Aquaponica: Home-Scaled Aquaponics Systems

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Abstract

Food insecurity is a growing problem across the world, but aquaponics provides a potential sustainable solution. Both the fish and plants can be harvested for food, and the system can be constructed with recycled materials. Leveraging the nitrogen cycle in a soil-less environment, the waste from fish provide essential nutrients for the plants, and this enables a recirculating aquaponics system.

The goal of this project was to ideate, design, and build an aquaponics system that is **small**, **sustainable**, **sufficient**, **simple**, and **affordable**. The design is estimated to be only $124.05 for an indoor system and $53.81 for an outdoor system when materials are recycled. Next steps will be to test and compare the performance of the systems, as well as develop a consumer aquaponics tutorial.

Background

As the world's population grows, demand for food increases, and there are finite land and water resources for food production. These and other factors (i.e. political conflict, adverse weather events, pollution, etc.) have contributed to food insecurity around the globe. In America, about 18 million households face food insecurity, according to the USDA in 2023. Imagine if someone, instead of going to the grocery store, could shop from their own house. We achieve this through small-scale *aquaponics*.

What is Aquaponics?

Aquaponics is a system in which fish are raised (aquaculture) in tandem with plants in a water-based, soil-less environment (hydroponics). The water and excrement from the fish provide essential nutrients for the plants, and when properly maintained, this creates an environment in which the fish and plants can thrive and provide both protein and vegetables. A recirculating aquaponics system recycles water, which limits water consumption and makes it an ideal choice for urban or water-insecure areas.

Maintaining water quality is paramount for survival of both the fish and the plants. Temperature and pH are critical, as fluctuations can stress or kill the fish and plants, and nitrogen balance must be maintained by use of nitrifying bacteria in a biofilter. Additional parameters include, but are not limited to, dissolved oxygen, turbidity (suspended solids), and stocking density (~3-5 gallons per 1 pound of fish).

System Parameters

For an aquaponics system to be feasible for any consumer, several conditions must be met:

- The system must be small enough for a house or apartment.
- It must be cheap enough to afford on a limited budget.
- It can be constructed with recycled and easy-to-find materials.
- It can produce sufficient food to supplement one's diet.
- It can be environmentally and economically sustainable by minimizing water consumption and recycling materials.

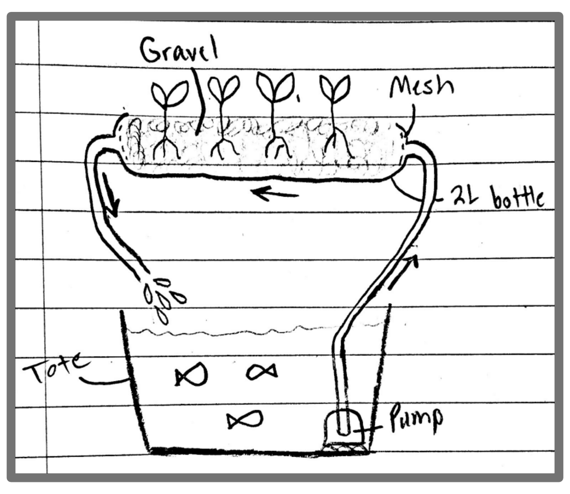

Figure 1.
Picture from the lab notebook of the indoor system, with a tote base and 2-liter bottle configuration.

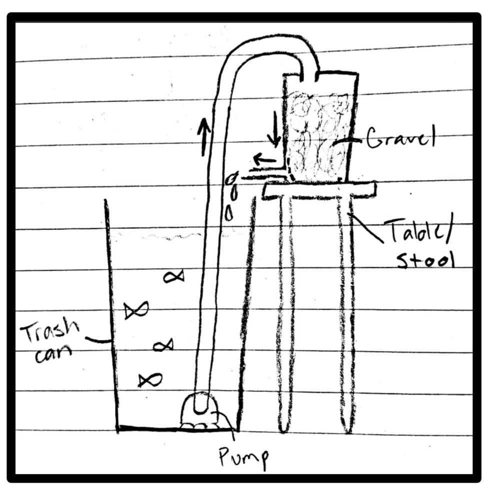

Figure 2.
Picture from the lab notebook of the outdoor system, with a trash can base and Styrofoam boat configuration.

Indoor Design

The indoor design focus was ease of use. Using an LED grow light and DIY gravel plant troughs, it eliminates the need for a separate biofilter, therefore minimizing space and resources.

Recycled Materials:
Tubing, gravel, 2-liter bottles, adhesive, cutting tools

Purchased Materials:
LED grow light(s), water pump, air pump, air stones, nitrifying bacteria, 55-gallon tote

Potential Limitations:
- Stagnant water zones at water inlet and outlet on troughs (root rot)

Issues in Testing:
- Gravel's resistance to water flow risked water overflowing from troughs.
  - Try a vertical or tilted system, so gravity pulls water through.

Outdoor Design

The outdoor design focus was cost effectiveness. Using natural sunlight and DIY plant boats, it recycles trash Styrofoam and containers to save on costs.

Recycled Materials:
44-gallon trash can, 5-gallon bucket, gravel, cutting tools, Styrofoam, tubing, sponge

Purchased Materials:
Water pump, air pump, air stones, nitrifying bacteria

Potential Limitations:
- Limited lateral swim space for fish
- Limited space for plants

Issues in Testing:
- Smaller Styrofoam boats were subject to capsizing.
  - Use one large raft with holes for roots.
- Higher biofilter placement requires a stronger pump.

Figure 3.
Picture from testing the indoor system, with the trough tilted and supported

Figure 4.
Picture from testing the outdoor system, with large boats and a covered biofilter

Results

The estimated cost of the indoor system in Figs. 1 and 3 is **$123.05** when recycled and **$137.83** when purchased. The estimated cost of the outdoor system in Figs. 2 and 4 is **$53.81** when recycled and **$132.13** when purchased.

Next Steps

Additional work is needed on this project. Future goals include:
- Performing water quality assessments on the systems
- Comparing the yields between indoor and outdoor systems
- Statistically determining based off yields whether either system can amply supplement one's diet
- Analyzing energy and water consumption
- Developing an aquaponics tutorial (including fish filleting)

The expected outcomes of these goals are:
- Consumers gain knowledge of aquaponics.
- Consumers understand which system is better for their lifestyle.
- More fish and vegetables produced at a household level.

We hope this work will contribute to improving local food systems and increasing food security.

References and Acknowledgements

USDA. (2025, January 8). *Food security in the U.S. - Key Statistics & Graphics | Economic Research Service*. https://www.ers.usda.gov/topics/food-nutrition-assistance/food-security-in-the-us/key-statistics-graphics#foodsecure

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