that this thesis is based on my original work except for quotation and citation which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.



Gholamreza Rafiee
Date: 03/04/2008

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