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Food safety, economics and environmental impacts of aquaponics in Iowa

Allen Pattillo
Iowa State University, pattillo@iastate.edu

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Abstract
Aquaponics offer promise as an alternative crop and protein production system for smaller farm operations. This project examined several aspects of aquaponic production: food safety, how UV treatments might mitigate food safety issues, what levels of profitability might be attained, and what the environmental impacts are for aquaponics operations.

Keywords
aquaculture, economic impacts, fruits and vegetables

Disciplines
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FOR SUSTAINABLE AGRICULTURE

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Abstract:

Aquaponics offer promise as an alternative crop and protein production system for smaller farm operations. This project examined several aspects of aquaponic production: food safety, how UV treatments might mitigate food safety issues, what levels of profitability might be attained, and what the environmental impacts are for aquaponics operations.

Principal Investigator:

D. Allen Pattillo
Natural Resource Ecology and Management

Co-investigators:
Angela Shaw
Food Science and Human Nutrition

Kurt Rosentrater
Agricultural and Biosystems Engineering

Linda Naeve
Dan Burden
Value Added Agriculture
Iowa State University

Budget:
$48,750 for year one

Q1) Can aquaponics be profitable in Iowa?
2) Is aquaponics truly environmentally friendly?
3) What food safety threats are there for aquaponics, and how can we mitigate them?

CROSS-CUTTING

A The PIs approached these questions by building six research-scale aquaponics systems and evaluating the resource use and production yields from these systems. Using that production, the team modeled what a scaled-up system would look like and evaluated it for economic efficiencies through a techno-economic analysis (TEA) and life cycle assessment (LCA). The results indicated there is hope for profitability at a commercial scale.

Background

Aquaponics is an environmentally friendly agricultural practice that involves the cultivation of crops in a non-soil medium (known as hydroponics) by feeding the plants with nutrient-rich water from intensively cultured aquatic organisms such as fish (i.e., aquaculture). Benefits to aquaponic crop production include increased plant growth rates, smaller production footprint than soil, reduced water resource inputs, and reduction of plant pathogens.

Aquaponics can be implemented using low-cost materials, which keeps capital overhead modest making it more attractive for small farm adoption. Also, the multiple crops produced in an aquaponics system (plants and fish) allow small-scale family farmers to diversify their incomes, which reduces risk of crop failure and increases revenue by providing products for multiple markets. There is tremendous potential to increase economic, social, and environmental sustainability of Iowa agriculture through aquaponics. However, there has been little research conducted for aquaponics in Iowa.

This project assessed the potential for these systems to transmit bacterial contamination into fish and vegetative tissues, as well as the production economics of aquaponics systems, including capital equipment and facilities requirements, energy systems, water systems, and other operational expenses. These types of assessments are required because data regarding food safety, economies of scale, and facility/energy dynamics do not exist for aquaponics systems. Because the plants utilize fish effluent within a closed system, aquaponic food production should be more sustainable and environmentally friendly than many other livestock or agricultural production systems. But winters in the Midwest United States will require high energy consumption to maintain proper environmental conditions.

A student swabbing a fish grown in a research-scale aquaponics system for analysis of potential disease -causing microbes. (Photo courtesy Allen Pattillo)

Objectives for the project were to:

- Determine food safety status and efficacy of UV sterilization as a food safety intervention for aquaponics in Iowa.
- Perform a techno-economic analysis for an aquaponics system in Iowa.
- Determine environmental impacts of an optimized aquaponics system in Iowa.

Approach and methods

The aim of this study was to determine the food safety status and the effectiveness of ultraviolet sterilizers as a food safety intervention in a model aquaponic unit that is growing lettuce, basil and Barramundi. Growth characteristics for Barramundi were assessed with respect to increased length, weight, growth efficiency, as well as survival when grown in conjunction with high-value crops (such as basil, lettuce, or other leafy greens). Crop production was checked for biomass growth, yield and composition, as well as nutrient deficiencies, nutritive value, and moisture content. Growth parameters for fish and plants were collected bi-weekly. Dissolved oxygen, pH, temperature and specific conductance data were collected daily from the recirculating water supply. Total ammonia nitrogen, nitrate, and nitrite data were collected twice weekly, while total water nutrient data were collected weekly. Consumptive input data collected continuously was used to conduct a techno-economic analysis (TEA) and Life Cycle Assessment (LCA) of all culture scenarios. Upon harvest, at the end of a predetermined culture period, the fish and plants were weighed and sacrificed for nutrient analysis. The collected data was analyzed for significant differences in growth, nutrient utilization, and consumptive inputs via repeated measures ANOVA ($a=0.05$), and relationship correlations between fish and plant species were evaluated to determine optimized growth parameters. This data was used to evaluate the economic feasibility of aquaponics for potential producers in Iowa.

Results and discussion

Samples were collected throughout the 118-day production period and microbial analysis was conducted for the presence of *E.coli* O157:H7 and *Salmonella spp.* and the prevalence of aerobic plate counts, coliforms, and fecal coliforms in the systems in triplicates. A significant increase was observed in microbial counts over the trial period, in the presence and absence of ultraviolet (UV) treatment. UV sterilization did not significantly reduce the aerobic plate counts, coliform, and fecal coliform counts when compared to the control systems samples.

Also, the aquaponics system and protocols used for this project did not create conditions conducive to utilizing ultraviolet sterilization as a food safety intervention. Although untested, the researchers suspect that improved water filtration will greatly reduce potential pathogens in the system. Though the UV intervention method was not effective in reducing microbial presence, future work should focus on improving the unit design and other food safety interventions that can be effective in the presence of living system while maintaining fish homeostatic environment.

Lettuce samples collected from a research-scale aquaponics system for analysis of potential disease-causing microbes. (Photo courtesy Allen Pattillo)

In this study, both LCA and TEA of a tilapia and basil aquaponic system were conducted. Three scales, including a truly running system, pilot scale, and commercial scale of aquaponics were considered and analyzed. When the system is maintained properly and is in a balance status, aquaponics will mimic the natural ecosystem, use much less water than traditional aquaculture, and have almost no effluent. As a result, it is thought to be more environmentally friendly and sustainable.

This study also showed that the operating scale and basil price had obvious effect on profits. When the scale was large enough, such as with the grow bed area of 75.6 m2 and when the basil price equals or is greater than $60/kg, operating an aquaponics system was profitable.

Conclusions

Presence and abundance of potential food pathogens were evaluated in the fish, plants, and water of the aquaponics systems. Three systems were run with ultraviolet (UV) irradiation and three without to assess the impacts of this intervention method on reducing potential pathogens. Results suggest that no human pathogens (*E. coli* or *Salmonella*) were present in the aquaponics systems and produce; however, some bacteria cultures were present and UV usage had no detectable effect in this system. Additionally, many potential pathogens were not evaluated, thus this research needs to be continued.

The food safety project revealed that, although *E. coli* and *Salmonella* are likely not major threats to aquaponic food safety, there are concerns with other potential food pathogens. Also, the aquaponics system and protocols used for this project did not create conditions conducive to utilizing ultraviolet sterilization as a food safety intervention. Further research is needed to refine the system and identify an effective kill step for potential food safety pathogens.

The LCA and TEA models revealed that small-scale aquaponics is not likely to be a profitable business. However, due to efficiencies in economies of scale, larger systems seem to have some promise for creating an economically viable aquaponics business. Basil price is the single most influential factor in determining whether an aquaponic business is profitable, therefore high-yielding niche marketing is recommended. Further research is needed to refine the results and create economic models for species other than tilapia and basil..

Impact of results

Over the grant period, 20 aquaponic-related outreach activities were conducted reaching over 600 participants from Iowa, the Midwest and beyond. Results have been shared with partners in ISU Extension, the North Central Regional Aquaculture Center (NCRAC), various current and potential aquaponic producers, educators, students (from high school to college level including the World Food Prize students), community members, and state agencies. This project has been publicized outside of Iowa with other food safety extension specialists engaged with farm outreach efforts and who also have active farm to school programs and/or university research farms. Iowans can use the results of the project to educate their local schools, community gardeners, community colleges, and universities on safe handling of produce.

Education and outreach

Two ISU Extension fact sheets were prepared: an introduction to the practice and one related to food safety. Two publications are being prepared for peer-reviewed aquaculture journals.

Six informational videos were produced for ISU Extension (see https://www.youtube.com/playlist?list=PLyDHx-rmZpCljgr4za05H2eHKwmMhJYI1).

Eight presentations were given on the project results in Iowa and other states in 2014 and 2015.

The project was featured on Iowa Public Television's "Market to Market" program in July 2014.

Leveraged funds

Funding from this grant and other seed monies from the Leopold Center and donations from FarmTek were utilized for the "Biodome" display at Reiman Gardens from April to November 2014. "Biodome" had over 41,000 visitors and several news releases and televised pieces highlighting the potential of aquaponics as a method of food production in space.

For more information, contact:
Allen Pattillo
Natural Resource Ecology and Management
107 Science II
Iowa State University
Ames, IA 50011-3221
(515) 294-8616
e-mail:
Pattillo@iastate.edu