Discovery, The Student Journal of Dale Bumpers College of Agricultural, Food and Life Sciences

Volume 20 Article 5

Fall 2019

Greenhouse Aquaponics: Custom Aquaponic Systems at Home

Jesse L. Blanchard
University of Arkansas, drwizard856@gmail.com

David G. Hyatt
University of Arkansas

Jennie Popp
University of Arkansas

Leah English
University of Arkansas

Recommended Citation

Blanchard, Jesse L.; Hyatt, David G.; Popp, Jennie; and English, Leah (2019) "Greenhouse Aquaponics: Custom Aquaponic Systems at Home," *Discovery, The Student Journal of Dale Bumpers College of Agricultural, Food and Life Sciences*. University of Arkansas System Division of Agriculture. 20:*6-12*.
Available at: https://scholarworks.uark.edu/discoverymag/vol20/iss1/5

Greenhouse Aquaponics: Custom Aquaponic Systems at Home

Cover Page Footnote

* Jesse Blanchard is a May 2019 honors program graduate with a major in Agricultural Business. † David G. Hyatt is a faculty mentor and Clinical Assistant Professor in the Walton College of Business. § Jennie Popp is a thesis committee member and Associate Dean of the Honors College. ‡ Leah English is a thesis committee member and Technical Assistant II in Agri Economics and Business.

Greenhouse aquaponics: Custom aquaponic systems at home

Meet the Student-Author

Jesse Blanchard

Growing up on an equestrian farm with a range of explorable land having both terrestrial and aquatic life, I have always been interested in natural systems—especially below water. This is due in part to learning to fish as a child backpacking with my father, Mike, who continued to encourage this hobby and even landed me an internship opportunity on a fish farm at Bell Aquaculture while still in high school. With a combination of technical skills learned at home and from the Prairie Grove agricultural program paired with the new knowledge of fish farming operations, the ideas for small scale aquaculture began. I pursued an agribusiness marketing and management major with a minor in Sustainability at the University of Arkansas. These areas of study along with the opportunity to conduct funded research through the Honors College allowed me to construct and operate my first aquaponic system as a means of gaining research and physical experience in what I believe may be a possible future in producing fruits and vegetables. I would like to thank my thesis mentor, Dr. David Hyatt along with my committee members Dr. Jennie Popp and Leah English for guiding me through the research portion of this invaluable project. I would also like to give special thanks to Mike Blanchard, John Blanchard, and Alex Fisher for their help in constructing and improving the system and its greenhouse shell.

Research at a Glance

- Consumers nationwide are becoming more conscientious of where their food comes from and demand locally grown or environmentally friendly products.
- Aquaponic systems offer high-quality fruits and vegetables along with fresh fish proteins at home.
- "Do it yourself" (DIY) methods provide wide ranges of availability in production and aesthetic properties for all interested producers.

Jesse holding golden shiners from his aquaponic project on his family's farm in Prarie Grove, Arkansas.

Undergraduate Research Articles

Greenhouse aquaponics: Custom aquaponics systems at home

Jesse Blanchard, David G. Hyatt†, Jennie Popp§, and Leah English‡*

Abstract

Taking advantage of inherent natural systems, aquaponic practices hold the potential to serve as an educational, sustainable, and profitable hobby for home gardeners facing common constraints such as temperature, space, and pests. The goal of this research was to assess the feasibility of implementing a small scale (4542-L) home-based aquaponic system in a small (48.768 m^2) greenhouse to produce fresh produce and fish protein. System construction and maintenance costs were compared to the value of crops and fish produced to determine whether this aquaponic system is a feasible option for the home grower. It was hypothesized that this system would break even in five years. Results showed that such a system can be successfully built and operated to yield fresh produce, fish protein, and a high value composted fertilizer on an annual basis. However, the payback period for the system can be five years or even longer, depending on the estimation of future costs and benefits and discount rates used. Results and experience from the greenhouse system have been and will continue to be used for system improvements, education on natural systems, designs for others, as well as a guide for aquaponic systems moving forward.

---

[*] Jesse Blanchard is a May 2019 Honors program graduate with a major in the Department of Agricultural Economics and Agribusiness.

[†] David G. Hyatt, faculty mentor, research associate professor, Walton College of Business.

[§] Jennie Popp, professor, Department of Agricultural Economics and Agribusiness.

[‡] Leah English, technical assistant II, Department of Agricultural Economics and Agribusiness.

Introduction

Aquaponics can be defined as "the cultivation of fish and plants together in a constructed, re-circulating ecosystem utilizing natural bacterial cycles to convert fish wastes to plant nutrients" (Sawyer, 2010). This process is the combination of aquaculture and hydroponics which can be thought of as fish farming and soilless gardening, respectively. By first taking advantage of *Nitrosomonas* sp. bacteria in order to convert the ammonia from fish waste into nitrites (NO_2) aerobically and then into nitrates (NO_3) with *Nitrobacter* sp. bacteria, the ammonia which is toxic to fish is efficiently converted into a readily available solution for healthy plant growth (Backyard Aquaponics, 2012).

The goal of this research was to assess the feasibility of implementing a small-scale, home-based aquaponic system to produce fresh produce and fish protein. System construction and maintenance costs were compared to the value of crops and fish produced to determine whether this aquaponic system is a feasible option for the home grower. It was hypothesized that this 4542-L system would break even in five years.

Materials and Methods

System Design

Unlike James Rakocy and a team at the University of the Virgin Islands who constructed what is regarded as the first successful commercial system, much of the aquaponic world revolves around "do it yourself" (DIY) style builds (Rakocy, 1989). An online search yields abundant sources for custom designs that the average person with a few minor technical skills in construction and plumbing can manage. For this project, the greenhouse system was designed completely from DIY methods devised and implemented on the go, in order to add the crops desired by the family (Michell, 2019).

The greenhouse system included: the construction of both a small (48.768 m^2) greenhouse (Fig. 1) as well as a 4742-L aquaponics system: one 2271-L lined sump tank below ground, one 1135-L and one 378-L Rubbermaid water troughs as fish tanks, three 208-L drums cut in half with bell siphons and filled with pea gravel, 7.62 m of 7.62 cm PVC with pea gravel-filled net pots, and one 0.914 × 2.438-m lined wooden box with Styrofoam rafts

Fig. 1. Greenhouse structure with horse manure compost heater and raised garden beds for transplanting larger plants.

complete with pea gravel-filled net pots. This system was completed in approximately 55 man-hours total between three people from March through June 2018.

The sump tank acted as the lowest point in a system where water is pumped up from and returned to by gravity. The sump tank received oxygen from an air pump via air-stone as well as mesh bags filled with expanded clay to serve as surface area for the nitrifying bacteria to convert ammonia into nitrates. Fifteen young bluegill perch and pond snails caught from the landholder's pond were put into the covered sump to aid in breaking up solid waste accumulation on the bottom as well as to consume any mosquito larva present.

From the sump tank, nutrient-rich water was pumped up to six half 208-L barrels filled with pea gravel before exiting through bell siphons. These media-filled growbeds were used to grow crops that required deeper root systems to hold up their stalks while also serving as a water oxygenation method (Fig. 2). Water fills the tank until it reaches the top of the standpipe where it creates a siphon that rapidly drains water out of the media down to the break in the bell. This ensured that the plants did not become oxygen-starved and flooded as each growbed filled with water and drained every 20 to 30 minutes.

After flowing through the standpipes, the water drained into the 1135-L primary fish tank stocked with 130 tilapia purchased from the Tilapia Depot (Tilapia Depot, 2019). This simple tank received a similar air-stone as the sump tank to provide oxygen to the fish along with a PVC and Styrofoam cover to prevent the fish from jumping. Here, the water flow split into two paths: one pumped up to 7.62 cm PVC pipes for a continuous flow growth method, and the other overflowed into the lined Styrofoam raft system. The continuous flow pipes resembled an overhead square with holes containing pea gravel-filled net pots on the top before draining down into the 378-L fish tank. Mesh wire was stapled around the PVC square to offer growth room for cucumber and watermelon vines planted in the net pots. Although the 378-L tank was never used to house fish in the initial system, it worked as an added buffer in water volume before draining back into the sump via overflow.

Fig. 2. Bell Siphon housed in media filled drums with tomatoes, bell peppers, mint, and basil present.

Overflowing through a 2.54 cm PVC pipe from the 1135-L tank, the other water route flowed into a 15.24 cm deep lined wooden box with a standpipe overflow into the sump. Floating styrofoam rafts with holes cut out to place pea gravel-filled net pots for planting filled this box (Fig. 3). This section received the most nutrients as it was directly after the main fish tank and thus acted as a plant nursery where seeds were planted to be later transplanted into the bell siphon grow-beds. After transplanting the other crops, mint was allowed to take over this section to create a massive filter for the accumulating nutrients in the system.

System Maintenance

Overall, daily maintenance in the greenhouse system was minimal and included feeding fish, trimming plants, measuring water quality, and adding weekly approximately 227 L of water when evaporation rates were highest in late August. In year one, there were a few small leaks in the system that were repaired with silicone sealant. After initial cycling, the water parameters settled into the ranges of 7 to 9 pH and <1 ppm ammonia, nitrite, and phosphate. These fall within optimal ranges for tilapia (Michell, 2019). Finally, the addition of three purchased common pleco (*Hypostomus plecostomus*) which were utilized as algae and waste removers, ladybugs caught near the greenhouse for aphid control, and a local beehive for easy pollination drastically reduced additional maintenance needs of the greenhouse system.

Fish and Plant Production Systems

Initially, 130 tilapia were stocked in the system to grow. Once harvested, they were replaced with 3000 fingerling golden shiners (Anderson Minnows, n.d.). Additionally, nine fancy koi and 20 goldfish were added along with cattails, Salvinia, and other aquatic plants for aesthetics. The three common *Plecostomus* remained in the system for algae control. The fish waste was composted, and with

Fig. 3. Styrofoam raft nursery with tomatoes, basil, peppers, mint, lettuce, and watermelon seedlings present in gravel-filled plastic net pots.

the addition of worms could be transformed into valued vermicompost to be used in gardens.

Tomatoes, cucumbers, bell peppers, jalapeño peppers, watermelon, broccoli, rocket lettuce, squash, basil, and mint were grown from seed placed into the system in July 2018. Harvest began in late August with the leafy greens and early October for the fruiting plants. Harvesting continued until March 2019 when many of the plants were removed/relocated for remodeling. Even with cool temperatures, the greenhouse encasing the crops allowed production to continue throughout the winter and ripe tomatoes were even picked in March.

Cost-Benefit Analysis

A cost-benefit analysis was conducted using actual system expenditures and revenues for 2018 and projections of costs and revenues for six more years. Note that estimations on costs are likely slightly overvalued to account for unknown issues that could be caused by weather, unforeseen damages, and replacement of equipment. Following Adler et al. (2000), the net present value (NPV) of the project was examined using discount rates of 4%, 6%, 8%, and 10% to determine: 1) whether the project broke even within the expected time period, and 2) under what range of discount rates the results held.

Results and Discussions

Current and Future Cost and Revenue Projections

System expenses totaled nearly $8400 in 2018. Infrastructure and electricity needs topped the costs (Table 1). In future years, nominal costs are expected to fall greatly as infrastructure and most electricity needs (tied to tilapia production) are removed. Based on lessons learned in the first year, improvements to system design and a shift to cold-water-tolerant baitfish and fancy koi will be made to benefit the system and to lower utility costs from heating.

Ninety-six of the original 130 tilapia survived with an average length of 17.78 cm and were moved to a personal pond to grow out to 25 to 30 cm. At a price of $3.25 per pound, mature tilapia will have an estimated value of $144 (Walmart, 2019). The baitfish and composted fertilizer will provide $1400 in revenue annually in future years (The Home Depot, 2019).

Crops produced in 2018 included tomatoes, jalapeno peppers, bell peppers, yellow squash, mint, and basil. Based on retail prices of $2.39, $2.39, $5.99, $2.39, $14.00, and $7.99 per pound, respectively, total crop value was almost $695.00 (Walmart, 2019). The most successful plants were tomatoes, bell peppers, basil, and mint. The most robust crop, mint, yielded an estimated 20.5 kg within the first year.

Table 1. Estimated costs and values of production for the first six years of operation for the greenhouse system including improvements and added sources of valuable products planned in the coming years.

	Greenhouse system 6 year projection, nominal costs and benefits							
	2018[a]	2019	2020	2021	2022	2023	2024	Total 6 Years
Production costs in $								
Infrastructure	5296	-	-	-	-	-	-	5296
Labor	825	90	50	-	-	-	-	965
Management	30	30	30	30	30	30	30	210
Fish and plants	252	400	-	-	400	-	-	1052
Feed	150	150	150	150	150	150	150	1050
Electric utility	1693	420	420	420	420	420	420	4216
Water utility	46.80	50	50	50	50	50	50	347
Repairs	25	50	50	50	50	50	50	325
Improvements	120	400	100	-	-	-	-	620
Total	8391	1540	800	650	1050	650	650	13,733
Production benefits in $								
Crops	695	1100	1100	1100	1100	1100	1100	7295
Tilapia fillets	144	-	-	-	-	-	-	144
Baitfish	-	440	440	440	440	440	440	2640
Fertilizer	-	960	960	960	960	960	960	5760
Total	839	2500	2500	2500	2500	2500	2500	15,839

[a] Year beginning 1 July 2018.

Cost-Benefit Analysis

The net present value of the project was calculated based on actual and expected costs and benefits listed in Table 1. Based on these values, net present valued ranged from a high of $1001.34 (at a discount rate of 4%) to a low of -$1048.61 (at a discount rate of 10%) over the full period of the projected study. When the discount rate is 4%, the system breaks even during its fifth full year in operation, as expected. This break-even year result holds until the discount rate is increased to above 5.85%. This result is expected as higher discount rates require large benefits related to costs in the early years of a project while lower discounts place a higher value on benefits that accrue later in a project period.

Conclusions

This study showed that an aquaponics greenhouse system can be designed, installed, and maintained successfully in a home environment. Further, it can yield sufficient amounts of fresh produce and fish protein for a family to replace much of the purchasing needs for those items. The cost-benefit analysis showed that only under low discount rates (<5.85%) did the system break even after five full years of production. However, this analysis provides the "pessimistic results" as the cost-benefit analysis likely: 1) overestimated both current and future costs as the "learning curve" continues on operations, and 2) underestimated benefits as there was no "premium" estimated on the sale of local products, and benefit estimates did not consider the non-market benefits of the aesthetics provided by the systems aquatic environment.

While difficult to replicate exactly, the extreme versatility of system designs behind aquaponic systems allows any interested and dedicated person access to an exciting method for producing homegrown fruits and vegetables alongside decorative or harvestable fish. Despite not yielding as much as projected in the first year due to cold temperatures, the first-year experience suggested the beginnings of a solid aquaponics operation able to care for itself with only minor maintenance in the coming years. Results and experience from the operation will be used to further optimize the greenhouse system as well as design and implement similar systems to meet specific goals for produced items or styles.

Acknowledgements

This research was made possible through funding by an Honors College Research Grant and a Bumpers College Undergraduate Research and Creative Project Grant as well as the construction location provided by Cedar Springs Equestrian Center in Farmington, Arkansas.

Literature Cited

Adler, P., J. Harpe, E. Wade, F. Takeda, and S. Summerfelt. (2000). Economic Analysis of an Aquaponic System for the Integrated Production of Rainbow Trout and Plants. Int. J. Recirc. Aquacult., pp. 15-34.

Anderson Minnows. (n.d.). Golden Shiner. Accessed March 2019. Available at: https://www.andersonminnows.com/species3.php

Backyard Aquaponics. (2012). The Nitrogen Cycle. Available at: https://www.backyardaquaponics.com/information/the-nitrogen-cycle/

Brand, R. (2014). Common Pleco- The Care, Feeding and Breeding of Common Plecos. Aquarium Tidings.

Michell, B. (2019, January). The School of Aquaponics. Accessed March 2019. Available at: https://theschoolofaquaponics.com/

Rakocy, J. E. (1989). Tank Culture of Tilapia. Southern Regional Aquaculture Center.

Sawyer, T. (2010, November 15). The Definition of Aquaponics. Accessed 21 March 2019, from The Aquaponic Source. Available at: https://www.theaquaponicsource.com/blog/the-definition-of-aquaponics/

The Home Depot. (2019). TheHomeDepot.com. Accessed March 2019. Available at: https://www.homedepot.com/

Tilapia Depot. (2019, January 1). Blue Tilapia. Accessed June 2018. Available at: https://tilapiadepot.com/collections/blue-tilapia

Walmart. (2019). Walmart.com. Accessed March 2019. Available at: https://www.walmart.com/