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I. What is Aquaponics?

1) Intro to Aquaponics

Before delving into the subject of aquaponics I will briefly explain what aquaponics is, as I believe that many of you will have little to no understanding of aquaponics. Aquaponics is a new method of food production that is gaining popularity. The word aquaponics comes from a mixture of the words *aquaculture* and *hydroponics*.[1] Aquaculture is a method of growing fish for eating, which involves breeding and growing the fish to maturity completely under human control. Hydroponics is a method of growing fruit and vegetables which many of you may know about. It is also referred to as "food factories" or "vertical farming". Hydroponically grown fruit and vegetables are grown without ever coming into contact with soil. The plants are put on rafts which float above the water, and nutrients are given to the plants through that water.

Aquaponics is a marriage between the two methods of food production which aims to take the positive aspects of both aquaculture and hydroponics.

"Aquaponics is the cultivation of fish and plants together in a constructed, recirculating ecosystem utilizing natural bacterial cycles to convert fish waste to plant nutrients. This is an environmentally friendly, natural food-growing method that harnesses the best attributes of aquaculture and hydroponics without the need to discard any water or filtrate or add chemical fertilizers.".

-Aquaponics Gardening Community, November 2010

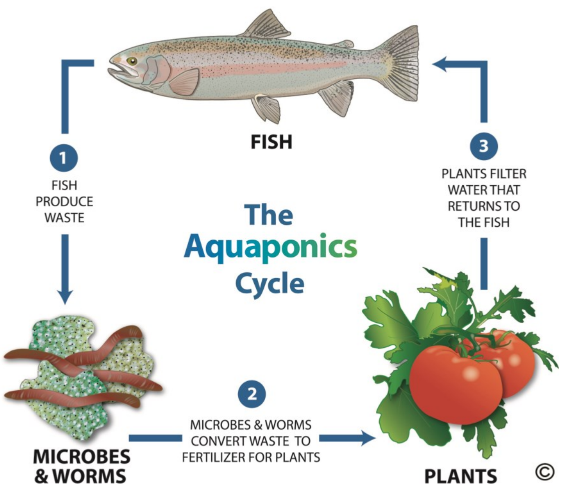

Fig. 1 The Aquaponics Cycle simplified

Aquaponics consists of three main types of living organisms: the fish, the plants, and the bacteria. The system is a cycle so it does not matter where I begin to explain, but I will start at the feeding of the fish; the only part of the cycle where an outside input is required. When the fish are fed, they will release ammonia through defecation and breathing through the gills. This ammonia is broken down in to nitrite, and subsequently nitrate by various bacteria. Ammonia is harmful to fish and is also useless to plants, but nitrate is less harmful to fish, and is a nutrient for plants. This nitrate is used by plants, effectively filtering the water for the fish to live in again. The core of aquaponics is this cycle. [1][2]

2) Types of Aquaponics Systems

There are many variations to the types of aquaponics systems, but the main type of aquaponics system used in large scale commercial aquaponics is the DWC system. DWC stands for Deep Water Culture, and it is characterized by the growbed which is a pool of water usually close to 30cm deep, which Styrofoam rafts carrying plants float on. This method is popular as it requires no cost for soil, easy access to monitor root health, and there is no need to clean the roots after harvesting.[2][3][4]

Fig. 2 A DWC system growing Lemongrass at The Plant Chicago

Another popular system is a MFG system. MFG stands for Media Filled Growbed, and it is characterized by the growbeds filled with various media, such as hydroton, an expanded clay ball, gravel, or volcanic rocks. This method is popular among hobbyists because an MFG system requires no filter as the surface area of the media will support a large enough bacteria colony to sustain the system's nitrate needs at smaller scales. This means a MFG system is much easier to design than other system types.

This system usually requires an ebb and flow (also referred to as flood and drain) mechanic, so that the bacteria can get access to the oxygen it needs to properly digest ammonia and nitrite. This plumbing system can be difficult to manage, but at a small scale, it is less hassle compared to building a separate filtration system. [2][3][4]

Fig. 3 An MFG System growing various plants including tomatoes, at The Plant Chicago

The third major type of aquaponics system is the NFT system. NFT stands for Nutrient Film Technique, and it is characterized by the thin layer of nutrient rich water that the plants are permanently exposed to. This method is the least popular method among the three types of aquaponics systems, but it is useful as an addition to an already existing system, as it requires very little water volume to run. It can be used temporarily to adjust nitrate levels when there is a lack of nitrate consumption.[2][3][4]

Fig. 4 An NFT System growing lettuce

<u>3) Media Coverage and Setbacks of Aquaponics</u>

I have noticed that there are more commercial aquaponics operations than there were previously, and I believe this is mainly due to the rise in awareness about the method of agriculture and its appearance on various mass media outlets.[5][6][7] However, most of the media exposure treats aquaponics as an interesting idea, and not a viable alternative to conventional agriculture. There are hurdles for aquaponics, such as the types of crops it can produce are mainly limited to those that consume large amounts of nitrogen like leafy greens.

Fig. 5 Micro Greens being raised in an aquaponics system at The Plant Chicago

4) Hypothesis

Commercial aquaponics is not a viable method of food production and will not become a major source of food for the world.

II. Interview with Great Lakes Aquaponics

JD from Great Lakes Aquaponics (GLA) gracefully accepted my e-mail interview in which we discussed several things.

Great Lakes Aquaponics is an aquaponics farm located in Royal Oak, MI. Their system has 14 4' x 8' rafts in DWC form, with a 4 raft system for seed germination and experimentation, and a 10 raft system for main production. Their main source of income is Romaine Lettuce which they sell to local restraints and retail stores. They also grow basil and asian herbs based on demand. Their distribution is all within 1.5 miles of their growing area which makes distribution costs close to nothing.

1) The first thing we discussed was the profitability of aquaponics. GLA has been making a profit since the first year of their system running, mainly due to:

A. Their distribution costs being so low

B. Low running costs due to the cost effective system design employed at GLA, which produces its own fish food, nutrient supplements, and requires low electricity input to power the setup.

C. Scaling the system up as more profits come in.

2) Next, we discussed what is needed to run a profitable aquaponics farm.

A. Scale : JD estimates that a profitable farm would at least require four rafts, but he notes that this is flexible based on the crops being grown and the price at which they are being bought.

B. Market : He also notes that it is very important to find buyers for the produce that an aquaponics farm produces. JD says that he once decided to grow Pak Choy but there were no buyers, and that production went to waste. Now, he grows things that have guaranteed buyers, or even custom grows rare herbs for restaurants.

3) Some of the numbers which JD has provided me with include:

A. He buys 32,000 romaine lettuce seeds for about $7.50USD and it gets about 80-90% germination.

B. He can plant about 50 heads of lettuce per raft (He has 14).

C. He can sell each head of lettuce for about $2.00 to $4.00 USD, and it costs roughly $0.26 in electricity to grow 15 heads of lettuce.

D. This means that growing a head of lettuce comes at about a 17000% profit margin.

E. JD says that they harvest about 2-2.5 rafts per week, this is 100 heads of lettuce, or $200 to $400 USD per week in revenue, with about $3.45 USD cost in electricity.

4) It appears that production costs and the flaws in aquaponics is not the problem for large scale commercial aquaponics, but rather it is finding buyers who will purchase aquaponic crops, which is difficult unless you have a very large system to sell wholesale to retailers.

Dixon, J. , personal communication, September, 2014.

Image: A sign at the front of The Plant Chicago.

III. The Plant Chicago Tour

This past August, I received the chance to go visit The Plant Chicago. The Plant is a building which incorporates various methods of food production and processing. Among those is an aquaponics system that is used for educational purposes and another aquaponics system that is run commercially. On my visit I got to take a look at the educational system, but sadly did not get to look at the commercial operation. The system's fish was entirely Tilapia, with several IBC tanks of them. It appeared as if each tank was a separate generation or age group from the other tanks, most likely to reduce the fish eating each other and because they clear out entire tanks at a time instead of looking for ripe fish in each tank. Abby, my guide at The Plant, told me that the tilapia takes about nine to twelve months to mature for harvest. The Plant allows their tilapia to mature more than other aquaponics farms, she said. The tilapia are roughly one pound each at that age. The Plant had been employing two large growbeds of DWC, and some smaller MFG systems. There were various crops being planted in the growbeds such as tomatoes, lemongrass, strawberries, lettuce, micro-greens, various herbs, and a tray of duckweed. There was a growbed that had red LED lights instead of the white lights that I imagined were the standard. Red LED lights do not enhance plant growth, but it is much more energy efficient compared to white lights because the spectrum absorbed by chlorophyll is in the violet and red spectrum, and all other lights are reflected, leading to wasted energy.

On my trip to Chicago, I also got a chance to purchase some aquaponics grown micro-greens, from a company called Farmed Here. They are located in Illinois, and are local aquaponics company. Sadly, I found that aquaponics grown micro-greens are of lower quality compared to conventional salad greens that I am used to eating. It was also much more expensive compared to vegetables that I usually purchase. Another hurdle in popularizing aquaponics would be to ensure that the taste is of similar or better quality compared to conventional agriculture. Also, getting the cost down from an "organic premium" cost to the price of an average vegetable will also be necessary if aquaponics is to supersede conventional agriculture.

Fig. 6 Farmed Here micro-greens in a Whole Foods in the suburbs of Chicago IL.

IV. Interview with Mr. Eri

Mr. Yoshikazu Eri is a co-founder of おうち菜園（*Ouchi-Saien* or “Home Garden”）, an internet media site which discusses food production. I first met Mr. Eri when I found his personal blog about aquaponics on the internet, and we have since met a couple times and discussed aquaponics over the internet over the past half-year. Mr. Eri feels that commercial aquaponics is not viable, and that if anything close to it were to succeed, it would be hydroponics. We discussed some of the pros and cons of aquaponics to see what kind of place that aquaponics belongs.

Pros:

- Aquaponics systems scale very well from the miniscule desktop systems to large scale warehouse level sizes.
- Aquaponics systems are very adaptable to various climates because it is a semi-closed system. It requires very little outside input from the outside world.
- It can be used to explain the nitrogen cycle, and the symbiosis of various organisms in a closed system very well, so it could be used in education. Mr.Eri feels that this will be the best option for aquaponics to integrate into society in the future.
- Aquaponics requires no soil, and very little water, so it can be used in climates where conventional agriculture is difficult to sustain, like urban areas or deserts.

Cons:

- Aquaponics runs on fish poop, and that may gross out some people. If there is a significant portion of society that cannot accept this, truth of fact, aquaponics cannot be popularized by definition.
- Although aquaponics requires very little maintenance, it still requires a certain degree of knowledge about various chemicals that need balancing. This can be a hurdle to some hobbyists but the technology exists to automate or make this less difficult for commercial farmers.
- Lack of good design and functional systems in hobby systems. So far most kickstarter crowd funding aquaponics systems look hideous and function, or function terribly yet look very pretty. This gap needs to bridged before hobby aquaponics catches on. An explosion in hobby aquaponics could connect to higher exposure of aquaponics, and lead to more people stepping into the commercial field.
- The fish raised in aquaponics systems must be freshwater fish, and tilapia are the most commonly raised fish in aquaponics. However, tilapia is not a very popular fish in Japan, and fish in general are not popular in the US. Finding a way to grow fish that are in demand is necessary to make aquaponics popular.

Mr. Eri feels that the future of aquaponics does not belong in the commercial large scale sector. Instead, it belongs in education because it helps to explain multiple concepts in biology. We agreed that many of the negative points that aquaponics holds can be mitigated by resorting to hydroponics, such as the fish poop problem, balancing of chemicals, and finding suitable fish. Hydroponics can use a chemical blend tailored to each plant, so it has less problems compared to aquaponics to deal with.

Eri, Y., personal communication, September 18, 2014

V. Conclusion

Although Mr.Eri says that aquaponics has many obstacles it must overcome, such as the lack of public knowledge on the exact use of fish poop potentially causing disgust, limits on the fish type to freshwater fish, limits on the crop type to heavy nitrogen consumers, and lack of full control over the nutrients given to plants, aquaponics has been proven to be profitable in certain settings by JD and GLA. However, both JD and Mr.Eri believe that aquaponics will only fill in the cracks of commercial agriculture and it will never fully replace or compete with the largest elements of agriculture. The people working at The Plant are optimistic that aquaponics will be used all over the world, but they also appear to be headed in a local grown local consumed model of agriculture with their complex. Almost all the interviewees tend to agree that aquaponics is not going to replace conventional dirt and soil agriculture.

To conclude, aquaponics has many obstacles it must overcome and even if those obstacles are cleared, aquaponics may never be a large scale player in commercial aquaponics. However, it has been proven that aquaponics has its place in small scale local operations where small amounts of fresh crops are required, and aquaponics may become an important aspect of agriculture by supplementing the existing agriculture.

VI. Experiment Plan for Next Year

1) Problem Statement

It is unknown whether aquaponics is more effective than conventional agriculture.

2) Hypothesis

Aquaponics uses less water than conventional agriculture, and it will have better plant growth.

3) Aim

To measure the water use and growth of *organism* in aquaponics and conventional agriculture.

4)Apparatus and Materials

Aquaponics system (goldfish, gravel, plastic boxes, *organism*, pump, and piping), Conventional system(pots, soil, *organism*,), yardstick/ruler, and a beaker.

5)Method

After cycling the aquaponics system, germinate the seeds of *organism* on the same day.

Apply water to conventional system as needed, and to the aquaponics system when the water levels appear low.

Measure the amount of water applied to each system, and measure the height of plant growth for both systems.

6) Variables

Controlled - amount of sunlight, temperature, CO_2 density.

Manipulated - method of agriculture.

Responding - water use, plant height.

7) Expected Results

Total water use should be less in the aquaponics system and the total plant height should be higher in the aquaponics system.

8) Treatment of Results

If the water use of aquaponics is lower and the plant height is higher as well, then Aquaponics is more space efficient than conventional agriculture.

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