Aquaculture

Building and Caring for a Miniature Aquaponics System

INTRODUCTION

Aquaponics is a method of sustainable agriculture that uses the symbiotic relationships between fish, beneficial bacteria, and plants to grow food. Iowa State University has conducted research and extension programs on aquaponics for several years, evaluating production methods, plant and fish species, lighting technology, food safety, economic feasibility, and sustainability. Although this research has advanced the aquaponics industry as a whole, the cost of the systems and the newness of the technology presents challenges for adoption by the general public. Therefore, a small-scale system was devised that could meet the needs of the public and be used to increase awareness of the aquaculture industry.

A miniature aquaponics system can serve as a learning tool for hobbyists, educators, and potential commercial producers. Because aquaponics is a self-contained ecosystem in which each of the components are co-dependent, there are opportunities to learn about the complex natural processes that occur in the environment. These systems provide an opportunity to improve student involvement in the science, technology, engineering, and math (STEM) fields by providing a model system for interactive learning.

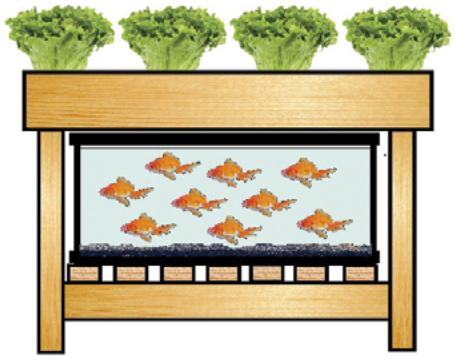

Figure 1. Concept of miniature aquaponics system.

Figure 2. Miniature aquaponics system.

The miniature aquaponics system described in this publication was built using readily available and cost-effective materials to promote adoption by the general public. This benchtop system is fully functional, and can be used to produce food and learn the aquaponics production concepts that can be scaled-up to larger, more robust systems, thereby advancing public education and adoption of sustainable aquaculture practices.

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IOWA STATE UNIVERSITY
Extension and Outreach

BUILDING A MINIATURE AQUAPONICS SYSTEM

MATERIALS NEEDED:

1. 1, 12-gallon clear tote with hinged lid
2. 1, black polypropylene bus tub
3. 1, 80 GPH submersible water pump
4. 1, indoor 24-hour outlet timer
5. 1 foot, 5/8" O.D. PVC clear vinyl tubing
6. 1, hydroponics fitting kit with adapter
7. 1.5 cubic feet, clay pebbles (may be supplemented with lava rock)
8. Seeds of choice (leafy greens or herbs preferred)
9. 5, 1-3 inch goldfish (or freshwater fish of choice)
10. Fish food
11. 10 gallons of water
12. Water conditioner

OPTIONAL MATERIALS:

1. Growing lamp
2. Light stand or hanging brackets
3. Tank stand
4. Aquarium heater

Figure 3. Required building materials. (Photo credit: Shelly O'Neal, Linn County Extension)

Figure 4. Cutting access holes. (Photo credit: Shelly O'Neal, Linn County Extension)

TOOLS NEEDED:

1. Cordless drill with adjustable bit
2. Power extension cord
3. 2 inch hole saw
4. 1 inch drill bit or hole saw (sized to match hydroponic fittings)
5. Reciprocating saw, jig saw, or hack saw
6. Box cutter blade or knife
7. Measuring tape or ruler
8. Marker

HOW TO BUILD IT:

STEP 1: CUT HOLES FOR PLUMBING IN LID OF BOTTOM TOTE

1. Using the 2 inch hole saw, cut two holes in each lid flap of the bottom tote.
2. Holes should align with the large squares in the plastic lid grid at one end of the tote.
3. These plumbing holes will allow access for the hydroponic fittings in the top tote.

STEP 2: CUT SMALL ACCESS DOOR IN LID OF BOTTOM TOTE

1. Place the top tote crosswise on the bottom tote over the plumbing holes cut in Step 1.
2. Use a marker to draw a straight line across one of the lid flaps from the center crease to the hinge.
3. Using a saw, cut along the line until the access door swings independent of the rest of the lid.
4. Use a flat piece of metal or knife to scrape off the excess waste material from the cut.

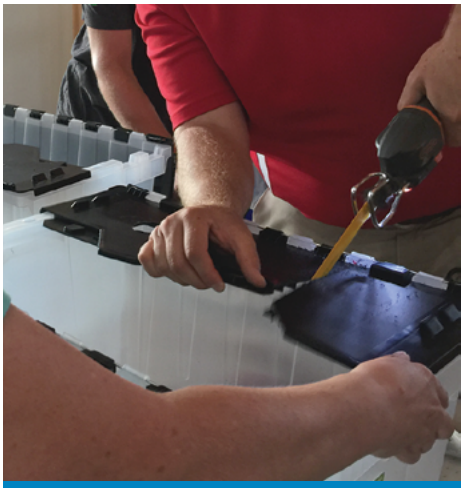

Figure 5. Cutting access door. (Photo credit: Shelly O'Neal, Linn County Extension)

Figure 6. Drilling holes for hydroponic fittings. (Photo credit: Shelly O'Neal, Linn County Extension)

Figure 7. Assembled hydroponic fittings. (Photo credit: Shelly O'Neal, Linn County Extension)

STEP 3: MARK AND DRILL PLUMBING HOLES IN BOTTOM OF TOP TOTE

1. With the top tote in position over the top of the plumbing holes, use a marker to mark the hole positions on the bottom side of the top tote.
2. Flip the top tote over and ensure the circles are visible and in the flat portion of the tote's bottom surface.
3. Mark an "X" across the diameter of the circles just marked to find the center point.
4. Use the 1 inch drill bit to cut through the top tote in the locations marked by the "X". Do not to drill too quickly or carelessly, the holes should be a perfect circle to prevent leakage around the plumbing seals.

STEP 4: ASSEMBLE HYDROPONIC FITTINGS IN TOP TOTE

1. Remove the hydroponic fittings from their packaging and disassemble the fittings.
2. Insert the fitting ends with the strainers and rubber gaskets on the inside of the top tote. The fit should be tight, and may require threading them in.
3. Thread on the nuts of each respective fitting and hand tighten.
4. The nipple and open ends of the hydroponic fitting should be on the bottom side of the tote, and should match up with the plumbing holes cut in Step 1.

STEP 5: CONNECT PLUMBING TO THE SHORT HYDROPONIC FITTING NIPPLE AND INSTALL THE WATER PUMP IN BOTTOM TOTE

1. Using a ruler, mark a nine-inch length of 5/8 inch diameter tubing, and cut it at 90 degrees straight across. This length of tubing should be appropriate to connect the pump to the hydroponic fittings in a straight line; adjust accordingly.
2. Attach the tubing to the short hydroponic fitting by sliding the tubing over the nipple.
3. Align top tote on top of bottom tote and insert the tubing through one of the plumbing holes.
4. The bottom section of tube will attach to the pump using the appropriate size nipple attachment.
5. Place suction cups to the bottom of the pump and attach the pump to the bottom of the bottom tote.

Figure 8. Installed hydroponic fittings. (Photo credit: Shelly O'Neal, Linn County Extension)

Figure 9. Pump attached to tubing. (Photo credit: Shelly O'Neal, Linn County Extension)

STEP 6: INITIAL SET-UP

1. This system will be heavy when it is installed. Start by placing the bottom tote in a sturdy location that can get wet, and can support up to 100 pounds. Ensure that this location is easy to access for maintenance and has access to electricity for the pump and supplemental lighting.
2. Reassemble the top tote on the bottom tote, connect the pump and tubing.

Figure 10. A system with a supplemental light. (Photo credit: Phillip Pfister, Linn County Master Gardener Program)

STEP 7: RINSE CLAY PEBBLES AND ADD THEM INTO THE TOP TUB

1. The clay pebbles are covered with dust that will make the water murky. The pebbles should be rinsed with water before being added to the top tote. Flush them with water until the outflowing water runs clear.

Figure 11. Growbed media. Lava rock (left) and pebbles (right). (Photo credit: Shelly O'Neal, Linn County Extension)

2. Make sure the hydroponic fittings and strainers are secure before adding the pebbles. Once the pebbles are added they may clog uncovered pipes.
3. If using multiple types of rocks (e.g. lava rocks and clay pebbles), add the large rocks first, then top dress with the smaller pebbles.

STEP 8: ADD WATER TO THE SYSTEM, START THE PUMP, AND SET THE WATER LEVEL

1. Pour approximately 10 gallons of clean water into the bottom tote.
2. Plug in the pump and watch to make sure the top tote fills with water and drains properly.
3. The water level in the top tote should be about 1/2 inch below the top layer of rocks. Too much water can make the seeds rot. Too little water will prevent them from germinating. Depending on the type of hydroponic fitting used, either the height of the fitting or the height of the rocks can be altered.
4. Plug the pump into the timer, making sure the timer is set to turn on and off every 30 minutes.

STEP 9: ADD WATER CONDITIONER

1. Tap water does not provide a healthy environment for fish so it must be treated before fish are added to the system. To do so, fill the container with approximately 10 gallons of room temperature tap water. Add the appropriate amount of water conditioner (required for city water) and bacterial supplements (optional) for 10 gallons of water as described on the bottle.
2. Fish should not be added immediately, because the biofilter is not yet established. If fish are added immediately, the water should be exchanged at two gallons per day for the first two weeks. Fish should not be fed for the first week, with limited feeding for the first month. Follow the feeding directions provided on the fish feed packaging for further instruction.

STEP 10: SOW THE SEEDS

1. Add the seeds to the top container according to the directions on the seed package. Generally, leafy greens and herbs should be sprinkled on top, and larger vegetable seeds should be sown at a depth of 1-2 inches.
2. Seeds should begin germinating within the first week for most plants. Smaller seeds tend to germinate faster than large seeds.

STEP 11: ESTABLISH THE BIOFILTER

1. The biofilter is made of beneficial bacteria that grows on the pebbles in the top tote and on the sides of the tank. This bacteria performs the critical job of converting toxic chemical into plant food. Beneficial bacteria takes 2-6 weeks to establish. Adding water or gravel from an established aquarium can help speed up the process.
2. Small amounts of fish feed in the water every couple of days will give the beneficial bacteria what they need to grow. Add a pinch of fish food 2-3 times per week for the first month, prior to adding fish.

Table 1. Water quality recommendations.

Dissolved Oxygen (mg/L)	pH	Temperature (°F/°C)	Ammonia (mg/L)	Nitrite (mg/L)	Nitrate (mg/L)
> 5.0	6.5-7.0	70-80 / 21-27	< 0.1	< 0.1	> 40

3. Excess fish food degrades water quality for fish. Remove any excess feed 15 minutes after feeding if fish are present. If no fish are present, clean the feed out twice per week to prevent fungus from growing.
4. Monitoring water chemistry is the only way to know if the biofilter is established. Once low levels of ammonia and nitrite and high levels of nitrate are measured, then the biofilter is functioning and fish can be safely added.

STEP 12: MONITOR WATER QUALITY

1. Dissolved oxygen, pH, temperature, ammonia, nitrite, and nitrate are all important water chemistry factors that affect the plants, fish, and bacteria in an aquaponics system. It is important to monitor them just as they would be in an aquarium. Table 1 defines the ideal ranges for each of these water quality components. See ISU Extension and Outreach publication "Water Quality Management for Recirculating Aquaculture" (FA 0003A) (https://store.extension.iastate.edu/product/14271) for more detailed information.
2. Water chemistry test kits can be purchased at a local pet store or online. Follow the manufacturer's instructions to obtain the levels for each parameter.
3. Be sure to record track measurements over time. Changes in water chemistry trends can help monitor progress and predict issues before they arise. Create a data log or use one available online. One example can be found in ISU Extension and Outreach publication "Water Quality Management Monitoring Sheet" (FA 0003C) (https://store.extension.iastate.edu/product/14273).

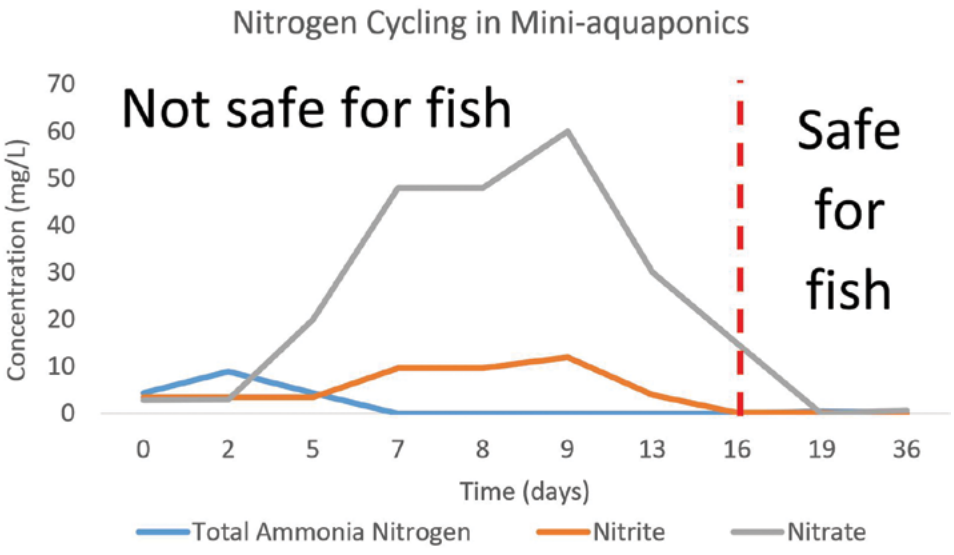

Figure 13. Nitrogen cycling timeline.

Figure 14. Commercial water chemistry kit.

STEP 13: ADD FISH TO THE SYSTEM

1. Fish should be added after the biofilter has been established to prevent unnecessary losses due to poor water chemistry. It is typically safe to add fish after the system has been cycling four weeks or more.
2. When choosing fish to add into an aquaponics system, make sure they are healthy. Look for erratic swimming behavior, sores or lesions, bulging eyes, and external parasites. Even fish that appear healthy can be carriers of disease and become sick once they become stressed in the transport process. Even with the best handling methods, fish may still die—don't be discouraged! More information can be found in ISU Extension and Outreach publication "Fish Health Considerations for Recirculating Aquaculture" (FA 0001A) (https://store.extension.iastate.edu/product/14263).
3. When the fish get home, it is a good idea to add more water conditioner to the water just in case. The bag of fish should be floated in the bottom tote for 10-15 minutes to allow the fish to acclimate to their new water temperature. It is also beneficial to slowly add your system water (using a cup at a time) to the bag of fish to acclimate them to the new water quality. After acclimation, the fish can be added to the aquaponics system. However, it is wise to remove the fish from the bag with a net and place the fish in your system rather than pouring the bag water in, because some diseases can be transported in the water.

STEP 14: ADD FISH FOOD AND MONITOR WATER QUALITY

1. Transporting fish is a stressful process for the fish, and therefore the fish probably will not want to eat right away. Fish should be allowed to become accustomed to their new home for a couple of days before trying to feed them to keep from degrading the water quality with uneaten feed. **Uneaten feed produces toxins like ammonia that can kill the fish.**
2. Check water quality before trying to feed fish. If the parameters meet the recommendations in Table 1, proceed with feeding.
3. Once the fish are settled, add a pinch of feed to see if they are hungry. If they eat, add more feed a pinch at a time until they are no longer interested, or for up to 15 minutes. If they do not eat, stop feeding and remove the excess feed after 15 minutes to prevent water quality issues. Some fish are shy feeders, and may not feed in bright light or if they can see movement—be patient.
4. Continue this process of testing water quality weekly, and checking the fish's desire to eat at every feeding. More information on feeding can be found in ISU Extension and Outreach publication "Feeding Practices for Recirculating Aquaculture" (FA 0002A) (https://store.extension.iastate.edu/product/14267).

Figure 15. Feeding fish

STEP 15: MAINTAIN THE SYSTEM

1. The fish food makes the plants grow, so it must be continuously added to the system. Fish food means waste buildup in both the fish tank and the plant container. Cleaning the waste out of the bottom tank and off the pump should be done weekly, or more often if necessary.

2. Water removed after cleaning, through evaporation, or as transpired by plants should be replaced as needed. Water levels in the fish tank should remain above the half-way mark, but below the three-fourths water level, or at a depth of 6-9 inches. **Be sure to condition the water with the treatment and allow it to reach room temperature before adding it to an aquaponics system.**
3. Plants may show signs of nutrient deficiency of there aren't enough provided in the feed. Iron is commonly lacking in the water, therefore a chelated iron (e.g. Fe-EDTA) should be added at a rate of 2 mg/L every two weeks.

STEP 16: HARVEST PLANTS

1. Once plants have grown to a harvestable size, it's time to harvest and try the produce. Some plants grow back if harvested properly, especially leafy greens and herbs. Pick lettuce one leaf at a time from the outside to the inside, leaving the small leaves in the middle to keep growing. Harvest herbs from the top, leaving a few leaves and branches down low for the plant regrowth.

Figure 16. Lettuce harvested from an aquaponics system.

AQUAPONICS RESOURCES

Iowa State University Fisheries Extension
www.nrem.iastate.edu/fisheries

Aquaponics Youtube Playlist
https://www.youtube.com/watch?v=xAudq28n8l0&list=PLyDHx-rmZpCljgr4za05H2eHKwmMhJYI1

Aquaponics System Design and Management
www.extension.iastate.edu/forestry/tri_state/tristate_2014/talks/PDFs/Aquaponic_System_Design_and_Management.pdf

An Overview of Aquaponic Systems: Hydroponic Components
https://store.extension.iastate.edu/Product/15111

SRAC Aquaponics
https://srac-aquaponics.tamu.edu

AQUACULTURE RESOURCES

Iowa State University Fisheries Extension
http://www.nrem.iastate.edu/fisheries

North Central Regional Aquaculture Center
www.NCRAC.org

Southern Regional Aquaculture Center
http://srac.msstate.edu

ISU Extension Store (search: Aquaculture)
https://store.extension.iastate.edu/ProductList?Keyword=aquaculture

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