The Biology of Aquaponics

Adapted from the Texas Aquaponic Guide

THE BIOLOGY OF AQUAPONICS

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Introduction

This publication is adapted from the Texas Aquaponic Guide. For a complete understanding of Backyard Aquaponics in Texas, click the above link and download this wonderful resource for Aquaponic success.

Aquaponics is the combination of aquaculture (fish farming) and hydroponics (soil-less plant culture). In Aquaponics, the nutrient-rich water resulting from raising fish provides a natural fertilizer for the growing plants. As the plants consume the nutrients, they help to purify the water in which the fish live. A natural microbial process keeps both the fish and plants healthy, and helps sustain an environment where all can thrive. Essentially, Aquaponics is organic gardening, without the soil.

In Aquaponics, both fish and plants are grown in one body of water, using one "infrastructure". Water circulates from the fish tank, through a biofilter/clarifier if present, to the plant grow beds and then flows back to the fish tanks, completing the loop. Other than an occasional supplement, the use of fertilizer is not required because the fish waste provides the nutrients the plants need.

The daily water use is minimal, and a large volume of food crops can be grown using much less space compared to growing crops in a conventional garden. Since soil isn't required, Aquaponics can be set up in urban areas supplying food to local markets, in arid regions with poor soil, in developing countries, in rural communities, in a small backyard, or in an apartment; anywhere that fresh food is needed. Aquaponics is one of the most sustainable and productive farming systems in the world.

One of the most important aspects of operating an Aquaponic system is the biology. This will include an understanding of the Nitrogen cycle, what cycling a system means, the bacteria that makes Aquaponics

possible, and the symbiotic relationship between the fish, bacteria, and plants. This publication is designed to give you a high level overview of what these aspects are and how to manage them for a healthy system.

The Nitrogen Cycle

Ammonia, nitrites, and nitrates are all forms of nitrogen that exist within any Aquaponics system. Beneficial bacteria within an Aquaponics system convert ammonia into nitrites and then into nitrates. Nitrates are then utilized by the plants and flourish within the system. One of the most important yet least understood aspects of Aquaponics is the bacteria. Since they are not visible to the naked eye, they tend to be ignored. But they are essential to the Nitrogen Cycle which is what makes Aquaponics work.

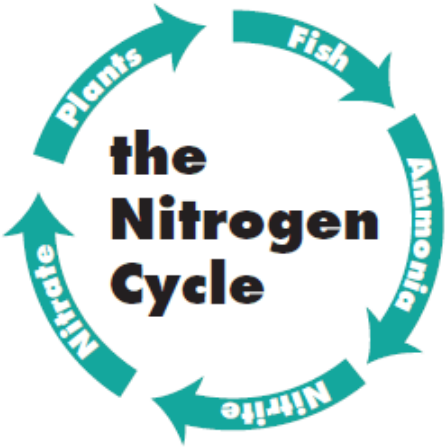
The Actual Nitrifying Cycle is simple

1. Fish excrete ammonia (waste),

2. The ammonia is converted to nitrites then nitrates by the bacteria,

3. Plants absorb the nitrates and clean the water,

4. The clean water is cycled back into the fish tank.



It's that simple, but each stage is crucial to understand. Let's look at this in more detail.

The Fish

Fish excrete ammonia which is toxic to them. In large bodies of water, this is not a problem because of dilution. But in an enclosed tank, this accumulates quickly and becomes deadly. Excess ammonia can cause tissue damage to fish's gills and kidneys, impair their resistance to diseases, and stunt growth. In an Aquaponic system, ammonia is also toxic to the bacteria and plants. The only practical way to reduce a sudden "spike" in ammonia is to do a partial water

change. A standard water change involves dumping and replacing one third of the water volume with clean, off gassed water.

You must never over feed the fish as this will also result in the production of more ammonia.

The Bacteria

Bacteria break down the ammonia into nutrients on which plants thrive. This is fundamentally a two stage process. During the first stage, bacteria (Nitrosomonas) convert the ammonia into nitrites. Nitrites are toxic to fish and interfere with their ability to uptake oxygen. If enough is present in the water, it will kill the fish and bacteria, as well as the plants. Fortunately, the second stage involves another bacteria (Nitrobacter) which is a slower growing bacteria that feeds on the nitrites. Their waste product is nitrates, which plants love. It is rich in nitrogen, and a great fertilizer. Fish can tolerate a much higher level of nitrates than of ammonia or nitrites.

Things to Know About Nitrifying Bacteria

Nitrosomonas and Nitrobacter are very photosensitive, that is very sensitive to sunlight. The water in your fish tank and plant trough must be protected from direct sunlight. There are several species of Nitrosomonas and Nitrobacter bacteria and many strains within those species. In general, the vast majority of this information can be applied to most species of nitrifying bacteria, although, each strain may have different environment and nutrient preferences.

Bacteria colonize on all surfaces including rafts, fish, media, fish tank, and bio-filter. Therefore, the more surface area you can create (such as with a bio-filter), the better for the Nitrogen Cycle. Nitrifying bacteria have long reproduction times. Under perfect conditions, Nitrosomonas may double every 7 hours and Nitrobacter every 13 hours. Under most conditions, they will double every 15 – 20 hours; this is slow. For reference, in the time it takes for a single Nitrosomonas cell to double in population, a single E. coli bacterium

would have produced a population exceeding 35 trillion cells. The upside to them growing slower is that they also die slower and are pretty hearty. There must be plenty of oxygen in the water for nitrifying bacteria to flourish. Also, they cannot survive in dry conditions or handle sustained temperatures higher than 120° F. Of course by that time, you are cooking fish. As a general rule an uncycled system will require about 4 weeks to cycle completely at around 70° F. It will take longer in colder temperatures.

Biofilters

Biofilters can help accelerate cycling if you do not have sufficient surface area to populate the nitrifying bacteria. This is usually the case with a raft or NFT system. If you are using a media based system, the media will serve as the Biofilter.

The Water

Aquaponic water is circulated repeatedly throughout the system. Once it has passed through the plants for cleansing, it is returned to the fish tank to be "re-fertigated". Water is generally only added to compensate for evaporation and respiration. If municipal water is being used, it is important to always have at least one third of the system water volume available for use in case of an emergency. Any water change will require off gassed water.

Off-Gassing Chlorine

Chlorine must be off-gassed by letting it sit for a few days in a 5 gallon or so bucket or by bubbling it with an aerator over night. If you are off-gassing a 300 gallon tank or any increment of this volume, bubble the water for 3-5 days then, then always test for chlorine.

The Plants

Plants absorb the converted ammonia and flourish. The plants not only clean up the nitrates, they also filter and clean the water as nature intended. Plants can be added at any time during the cycling process, but is not recommended during a nitrite spike. Never add fruit bearing

plants to the system before it is fully cycled. It is fine to add greens such as lettuce and herbs, but not tomato or bell peppers. As mentioned above, it is best to wait about 3-4 weeks before adding fruiting plants.

Adding Plants

Plants can be added at any time. You will not realize any significant growth until the cycle is completed and nutrient rich water is being circulated. Think of it as putting a plant in a glass of water, which only keeps it alive. Do not add flowering plants, that is fruits such as tomato, cucumber, bell peppers, etc., at this stage as they require way more nutrients than vegetables and will impact all plant growth at this stage.

There are various methods of cycling an Aquaponic system and the most popular are outlined below.

Cycling an Aquaponic System

Cycling an Aquaponic system refers to the point at which the biological process begins in your new Aquaponic system. There are several methods of cycling an Aquaponic system, but there are a few things to keep in mind regardless of which method you apply. Use inexpensive fish. It is recommended you cycle your system using goldfish which can be purchased at most pet stores. Goldfish (feeder fish) are desirable for several reasons, they are tough little guys, they produce a large amount of ammonia (which is why you seldom see them in an aquarium), and as mentioned, not expensive.

Note on Cycling an Aquaponic System:

Keep a Log. It is helpful to keep a log during this stage which includes dates, times, test reading levels, and recordings of any changes you made to your system. This includes adding or removing fish, plant growth, test results, temperature, and amount of feed. The more detail that is recorded in your log, the more your chances for success or of helping others diagnose any system problems for you.

Cycling with Ammonia (Fishless Cycling)

To get your Aquaponic system cycled using ammonia, you must first ensure there is no chlorine in the water. Be sure to sufficiently off-gas the water beforehand. You can start your system's biological process by using ordinary pure ammonia. Add 1 teaspoon of pure ammonia a couple of times a week to build up your bacteria colonies. DO NOT add too much at a time as it will then become toxic to the bacteria. Mix ammonia in a bucket first, then slowly add to system. Check your water regularly (every day or two) to ensure the ammonia level does not exceed 1.0 ppm.

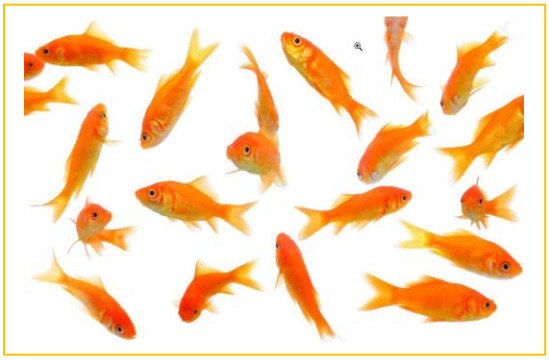
Note that when cycling your system, only use pure ammonia, or ammonia with ammonium hydroxide. Any other ingredients will destroy your system. Ammonia bottles labeled as CLEAR AMMONIA may contain surfactants which will foam if you shake the bottle. It will also kill your fish and bacteria. Perfumes and dyes (such as in bottles of Parson's Ammonia) will kill your fish as well. Sometimes the ingredient list is difficult to find and is mixed in with the directions.

ALWAYS MIX AMMONIA WITH WATER BEFORE ADDING TO SYSTEM!

Soon you should realize readings for nitrites which indicate the first nitrifying bacteria have started processing the ammonia into nitrites.

NOTE: This is the prime time for a nitrite spike. Be very cautious at this stage. Don't add any fish until the nitrite level drops back down to zero. Stop adding ammonia at least three days before adding fish. Test the levels and watch for nitrates which indicate the second nitrifying bacteria have begun to process the nitrites.

Cycling with Fish



To get your Aquaponic system cycled using fish, you must first ensure there is no chlorine in the water. Be sure to sufficiently off-gas the water beforehand. Know that the number of fish you use to cycle your system should be much less than your system is intended to hold. If you use too many fish, there is a danger of a quicker ammonia and nitrite spike which can compromise the system. This in turn will likely kill or severely damage the fish and will require more frequent and larger water changes.

Also, be sure not to overfeed the fish as this will also result in the production of more ammonia. Many people choose to use cheap goldfish for the cycling process, due to the minimal cost and their high tolerance to poor water conditions. The best advice you can take when cycling your system is to be patient and let nature take its course. Do frequent tests (at least daily) during this period and perform water changes as required. Fish produce ammonia as waste. To start with, depending upon your size fish tank, add about 1 medium to large goldfish per every 10 gallons. Small fish produce little waste.

When first introducing the fish into the system, do not feed them for a couple of days until they have had time to acclimate. Check the water quality at least once a week for each week you have been using this method. You will be concerned about ammonia, nitrites, and pH. The first indication that cycling has begun is when nitrites appear. Allow the system to operate in this way for two to three weeks until your ammonia and nitrite levels are back very close to zero. If you haven't already, you may add plants at this point.

Cycling Using Another Aquaponic System

To get your Aquaponic system cycled using another Aquaponic system, you must first ensure there is no chlorine in the water. Be sure and

sufficiently off-gas the water beforehand. If fish are already present in the system, they will produce ammonia which will also accelerate the process. Adding a gallon or so of cycled water from another fully cycled system is the quickest method to get cycled from zero.

The bottom line is, the more previously cycled water you can introduce to your system, the faster it will cycle. This is because you are introducing both nitrifying bacteria and ammonia to your system which jump starts the cycling process. You can add previously cycled water at any stage (except during a nitrite spike) of any of the cycling methods described. Make certain you are getting your cycled water from a source you trust. DO NOT use water from a pet store. Because they routinely deal with thousands of fish from all over the world fish, diseases are common. They must add a plethora of chemicals to combat this problem. Additionally, these chemicals will be introduced into your systems food chain.

Cycling With Purchased Nitrifying Bacteria

Nitrifying bacteria is available for purchase from a number of locations. Online, PentairAES.com carries a product called Nitrifying Bacteria by Proline® which you can add to your water to jump start the nitrification process. Different quantities can be purchased depending upon your needs. Be sure and sufficiently Off-gas the water beforehand. As with pre-cycled Aquaponic water, fish and plants can be added at any time.

Managing a Nitrite Spike

Once your system has a sufficient number of nitrifying bacteria to convert the ammonia to nitrates, your system is said to be cycled. The first stage though will show ammonia appearing on the tests. Then, as the first bacteria starts reproducing, nitrites will appear. This is probably the most critical stage of your Aquaponic system development. At this point there can occur what is called a "nitrite

spike". This situation is tough on everything. Testing is critical at this time. Look for indications of stress. Some signs that there is a problem may be that the bubbles are lingering atop the water longer than normal. The water may appear thick and slow moving. The fish may be trying to jump out of the tank, gasping for air, swimming listlessly, or dying.

At this stage, the best way to level things out is to do a partial water change, that is, replace about 1/3 of the system water with clean, de-chlorinated water. Always have at least this amount of water on hand. When a nitrite spike occurs, there is no time to de-chlorinate the water. Test the water regularly during this time until things level out.

Texas TransFarming Builder Series Supplement

Water Conservation with TransFarming and Aquaponics

Here in Texas we face myriad obstacles to growing food in a "sustainable" fashion. What does sustainable mean? Well, it has a lot to do with producing food in a manner that is not interrupted by "outside influences". One of the major outside influences here in Texas is the weather – long seasons of heat, extended periods of cold, rapid changes between those two conditions, and no rain in between.

The entire premise of TransFarming was started on the realization the weather here in Texas can be brutal and a different approach must be taken to combat the elements in light of our modern challenges.

At the core of all this is water. Without water, nothing prospers. TransFarming is about "re-thinking" traditional gardening methods to address *regional environmental challenges* like droughts and water restrictions, while keeping in mind techniques for prosperous food production. These approaches involve growing food in ways that conserve water.

Weather wise, not much has changed from the days of our ancestors, but they used vastly different approaches to dealing with the climate than we do today. Following are a few techniques used to conserve water on a TransFarm.

Wicking Beds

Wicking beds have proven to be a viable solution to the Texas heat and water conservation. These simple structures, based on a raised bed garden, incorporate a reservoir underneath the bed to store water. The garden is watered through an exposed pipe which then wicks water upward through the soil to the roots where water is needed the most. There is minimal evaporation.



Traditional Raised Bed Gardens

Traditional raised bed gardening involves selecting the correct structure and materials for a specific outcome base on environmental factors such as shading, sun path, wind direction and desired crop. Additionally, soil composition will play a very large part in crop success and water conservation. A simple small hoop house may be desirable to protect from direct sun and winter cold.



Aquaponics

Aquaponics is the combination of aquaculture (fish farming) and hydroponics (soilless plant production). With Aquaponics, the nutrient-

rich water that results from raising fish provides a source of natural fertilizer for the growing plants. As the plants consume the nutrients, they help to purify the water in which the fish live. A natural microbial process keeps both the fish and plants healthy, and helps sustain an environment where all can thrive. Both the plants and fish are harvested.



HugelKulture

A HugelKulture is a type of raised bed garden that allows one to use organic materials that are too big to go in the compost. Over time, that is 3- 5 years, the materials in the bed decompose, and provide a slow release of nutrients for garden plants.

Because of its three-dimensionality, a HugelKulture raised bed garden combines the multiple functions of rainwater harvesting, catchment, and irrigation using no cistern, pumps, or pvc pipes. Done properly, there may be no need to water all summer!



Keyhole Gardens

A keyhole garden uses the same principle as a HugelKulture in that decomposing matter is used to absorb and retain water in the soil.

Large amounts of "rotting" wood and kitchen scraps are used in the soil which is stacked within layers of cardboard and paper. Kitchen scraps are also added to the bed via a foot-wide tube which nourishes the entire system. A wedge is cut in the circular bed to access the tube, which makes the garden look like a keyhole when viewed from above.



Hoop House/Monkey Huts

One of the major concerns with growing food (and fish) in the winter is the cold. The wind does not help much either. Greenhouses are expensive, and any constructed structures tend to be somewhat permanent.

Enter the simple Monkey Hut. These structures are by their very nature flexible, and designed to withstand strong wind and rain (dust too). Built correctly, they are easily dis-assembled in the Spring, or used to support a shade cloth in the Summer.



Worm Composting is an excellent way to create organic matter for gardens and Aquaponic systems. They can be added directly to gardens and Aquaponic media systems, and also used to feed fish and chickens. Worms are important in the garden because they aerate the

soil which helps lock in moisture. Worm farming includes choosing a worm and bin type, setting up the worm composting bin, maintaining the system, harvesting compost and worms, making and using worm tea, and such activities.