



UNIVERSITI PUTRA MALAYSIA

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

GHOLAM REZA RAFIEE

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**Thesis Submitted to the School of Graduate Studies, Universiti Putra
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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
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By

Gholamreza Rafiee

March 2003

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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/m³ and from 0.851 to 2.87 kg/m² 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 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/ m²) 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
MENGUNAKAN IKAN TILAPIA MERAH (*Oreochromis sp.*) DAN SAYUR
SALAD (*Lactuca sativa var Longifolia*)**

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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 dinilai. 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/m³ dan dari 0.851 hingga 2.87 kg/m² 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/m²) 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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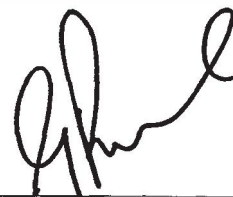
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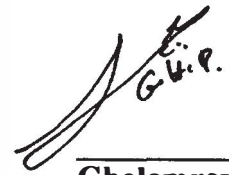


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DECLARATION

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

TABLE OF CONTENT

| | Page |
|--|-------------|
| DEDICATION | ii |
| ABSTRACT | iii |
| ABSTRAK | vi |
| ACKNOWLEDGEMENTS | ix |
| APPROVAL | x |
| DECLARATION | xii |
| TABLE OF CONTENT | xiii |
| LIST OF TABLES | xviii |
| LIST OF FIGURES | xxiii |
| LIST OF ABBREVIATIONS | xxv |
| CHAPTER | |
| I | |
| INTRODUCTION | 1 |
| Background of the Study | 1 |
| Statement of the Problems | 4 |
| Significant of the Study | 6 |
| Objectives of the Study | 8 |
| | |
| II | |
| LITERATURE REVIEW | 10 |
| Recirculating Aquaculture System | 11 |
| Integration of Hydroponics in a Recirculating Aquaculture System-Aquaponics | 14 |
| Use of Plant As a Biofilter | 16 |
| Aquatic plants | 16 |
| Terrestrial plants | 18 |
| Pests and Diseases Control | 19 |
| Selection of Fish for Culture in a Recirculating Aquaculture System | 20 |
| Important Cultured Fish in RAS | 20 |
| Catfish and Tilapia | 21 |
| The Effect of Food and Feeding on Water Quality Parameters | 24 |
| Oxygen (O ₂) | 26 |
| Total Suspended Solid (TSS) | 28 |
| Biological Oxygen Demand (BOD ₅) | 28 |
| Ammonia-N | 29 |
| Toxicity of N-compounds | 31 |



| | | |
|------------|--|-----------|
| | Ammonia-N | 31 |
| | Nitrite and Nitrate-N | 32 |
| | Roles of Bacteria on the Removal of N-compounds | 33 |
| | Co-existence Between Bacteria and Plants | 35 |
| | Epiphytic Bacteria | 36 |
| | Nutrient Requirement of Plants in the Hydroponics and Aquaponic Systems | 36 |
| III | REMOVAL OF N-COMPOUNDS AND INTENSIVE PRODUCTION OF RED TILAPIA (<i>Oreochromis</i> sp.) IN THE THREE SIMPLE RECIRCULATING AQUACULTURE SYSTEMS | 39 |
| | Introduction | 39 |
| | Materials and Methods | 40 |
| | Location of Running Experiments | 40 |
| | System and Experimental Design | 41 |
| | Water Supply | 42 |
| | Preparation of Nutrient Solution (media) Based on Cooper's Formula | 44 |
| | Feed and Feeding | 45 |
| | Production of lettuce seedlings | 45 |
| | Sampling the Water and Water Quality Parameters Measurement | 45 |
| | Sampling and Fish Weight Measurement | 46 |
| | Leaf Area Measurement | 46 |
| | Protocol | 46 |
| | Data Analysis | 47 |
| | Results | 47 |
| | Fish Growth | 47 |
| | Vegetable Production | 49 |
| | Water Quality Parameters | 50 |
| | Total Ammonia-N (TAN) | 50 |
| | Nitrite-Nitrogen (Nitrite-N) | 51 |
| | Nitrate-Nitrogen (Nitrate-N) | 52 |
| | Dissolved Oxygen (DO) and Temperature (T) | 52 |
| | The pH and EC (Electro- conductivity) | 53 |
| | Water Replacement | 54 |
| | Discussion | 55 |
| | Conclusion | 60 |

| | | |
|-----------|--|-----------|
| IV | TOTA AMMONIA-NITROGEN EXCRETION RATE OF RED TILAPIA (<i>Oreochromis sp.</i>) AND GASEOUS AMMONIA ESCAPE IN A WATER RECIRCULATING AQUACULTURE SYSTEM | 61 |
| | Introduction | 61 |
| | Materials and Methods | 62 |
| | Feed and Feeding | 63 |
| | Water Quality Parameters Measurements | 64 |
| | Sampling and TAN excretion measurement | 64 |
| | Protocol of experiment 1 | 65 |
| | Protocol of experiment 2 | 65 |
| | Protocol of experiment 3 | 66 |
| | Statistical Analysis | 66 |
| | Results | 66 |
| | Experiment 1 | 66 |
| | Experiment 2 | 68 |
| | Experiment 3 | 69 |
| | Feed consumption and amount of nitrogen excretion of feed by red tilapia | 70 |
| | Water Quality | 72 |
| | Regime of ammonia excretion as a factor of weight and time | 73 |
| | Discussion | 74 |
| | Conclusion | 77 |
| | | |
| V | NUTRIENT CONTENT OF FEED ASSIMILATED BY RED TILAPIA (<i>Oreochromis sp.</i>) IN A REPRESENTATIVE WATER RE-CIRCULATING SYSTEM | 79 |
| | Introduction | 79 |
| | Materials and Methods | 80 |
| | Water Supply | 81 |
| | Feed and Feeding | 81 |
| | The Sampling and Water Quality Parameters Measurements | 83 |
| | Biochemical Composition of the Feed Supply | 83 |
| | The Volume of the Water in the Fish Tanks | 83 |
| | Aeration of the Water in the Fish Tanks | 83 |
| | The Fish Sampling and Its Dry Weight Measurements | 84 |



| | |
|--|-----|
| Measurement of Solid Residual Inside the Hydroponic Troughs | 85 |
| Measurement of Total Suspended Solid (TSS) and Dissolved Solid (TDS) | 85 |
| Nutrient (minerals) Content of the Dry Fish, Feed and TS Measurements | 86 |
| Concentration of Dissolved Minerals in the Water | 87 |
| Data Analysis | 87 |
| Results | 87 |
| Fish Growth | 87 |
| Nutrient Content of Feed Assimilated by Red Tilapia | 89 |
| Water Quality Parameters | 90 |
| Total Ammonia-N | 90 |
| Nitrite-N | 92 |
| Total Inorganic Nitrogen | 93 |
| The Ec | 93 |
| The pH | 94 |
| Macro-elements | 94 |
| Phosphorous | 94 |
| Magnesium | 95 |
| Calcium | 95 |
| Potassium | 96 |
| Faecal Materials (Residuals) | 96 |
| Mineral Content of Solid (Residual) | 97 |
| Discussion | 99 |
| Conclusion | 105 |
| | |
| VI | |
| ASSIMILATION OF NUTRIENTS BY LETTUCE (<i>Lactuca sativa</i> Var <i>longifolia</i>) FROM THE WASTEWATER (MEDIUM) PRODUCED BY CULTURE OF RED TILAPIA (<i>Oreochromis</i> sp.) | 107 |
| Introduction | 107 |
| Materials and Methods | 108 |
| Experimental Design | 108 |
| Nutrient Content of Media | 109 |
| Wastewater Volume | 111 |
| The Sampling and Water Quality Parameters | 112 |
| Measurements | |
| The Lettuce Weight Measurement | 112 |
| The shoot and Root of Lettuce Sampling and Their Dry weight Measurements | 113 |
| Measurement of Solid Inside the Hydroponic Troughs | 113 |

| | | |
|------------|--|-----|
| | Measurement of Total Suspended Solid (TSS) and Dissolved Solid (TDS) in the Water | 114 |
| | Nutrient (minerals) Composition of Dried Root and Shoot of Lettuce and TS Measurements | 116 |
| | Concentration of Dissolved Minerals in the Wastewaters | 116 |
| | Data Analysis | 117 |
| | Results | 117 |
| | Lettuce Growth | 117 |
| | Water Quality Parameters | 118 |
| | Total Ammonia-N | 118 |
| | Nitrite-N | 119 |
| | Total Dissolved Inorganic Nitrogen | 119 |
| | The Ec | 119 |
| | The pH | 121 |
| | Macroelements | 121 |
| | Phosphorous | 121 |
| | Magnesium | 122 |
| | Calcium | 123 |
| | Potasium | 122 |
| | Total Solids | 124 |
| | Nutrient Content of Solid | 124 |
| | Nutrient Content of Water at the End of Experiment | 126 |
| | Assimilation of Nutrient by Lettuce | 126 |
| | Numeration and Identification of Bacteria | 128 |
| | Discussion | 131 |
| | Nutrient Assimilated by Lettuce | 131 |
| | Operation of the Bacteria During the Experiment | 134 |
| | Conclusion | 135 |
| VII | GENERAL DISCUSSION, CONCLUSION AND RECOMENDATIONS | 137 |
| | General Discussion | 137 |
| | Conclusion | 144 |
| | Recommendation | 145 |
| | REFERENCES | 146 |
| | APPENDICES | 165 |
| | VITA | 171 |



LIST OF TABLES

| Table | | Page |
|--------------|--|-------------|
| 2.1 | The characteristics of tap and well water supply | 42 |
| 2.2 | The percentage of TAN in its un-ionized form as a factor of pH and temperature | 29 |
| 3.3 | The concentration of minerals in the medium of Cooper's used for lettuce culture in NFT (Nutrient Film Technique) system | 44 |
| 3.4 | The mean (Mean \pm SD) of fish biomass (FB), weight of fish (WT), Daily growth rate (DGR), Feed Conversion Ratio (FCR), survival (Sur) in all treatments (Ts) at the end of experiment. | 48 |
| 3.3 | The mean (Mean \pm SD) percentage of water replacement in the fish tanks in the different treatment by the end of experimental period. | 54 |
| 3.4 | Concentration of N-compounds in rearing tank that were derived from studies of aquaponic systems | 63 |
| 4.1 | The mean (Mean \pm SD) TAN excreted by the different weight classes of red tilapia within a 24-h experimental period. | 67 |
| 4.2 | The mean (Mean \pm SD) retained TAN excretion by different weight classes of red tilapia in the fish tanks within a 24 -h experimental period. | 68 |
| 4.3 | The mean (Mean \pm SD) TAN excreted by different weight classes of starved red tilapia within a 24- h experimental period. | 70 |
| 4.4 | The amount (Mean \pm SD) of feed supplied for feeding different weight groups of red tilapia during the experiment | 70 |
| 4.5 | The mean (Mean \pm SD) percentage of nitrogen content of feed supply (EXN/ NFED) excreted as endogenous excretion (ENE / NFED) and exogenous excretion (EXNE/ NFED) by different weight classes (WC) of red tilapia. | 72 |



| | | |
|------|---|----|
| 5.1 | The (Mean \pm SD) percentage (%) of minerals* (Nutrients) content of supplementary fish feed. | 82 |
| 5.2 | The means (Mean \pm SD) of fish weight at the harvest time (FWT), feed conversion ratio (FCR), Total feed consumption (TFC), Daily growth rate (DGR) and feed consumption (g) per tank per day (FCD). | 88 |
| 5.3 | Percentage of mineral (nutrients) composition (Mean \pm SD) of dry body weight of red tilapia sampled at the start and end of experiment from each treatment. | 90 |
| 5.4 | Average nutrient values assimilated by different weight classes of red tilapia during the experiment (for 75 fish / tank in each treatment). | 91 |
| 5.5 | Average percentage of nutrients assimilated by red tilapia to nutrient content of feed supply in different weight classes of red tilapia during the experiment. | 91 |
| 5.6 | The mean (Mean \pm SD) concentration of total ammonia-N (TAN) and nitrite in different treatments in the fish rearing tanks during the experimental period. | 92 |
| 5.7 | The mean (Mean \pm SD) total inorganic nitrogen concentrations rates in the rearing tanks during the experiment | 93 |
| 5.8 | The Ec and pH changes (Mean \pm SD) in body of water in rearing tanks during the experiment | 94 |
| 5.9 | Changes in the concentration (Mean \pm SD) of total phosphorous (P) and magnesium (Mg) in the fish rearing tanks during the 3 weeks experimental period. | 95 |
| 5.10 | Changes in the concentration (Mean \pm SD) of total calcium (Ca) and potassium (K) in fish rearing tanks during the experiment. | 97 |
| 5.11 | The mean (Mean \pm SD) computed total dry solid (TSS+TDS) in rearing tanks and solid (TS) accumulated inside the hydroponic troughs in the treatments at the termination of experimental period. | 97 |

| | | |
|------|---|-----|
| 5.12 | Percentage (Mean±SD) of macro-and microelements (nutrients) in the solids (dried) that accumulated inside the hydroponic troughs in the different treatments (treat) at the end of experimental period. | 98 |
| 5.13 | The average total nutrient content of dried solid (DS) settled in the hydroponic troughs in the different treatments by the end of experimental period. | 98 |
| 5.14 | The average percentage of nutrients in the feed captured as solids in the hydroponic troughs by different weight groups of fish. | 99 |
| 5.15 | Total amount of minerals in the culture water at the beginning of the experiment | 107 |
| 6.1 | The average total nutrients (minerals)(g) content of the media (fish wastewater) produced due to culture of different weight groups of red tilapia in the culture system for a 3- week period without considering nutrient content of the water supply. | 109 |
| 6.2 | The average nutrient content (g) of dried solid (DS) settled in the hydroponic troughs in the different treatments at the initiation of the experimental period. | 110 |
| 6.3 | The average total nutrient content of wastewater in the different treatments at the initiation of the experiment. | 110 |
| 6.4 | The mean (Mean ±SD) wet weight of shoots or yield of lettuce (WWT), percent dry weight of shoots (DWS), wet weight of roots (WWR), percent dry weight of roots (DWR) and leave area (LA) at harvest time. | 117 |
| 6.5 | The mean (Mean±SD) concentration of TAN (mg L ⁻¹) in rearing tanks during the experimental period | 118 |
| 6.6 | The mean (Mean±SD) concentration of total nitrite-N in rearing tanks in different treatments (Treat) during the experiment. | 119 |
| 6.7 | The mean (Mean±SD) concentration (mg L ⁻¹) of total dissolved inorganic-N in the wastewater tanks during the experimental period. | 120 |

| | | |
|------|--|-----|
| 6.8 | The mean (Mean \pm SD) Electro conductivity (mmhos / cm) variation in the different wastewaters during the experimental period. | 120 |
| 6.9 | The average pH changes in the different fish wastewaters during the experimental period. | 121 |
| 6.10 | The mean (Mean \pm SD) concentration of P (mg L ⁻¹) in the different waste waters during the experimental period. | 122 |
| 6.11 | The mean (Mean \pm SD) concentration of Mg (mg L ⁻¹) in the different fish wastewaters during the experimental period. | 122 |
| 6.12 | The mean (Mean \pm SD) concentration of Ca (mg L ⁻¹) in the different fish wastewater during the experiment. | 123 |
| 6.13 | The mean concentration (Mean \pm SD) of K (mg L ⁻¹) in the different wastewaters during the experimental period. | 124 |
| 6.14 | The means (Mean \pm SD) of total dry solid values (TSS+TDS) in the wastewater and total solids (TS) settled in the hydroponic troughs in all the treatments at the initiation (1) and termination of the experiment (2). | 125 |
| 6.15 | The mean percentage (Mean \pm SD) of minerals (nutrients) in the dry weight of solid settled in the hydroponic troughs of different treatments at the termination of the experiment. | 125 |
| 6.16 | The average nutrient content (g) of dried solids* (DTS) retained inside the hydroponic troughs in different treatments at the end of experiment | 126 |
| 6.17 | The average dissolved nutrient content of wastewater in the tanks at the start and end of the experiment. | 127 |
| 6.18 | The average values of micro- and macronutrients absorbed by lettuce shoot at the end of experiment. | 127 |
| 6.19 | The average values of micro and macronutrients were absorbed by root of lettuce at the termination of the experiment. | 128 |



| | | |
|------|--|-----|
| 8-21 | The number and strains of bacteria in the water or associated with roots of lettuce. | 129 |
| 8-22 | Scientific name of some strains of bacteria coded during the experiment and their place of activity. | 130 |



LIST OF FIGURES

| Figure | | Page |
|---------------|---|-------------|
| 2.1 | Schematic arrangement of recirculating system compartments | 12 |
| 2.2 | Schematic arrangement of compartments in an aquaponic system. | 15 |
| 2.3 | General scheme of an aquaponics and factors determining the characteristics of the artificial ecosystem. | 16 |
| 3.1 | Schematic diagram of three systems: A) integrated fish and plant co- culture with use of a bacterial bio-filter (PB); B) integrated fish and plant co- culture without use of a bacterial bio-filter (P) and C) system consist of bacterial bio-filter(B) | 43 |
| 3.2 | Red tilapia growth in the different treatments during the experimental period. | 49 |
| 3.3 | Mean yields of lettuce gained from three crops cycle and harvesting during the experiment (VG 1, 2, 3 = The biomass of lettuce in first, second and third harvests in the different treatments). | 50 |
| 3.4 | The changes in TAN concentration in the rearing tank in the different treatments during the experimental period. | 51 |
| 3.5 | Nitrite-N concentration in different treatments during the experimental period. | 52 |
| 3.6 | The pH changes in different treatments during the experimental period | 53 |
| 3.7 | The EC changes in different treatments during the experimental period. | 54 |
| 4.1 | Schematic feature of the system; 1. The fish tank 2.The hydroponic troughs 3. The water pump. | 63 |
| 4.2 | Percentage of N content of feed excreted by different weight classes of red tilapia. | 71 |