The growth potential in the aquaponic system of Lophantus Anisatus

El potencial de crecimiento en el sistema acuapónico de Lophantus Anisatus

Constanta Laura Augustin*
"Dunărea de Jos" University of Galaţi - ROMANIA
zugravulaura@yahoo.com

Maria Magdalena Turek Rahoveanu*
"Dunărea de Jos" University of Galaţi - ROMANIA
mturek2003@yahoo.com

Gheorghe Adrian Zugravu*
"Dunărea de Jos" University of Galaţi - ROMANIA
zugravuadrian@yahoo.com

ABSTRACT

The paper main objectives are to identify an analysis potential to grow in the aquaponics system of Lophantus Anisatus. This model of integrated production system adds more value to end aquaponics products. The objective of this model is to test and predicts that mint plant and fish growth and net ammonium and nitrate concentrations in water in an aquaponic system.

Keywords: mint, management, aquaponics.

RESUMEN

Los objetivos principales del documento son identificar un potencial de análisis de crecimiento en el sistema acuapónico de Lophantus Anisatus. Este modelo de sistema de producción integrado agrega más valor a los productos acuapónicos finales. El objetivo de este modelo es probar y predecir que las plantas de menta y el crecimiento de peces y las concentraciones netas de amonio y nitrato en el agua en un sistema acuapónico.

Palabras clave: menta, manejo, acuaponia.

*Corresponding author.

Recibido: 08/01/2019 Aceptado: 12/05/2019

Introduction

The increased demand for fish, water and fertilizer for crop production and the concerns about environment and health are motivations to test innovative farming systems such as “aquaponics” as viable systems for sustainable fish and crop production.

Agricultural and livestock activities are considered the biggest consumers of fresh water. Estimations reveal that 85% of the global fresh water consumption is for agriculture and nearly one-third of the total water footprint of agriculture in the world is used for livestock products (Hoekstra and Chapagain, 2007), (Mekonnen and Hoekstra, 2012).

In the last 30 years, the increase in the income of the population in developing countries, led to an increase in fish consumption from 25.0 to 104.3 million ton fish per year. Due to the depletion of marine resources the FAO predicts that in the future the supply of fish for the population will be entirely dependent on fish production in aquaculture systems.

Aquaponics has ancient roots. Aztec cultivated agricultural islands known as chinampas in a system considered by some to be the first form of aquaponics for agricultural use (Diver, 2006), where mint plants were raised on stationary islands in lake shallows and waste materials dredged from the chinampa canals and surrounding cities were used to manually irrigate the mint plants in Boutwelluc (2007) and Rogosa (2013). Also, South China, Thailand, and Indonesia who cultivated and farmed rice in paddy fields in combination with fish are cited as examples of early aquaponics systems. These aquaponic farming systems existed in many far eastern countries, in USA, and Canada.

The Aquaponics Model

The hydroponic greenhouse production system requires a high degree of environmental control including supplemental lighting and moveable shade to provide a target amount of light which, in turn, results in a predictable amount of daily growth. Computer technology is an integral part in the production of hydroponic. A computer control system should be used to control the abiotic environment. Different sensors are used to monitor greenhouse environment parameters. These parameters include temperature of greenhouse air and nutrient solution, relative humidity and carbon dioxide concentration of greenhouse air, light intensities from sunlight and supplemental lighting, pH, Dissolved Oxygen (DO) levels, and Electrical Conductivity (EC) of the nutrient solution. Sensors will communicate the environmental conditions to the control computer which will activate environmental control measures such as heating, ventilation, and lighting. This is done by comparing the model outputs with measurements under controlled conditions in order to assess the accuracy of the tool to simulate nutrient concentrations in water and fish and plant biomass production of the system.

Water quality parameters such as NH4/NH3, NO3, NO2, PO4, pH and dissolved oxygen were measured fortnightly using test kits. Number of flowers, fruits and fruits weight were recorded. All the sampling data were recorded in the Microsoft Excel 7 for analysis.

To understand the environmental condition of pond, the physico-chemical parameters of water were needed to be measured. The main parameters including temperature, pH, dissolved oxygen, nitrate and ammonia were measured before starting the experiment.

For determine the growth parameters, length, weight and number of leaves and branches were taken into consideration. The percent gain of growth parameters of the aquaponic plan were measured using the following formula.

$$\%gain = \frac{\text{Final stage- Initial stage}}{\text{Initial stage}} \times 100$$

Recent advances by researchers and growers alike have turned aquaponics into a working model of sustainable food production. The integration of fish and mint plants results in a polyculture that increases diversity and yields multiple products.

Lophantus Anisatus, which is native to Asia, it is a special bee plant, being quoted by American specialists in the first 4 honey plants in the world.

Aquaculture development as a whole in the country in combination with production technology, favorable socioeconomic condition and culture environment has already proven successful in terms of increasing productivity, improving profitability and maintaining sustainability (Toufique and Belton, 2014).

Aquaponics is, farming technique in which water from aquaculture is used to grow crops and extra water returns back to the fish tank. When this water circulated near root zone, nitrogen fixing bacteria (manly nitrosomonas and nitrobactor) convert ammonia ($NH4$) into nitrite ($NO2$) and then to nitrate ($NO3$) form. By these, mint plants get nutrients as fertilizer and nitrates been less toxic to fish; fish grows better than normal aqua farming. By this integration of fish farming and agriculture, one can get maximum output.

Fishes produces nitrogenous compound mainly ammonia which is hazardous to fish, even in small quantities and toxicity increases in relation to pH and temperature in the water column. On the other hand, Nitrosomonas bacteria break down ammonia to $NO2$ and Nitrobacter convert the nitrite into nitrate which is food for the mint plants. By contrast, $NO3$ is less harmful to fish. Decaying organic matters can help to fertilize ponds, at the same time provides good environment for growing mint plants which are less prone to disease unlike soil. Raft aquaponics is one of the ways to use aquaculture site for vegetable production and can help to overcome nutritional demand for the growing population.

Aquaponics is an integrated and intensive fish-crop farming system under constant recirculation of water through interconnected devices. It is considered a promising technology, which is highly productive under correct set up and proper management (Lal, 2013). First, fish feed is eaten by fish and converted into ammonia ($NH3$). Some ammonia ionizes in water to ammonium ($NH4+$). Then, bacteria (Nitrosoma) convert ammonia into nitrite ($NO2-$) and consequently bacteria (Nitrobacter) oxidize nitrite into nitrate ($NO3-$) (Tyson et all, 2011). Finally, the water delivers nutrients and oxygen to promote plant growth. Graber and Junge, found similar yields between hydroponic systems and aquaponics systems. Finally, it is important to establish systems under "smart water" use and to balance nutrient concentrations in water to ensure maximum fish and plant growth (Graber, A., Junge, R., 2009).

Aquaponics is considered a method where water and nutrients are efficiently used and maintained within the system (Liang and Chien, 2013). In aquaponics it is possible to reduce daily water loss to 2% of the total water volume of the system. Due to the constant recirculation of water it is also possible to maintain evenly distributed high nutrient concentrations in the water (nitrate) as the small addition of water to compensate the daily loss will not dilute the nutrients (Rakocy, et all, 2006). The "water smart" approach makes aquaponics an alternative system to produce food under sustainable practices in areas where water is scarce.

Green leafy vegetables with low to medium nutrient requirements are well adapted to aquaponic systems, including lettuce, basil, spinach, chinese cabbage, chives, herbs, and watercress (www.backyardaquaponics.com).

The selection of plant species in aquaponics system is important. Lettuce, herbs, okra and especially leafy greens have low to medium nutritional requirements and are well suitable to aquaponics system. Mint plants yielding fruits like tomato, bell pepper and cucumber have higher nutritional requirement and perform better in a heavily stocked and well established aquaponics system in Adler et all, 2000.

Research conducted at University of Florida showed that cucumber crop can be successfully adopted with aquaponics system. This is estimated that 45.300 Kg of fish will produce sufficient nitrogen for 4050 lettuce or 540 tomato mint plants when they are fed with 3 % of their body weight.

Freshwater fish are the most common aquatic animal raised using aquaponics, although freshwater crayfish and prawns are also sometimes used (Drive, 2006).

A few fish species are adapted to recirculating aquaculture which includes tilapia, trout, perch, arctic char and bass. Most commercial aquaponics system in North America is based on tilapia. Furthermore, tilapia is tolerant of fluctuating water conditions such as pH, temperature, oxygen and dissolved solids in Rakocy, 1999. Tilapia is the fish species which is very hardy, can tolerate wide range of environmental parameters, can live with versatile of feed and are fast grow thing fish species in Salam, 2012.

Besides the melliferous characteristics, Lophantus Anisatus is also a medicinal herb, considering its therapeutic and calming properties. The aroma of the plant is a woven one, between anise and fennel, a flavor that gives it uniqueness and distinction.

The recorded data were entered into the spreadsheet in MS Excel 2010 and then summarized properly before statistical analysis. After entering the data, the descriptive statistical analyses were done by MS Excel.

Temperature controls the rate of plant growth. Generally, as temperatures increase, chemical processes proceed at faster rates. Most chemical processes in mint plants are regulated by enzymes which, in turn, perform at their best within narrow temperature ranges. Above and below these temperature ranges, enzyme activity starts to deteriorate and as a result chemical processes slow down or are stopped. At this point, mint plants are stressed, growth is reduced, and, eventually, the plant may die. The temperature of the plant environment should be kept at optimum levels for fast and successful maturation. Both the air and the water temperature must be monitored and controlled.

The relative humidity (RH) of the greenhouse air influences the transpiration rate of mint plants. High RH of the greenhouse air causes less water to transpire from the mint plants, which causes less transport of nutrients from roots to leaves and less cooling of the leaf surfaces. High humidity can also cause disease problems in some cases. For example, high relative humidity encourages the growth of botrytis and mildew.

Pond water quality is largely defined by temperature, transparency, turbidity, water color, carbon dioxide, pH, alkalinity, hardness, unionized ammonia, nitrite, nitrate, primary productivity, biological oxygen demand and plankton population (Bhatnagar and Devi, 2013).

The accepted level of ammonia should be under the range of 0.05 to 0.10 mg/l (Shoko et. all, 2014) and above range it is toxic to the cultured fish (Francis-Floyd et. all, 2009).

According to Mizanur et al., intensive aquaculture ponds sediments has various fertilizing components such as nitrogen, phosphorous, sulphur etc. which are very useful for growth and production of aquaponic mint plants in Mizanur, 2004 and Muntenita 2016. Moreover, water spinach is an efficient plant having clustered roots that can absorb nutrients from the water very efficiently in Kibria and Haque, 2012.

The length-weight relationship of water spinach depends on the fertility of media from where nutrients are supplied. The plant's length-weight relationship is attributed to a variety and concentration of nutrients, of which nitrogen is the dominating factor. Waste water of stinging catfish ponds supplied various nitrogenous components of which ammonia has considerable fertilizing supports to the plant under floating condition on the pond surface efficiently (Kibria and Haque, 2012).

Results and Discussions

The Aquaponics Feasibility Results are key profitability ratios and indices that have been calculated from reports and tables attached to the program. These include the following:

- Net Present Value (NPV): This is the discounted value of the ten year cash-flow stream. The NPV will depend on the discount rate (which is entered in the bio-economic variables input table); the value is usually equal to the current rate of interest.

- Internal Rate of Return2: The Internal Rate of Return (IRR) is the discount rate that equates the present value of net cash flows with the initial outlay. It is the highest rate of interest an investor could afford to pay, without losing money, if all of the funds to finance the investment were borrowed, and the loan was repaid by application of the cash proceeds as they were earned. Conventional projects involve an initial outlay followed by a series of positive cash flows. In this case, if the IRR is higher than the required rate of return then the NPV is positive.

- Benefit Cost Ratio: Instead of showing the NPV as an absolute amount, the benefit cost ratio relates the present value of cash flows to the initial outlay. If the ratio (sometimes called the profitability index) is greater than one, then the project is acceptable.

- Profit Margin (PM): Profit Margin is the sales return before interest. The Profit Margin is equal to the Net Income (NI) before interest {NI + after tax interest expense (ATI)} (averaged over 10 years) divided Revenue (averaged over 10 years). This ratio indicates the percentage of sales revenue that ends up as income. It is a useful measure of performance and gives some indication of pricing strategy or competitive intensity.

- Asset Turnover (AT): The Asset Turnover is equal to Revenue divided Total Assets (applicable to the year of the ten year production cycle). This ratio relates to the farm's dollar sales volume to its size, thereby answering the question, "How much volume is associated with a dollar of assets?". This ratio tends to move in the opposite direction to the Profit Margin. Companies with high turnover tend to have low margins, and those with low turnover tend to have high margins.

• Return on Total Assets (ROTA): This is the operating return, which indicates the company's ability to make a return on its assets before interest costs. ROTA equals Profit Margin (PM) times Asset Turnover (AT).

• Debt to Equity Ratio (DER): This relates ratio reveals the extent of debt that is part of the venture's financing. The ratio equals Liabilities divided by Equity (Owners investment contribution plus the value of assets already owned that are used for the venture plus retained earnings).

• Leverage Return: Measure the relationship between borrowings and equity. Financial leverage is measured by the Debt to Equity Ratio times {Return on Total Assets (ROTA) minus the Average Interest Rate after Tax (IN)}. The Average Interest Rate After Tax (IN) is equal to the After-tax Interest Rate Expense (ATI)

divided by Liabilities.

• Return on Equity (ROE): This is equal to Return on Total Assets plus Leverage Return. The company's return is made up of returns from operations and from borrowed funds. If there is a positive difference between the operating return and the cost of borrowing, a company may take advantage of this difference via using leverage to enhance its returns by borrowing relative to the owner's equity base.

• Hasegawa Index: The Hasegawa index is a convenient way to obtain an indication of the profitability of an aquaponics venture (given that detailed economic data may not be available). This index compares the ratio of the selling price and the price of feed to the ratio of the conversion ratio and the ratio of feed cost to total costs.

• Contribution to Overhead (CTO): CTO is the portion of revenue from each unit of sale that remains after variable costs are covered.

• Cost per Kilo: The cost per kilo of fish is equal to current costs (minus depreciation) divided by total production (tones).

Cash Flow Statement 3

The Cash Flow Statement shows the calculated Closing Cash Balance over the ten year cycle. This balance is assumed to be reported as cash in hand after each period, and can be used to reduce debt faster, buy more capital equipment or place in special savings portfolios such as a superannuation fund

Financial Ratios Module

This module details the Assets and Liabilities over each of the ten years. By inserting the Year number at the top of the screen, the accounts will change depending on the depreciation and liabilities.

The financial ratios calculated from this are:

• Profit Margin
• Asset Turnover
• Equity
• Return on Total Assets
• Debt to Equity Ratio
• Leverage Return
• Return on Equity.

Equity is calculated by subtracting total liabilities from total assets. It is calculated in the profit linkage model in a different way to show how the accounts interact.

Trading Results

The Trading Results Report summarizes the Assets/Liabilities and the resulting (Loss/Surplus) or equity and the trading results. This module is used to calculate the Cash Available for Debt Service (CAFDS) Ratio, which is used by financial institutions to determine the capacity of a proposed business to cover loan repayments. Financial institutions have certain performance measures that are used to determine the eligibility for a financial loan. For example, a bank may require that the minimum interest cover is a CAFDS which is twice the amount of an interest repayment. Equity is defined as the owner's capital investment for setup capital costs and the value of any assets contributed to the venture4.

Volume Cost Analysis

This system module shows a breakdown of Fixed and Variable Costs and calculates the following major indicators:

- Contribution to overheads
- Breakeven Volume

Profit Planning module is included to assist the farmer in determining what volume (sales) is required to attain a particular gross profit.

Fixed Cost module is included to assist the farmer in determining the amount of additional sales required to cover an addition to fixed costs (e.g. a new pump).

Variable Cost module has been included to determine the impact of expected inflation and its impact on variable cost.

Profitability Linkage Model

This screen shows how Return on Equity (ROE) is calculated. The calculations take into account the following data from the various accounts:

- Net Income
- Total Assets
- Total Liabilities
- Equity
- Return on Total Assets
- Debt to Equity Ratio
- Leverage Return

Print out Reports

Entrepreneurial management model produces a general report which summaries the farm scenario outlined in the assumptions laid down. Reports and graphics include:

- Consolidated Report
- Bio-economic variables
- Profit and Loss Account
- Financial Ratios (Assets and Liabilities)
- Trading Results (Cash available for Debt Service)
- Cash Flow Account
- Internal Rate of return Analysis
- Volume Cost Analysis
- Profitability Linkage Model (Return on Equity)
- Capital Start up Payback Period Bar Chart
- Current Costs Pie Chart
- Fish Tonnage Chart

Conclusions

The flower of Lophantus Anisatus blooms for a long period of time, about 5-6 months, from June until the coming of frost that is October to November. In the second year of development it blooms even 10-15 days earlier.

Developing an accurate and practical tool to predict plant and fish growth and monitor nutrient concentrations in water, will improve the adoption and implementation small or commercial scale of aquaponic systems as urban farming or as a business model for household food security.

Acknowledgment

Project H2020-MSCA-RISE-2014 No. 645691: Researches on the potential conversion of conventional fish farms into organic by establishing a model and good practice guide.

BILIOGRAPHIC REFERENCES

Adler, Harper, Wade, Takeda & Summerfelt. (2000). Economic analysis of an aquaponic system for the integrated production of rainbow trout and plants. International Journal of Recirculating Aquaculture. 1(1): 15-34.

Bhatnagar & Devi. (2013). Water quality guidelines for the management of pond fish culture. International Journal of Environmental Science, 3: 6.

Boutwelluc, Juanita. (2007). "Aztecs' aquaponics revamped". Napa Valley Register.

Diver, Steve. (2006) "Aquaponics — integration of hydroponics with aquaculture" (PDF). ATTRA - National Sustainable Agriculture Information Service (National Center for Appropriate Technology). www.backyardaquaponics.com/guide-toaquaponics/fish

Francis-Floyd R, Watson, Petty & Pouder 2(009). Ammonia in aquatic systems (Univ. Florida, Dept. Fisheries Aquatic Sci., Florida Coop. Ext. Serv. FA-16), <http://edis.ifas.ufl.edu/FA031>. Date of Access 01 January, 2015.

Graber & Junge. (2009). Aquaponic Systems: Nutrient recycling from fish wastewater by vegetable production. Desalination, Volume 246, Issue 1:147-156.

Hoekstra & Chapagain. (2007). Water footprints of nations: water use by people as a function of their consumption pattern, Water Resources Management 21(1): 35–48.

Kibria & Haque. (2012). Integrated Multi-Trophic Aquaculture (IMTA) Systems in Freshwater Ponds in Bangladesh: Initial Understanding. Department of Aquaculture, Bangladesh Agricultural University, Mymensingh, Bangladesh.

Lal R, (2013). Beyond Intensification. In: Paper presentation at the ASA, CSSA, & SSSA international annual meetings, Tampa, Florida, USA.

Liang & Chien (2013). Effects of feeding frequency and photoperiod on water quality and crop production in a tilapia–water spinach raft aquaponics system. International Biodeterioration and Biodegradation, Volume 85: 693-700.

Mekonnen & Hoekstra. (2012). A global assessment of the water footprint of farm animal products. Ecosystems, 15(3), 401-415.

Mizanur, Yakupitiyage & Ranamukhaarachchi. (2004). Agricultural use of fish pond sediment for environmental amelioration. Thammasat International Journal of Science and Technology, 9(4):1-12.

Munteniță, Bria, Eni, Cîrciumaru & Graur. (2016). Physical characterization of nano-ferrites modified epoxy resins, Materiale Plastice, Vol. 53, nr. 3, pp. 509-511, ISSN 0025/5289, September.

Rakocy, Masser & Losordo. (2006). Recirculating aquaculture tank production systems: aquaponics-integrating fish and plant culture. SRAC , Volume 454: 1-16.

Rakocy. (1999). Aquaculture engineering – the status of aquaponics, part 1. Aquacult. Magaz, 25(4): 83-88.

Rogosa, Eli. (2013). "How does aquaponics work?". Retrieved April 24

Salam, M.A., (2012) Raft Aquaponics for sustainable fish and vegetable production from high density fish pond. 5th Bi-annual Fisheries Conference and Research Fair 2012, Bangladesh Fisheries Research Forum, 18-19 January, 2012 at BARC, Dhaka.

Shoko, Limbu, Mrosso & Mgaya. (2014). A comparison of diurnal dynamics of water quality parameters in Nile tilapia (Oreochromis niloticus, Linnaeus, 1758) monoculture and polyculture with African sharp tooth catfish (Clarias gariepinus, Burchell, 1822) in earthen ponds. Aquaculture Research, 6: 1-13.

Toufique & Belton. (2014). Is Aquaculture Pro-Poor? Empirical Evidence of Impacts on Fish Consumption in Bangladesh, World Development, 64: 609-620.

Tyson,Treadwell & Simonne. (2011). Opportunities and challenges to sustainability in aquaponic systems. Horttechnology, Volume 21, Issue 1: 6-13.