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Aquaponics: A boon to horticulture

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Abstract
Aquaponics is a form of agriculture that combines raising fish in tanks (recirculating aquaculture) with soilless plant culture (hydroponics). In aquaponics, the nutrient-rich water from raising fish provides a natural fertilizer for the plants and the plants help to purify the water for the fish. Aquaponics can be used to sustainably raise fresh fish and vegetables for a family, to feed a village or to generate profit in a commercial farming venture, year round, in any climate. This paper discusses the applications of aquaponics, biological components, designs, maintenance and care of fish, cultivation of vegetables and companies involved in aquaponics.

Keywords: Aquaponics, hydroponics, biological components, designs and maintenance

Introduction
Soil-less culture is the method of growing agricultural crops without the use of soil. Instead of soil, various inert growing media, also called substrates, are used. Soil-less agriculture has been used to reduce pests and soil-borne diseases affecting monoculture crops. Hydroponics can in fact control soil-borne pests and diseases by avoiding the contact between plants and soil, and soil-less media can be sterilized and reused between crops. This reuse of substrates meets the particular demands of intensive production. Soil-less agriculture is one aspect of the major scientific, economic and technological developments in the general field of agriculture over the last 200 years. In general, predominantly in developed nations in temperate climates, there has been an increasing demand for out-of-season, high-value crops. Partly, this is a result of widespread improvements in living standards. This increase in demand has led to the expansion of many types of protected cultivation systems to boost production capacity and prolong the supply of crops throughout the year.

Fig 1: Hydroponic system

Aquaculture
Aquaculture is the captive rearing and production of fish and other aquatic animal and plant species under controlled conditions (Fig.2). Many aquatic species have been cultured, especially fish, crustaceans and molluscs and aquatic plants and algae. Aquaculture production methods have been developed in various regions of the world, and have thus been adapted to the specific

Environmental and climatic conditions in those regions. The four major categories of aquaculture include open water systems (e.g. cages, longlines), pond culture, flow-through raceways and recirculating aquaculture systems (RAS). In a RAS operation water is reused for the fish after a cleaning and a filtering process.

Although a RAS is not the cheapest production system owing to its higher investment, energy and management costs, it can considerably increase productivity per unit area of land and is the most efficient water-saving technology in fish farming. A RAS is the most applicable method for the development of integrated aquaculture agriculture systems because of the possible use of by-products and the higher water nutrient concentrations for vegetable crop production.

Fig 2: Aquaculture system

Aquaponics

Aquaponics is the integration of recirculating aquaculture and hydroponics in one production system (Fig.1 and Fig.3). In an aquaponic unit, water from the fish tank cycles through filters, plant grow beds and then back to the fish. In the filters, the fish wastes are removed from the water, first using a mechanical filter that removes the solid waste and then through a biofilter that processes the dissolved wastes. The biofilter provides a location for bacteria to convert ammonia, which is toxic for fish, into nitrate, a more accessible nutrient for plants. This process is called nitrification. As the water (containing nitrate and other nutrients) travels through plant grow beds the plants uptake these nutrients, and finally the water returns to the fish tank purified. This process allows the fish, plants, and bacteria to thrive symbiotically and to work together to create a healthy growing environment for each other, provided that the system is properly balanced.

Although the production of fish and vegetables is the most visible output of aquaponic units, it is essential to understand that aquaponics is the management of a complete ecosystem that includes three major groups of organisms: fish, plants and bacteria.

Fig 3: Aquaponics system

Current applications of Aquaponics

This final section briefly discusses some of the major applications of Aquaponics seen around the world. This list is by no means exhaustive, but rather a small window into activities that are using the Aquaponic concept.

- Domestic/small-scale Aquaponics: Aquaponic units with a fish tank size of about 1000 litres and growing space of about 3 m^2 are considered small-scale, and are appropriate for domestic production for a family household. Units of this size have been trialled and tested with great success in many regions around the world. The main purpose of these units is food production for subsistence and domestic use, as many units can have various types of vegetables and herbs growing at once.
- Semi-commercial and commercial Aquaponics: Owing to the high initial start-up cost and limited comprehensive experience with this scale, commercial and/or semi-commercial Aquaponic systems are few in number. Many commercial ventures have failed because the profits could not meet the demands of the initial investment plan. Most of those that do exist use monoculture practices, typically the production of lettuce or basil.
- Education: Small-scale Aquaponic units are being championed in various educational institutes including, primary and secondary schools, colleges and universities, special and adult education centres, as well as community-based organizations. Aquaponics is being used as a vehicle to bridge the gap between the general population and sustainable agricultural techniques, including congruent sustainable activities such as rainwater harvesting, nutrient recycling and organic food production, which can be integrated within the lesson plans.

Three basic biological components of Aquaponics

- Plants
- Bacteria
- Fish

Bacteria in Aquaponics

Bacteria are a crucial and pivotal aspect of Aquaponics, serving as the bridge that connects the fish waste to the plant fertilizer. This biological engine removes toxic wastes by transforming them into accessible plant nutrients.

The first step is converting ammonia to nitrite, which is done by the ammonia-oxidizing bacteria (AOB). These bacteria are often referred to by the genus name of the most common group, the Nitrosomonas. The second step is converting nitrite to nitrate is done by the nitrite-oxidizing bacteria (NOB) (Fig. 4). These are commonly referred to by the genus name of the most common group, the Nitrobacter. The nitrification process occurs as follows:

1. AOB bacteria convert ammonia into nitrite
2. NOB bacteria then convert nitrite into nitrate

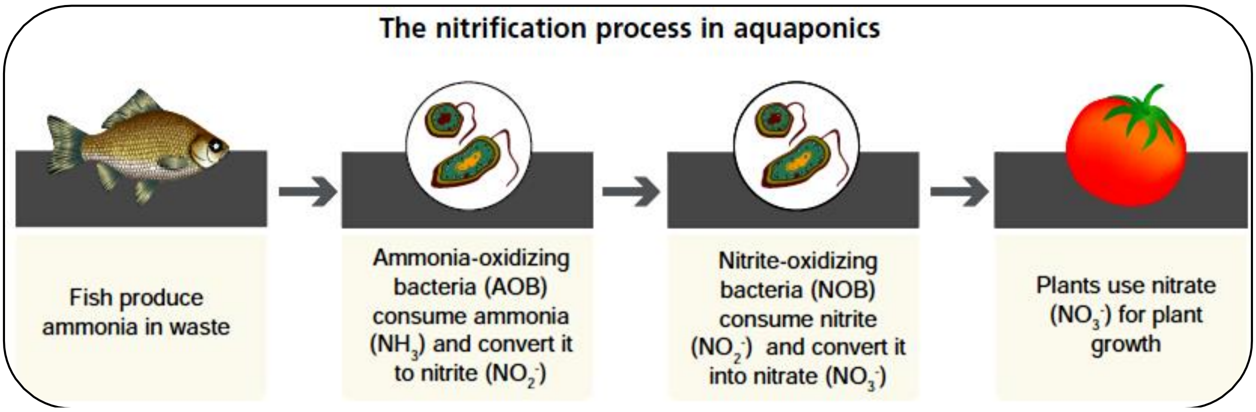

Fig 4: The nitrification process in Aquaponics

Maintaining a healthy bacterial colony

The major parameters affecting bacteria growth that should be considered when maintaining a healthy bio filter are adequate surface area and appropriate water conditions.

- Surface area
- Water pH
- Water temperature
- Dissolved oxygen
- Ultraviolet light

Filtration

The media beds serve as very efficient filters, both mechanical and biological. Unlike the NFT and DWC systems, the media bed technique utilizes a combination filter and plant growing area. In addition, the media bed provides a place for mineralization to occur, which is absent in the NFT and DWC systems. However, at high stocking densities (>15 kg/m3), the mechanical filtration can be overwhelmed and can face the risk of having the media clogged and producing dangerous anaerobic spots.

1. **Mechanical filter:** The medium-filled bed functions as a large physical filter, capturing and containing the solid and suspended fish waste and other floating organic debris. The effectiveness of this filter will depend on the particle size of the medium because smaller particles are more densely packed and capture more solids.
2. **Biological filtration:** All of the growing media herein outlined have a large surface area where nitrifying bacteria can colonize. Of all of the aquaponic designs, media beds have the most biological filtration because of the huge area of media on which the bacteria can grow. Biofiltration capacity can be limited or lost if the media beds become anoxic, if the temperatures drop or if the water quality is poor, but generally media beds have more than adequate biological filtration

Installation of aquaponic system

- **Site selection** is an important aspect that must be considered before installing an aquaponic unit. This section generally refers to aquaponic units built outdoors without a greenhouse. However, there are brief comments about greenhouses and shading net structures for larger units. It is important to remember that some of the system's components, especially the water and stone media, are heavy and hard to move, so it is worth building the system in its final location.

- **Essential components of an Aquaponics unit**

1. Fish tank/rearing tank: Plastic, fiber glass or concrete
2. Air pumps: Inject air into water through air pipes and air stones
3. Filters: Mechanical filter, Biofilter
4. Sump

Designs of Aqauaponics

1. Raft/DWC system
2. Media-filled bed
3. Nutrient Film Technique (NFT)

1. Raft or deep water culture system

- In a raft system (also known as float, deep channel and deep flow)
- The plants are grown on Styrofoam boards (rafts) that float on top of water (Fig.5 and Fig.6).
- Water flows continuously from the fish tank, through filtration components, through the raft tank where the plants are grown and then water goes back to the fish tank.
- The DWC method involves suspending plants in polystyrene sheets, with their roots hanging down into the water. This method is the most common for large commercial aquaponics growing one specific crop (typically lettuce, salad leaves or basil, and is more suitable for mechanization. On a small-scale, this technique is more complicated than media beds, and may not be suitable for some locations, especially where access to materials is limited.

Fig 5: Deep water culture system

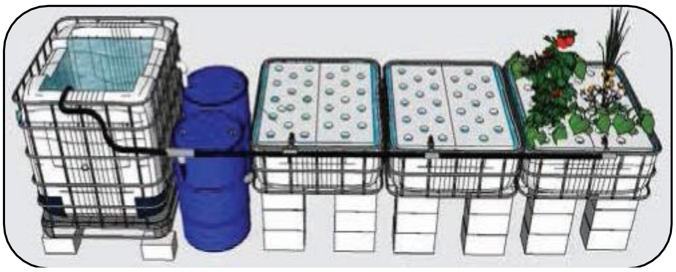

Fig 6: Deep water culture system

2. Media-filled bed

- A tank or container is filled with gravel, perlite or other media for the plant bed (Fig.7 and Fig.8).
- This bed is periodically flooded with water from the fish tank.
- The water is used by the plants.
- Then the water drains back to the fish tank.
- This method uses the fewest components and no additional filtration, making it simple to operate.
- The medium must be inert, not dusty, and non-toxic, and it must have a neutral pH so as not to affect the water quality.
- It is important to wash the medium thoroughly before placing it into the beds, particularly volcanic gravel which contains dust and tiny particles.
- These particles can clog the system and potentially harm the fishes' gills.

Fig 7: Media-filled bed

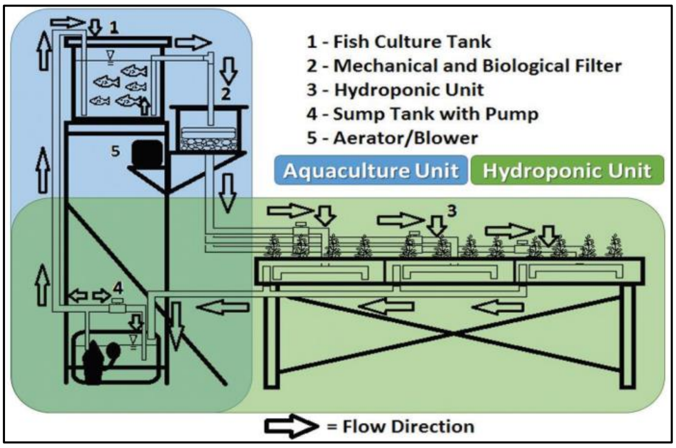

Fig 8: Media-filled bed

2. Nutrient Film Technique (NFT)

- NFT is a method in which the plants are grown in long narrow channels (Fig.9).
- A thin film of water continuously flows down each channel, providing the plant roots with water, nutrients and oxygen
- The NFT is a hydroponic method using horizontal pipes each with a shallow stream of nutrient-rich aquaponic water flowing through it. Plants are placed within holes in the top of the pipes, and are able to use this thin film of nutrient-rich water. Both the NFT and DWC are popular methods for commercial operations as both are financially more viable than media bed units when scaled up. This technique has very low evaporation because the water is completely shielded from the sun. This technique is far more complicated and expensive than media beds, and may not be appropriate in locations with inadequate access to suppliers. This technique is most useful in urban applications, especially when using vertical space or weight-limitations are considerations.

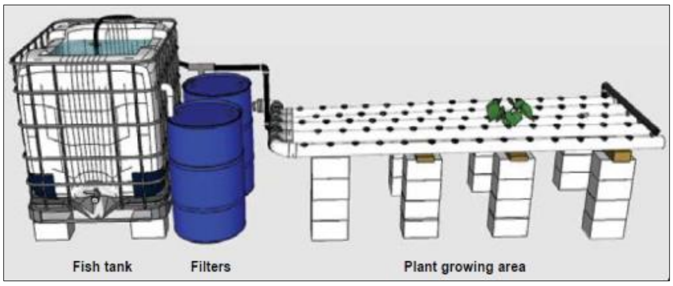

Fig 9: Nutrient Film Technique

Fish in Aquaponics

The first step includes collection of information on fish anatomy and physiology, including how they breathe, digest food and excrete wastes. The feed conversion ratio (FCR) is introduced, important for all aquaculture, which refers to how efficiently the fish convert feed into body mass. Special attention is then devoted to the fish life cycle and reproduction as it relates to breeding and maintaining stocks.

Several fish species have recorded excellent growth rates in aquaponic units. Fish species suitable for aquaponic farming include: tilapia, common carp, silver carp, grass carp, barramundi, jade perch, catfish, trout, salmon, Murray cod, and largemouth bass. Some of these species, which are available worldwide, grow particularly well in aquaponic units. In planning an aquaponic facility it is critical to appreciate the importance of the availability of healthy fish from reputable local suppliers.

Fish feed and nutrition

- Correct balance of proteins, carbohydrates, fats, vitamins and minerals
- Plant based proteins can include soya meal, corn meal, wheat meal.
- Most commercial feeds contain protein between 10 and 35%.

Recommended daily fish feed rate

- For leafy green vegetables: 40–50 grams of feed per square metre per day
- For fruiting vegetables: 50–80 grams of feed per square metre per day

Fish Health and Disease

The most important way to maintain healthy fish in any aquaculture system is to monitor and observe them daily, noting their behaviour and physical appearance. Typically, this is done before, during and after feeding. Maintaining good water quality, including all of the parameters discussed above, makes the fish more resistant to parasites and diseases by allowing the fishes' natural immune system to fight off infections.

The key aspects are

- Observe fish behaviour and appearance on a daily basis, noting any changes.
- Understand the signs and symptoms of stress, disease and parasites.
- Maintain a low stress environment, with good and consistent water quality, specific to the species.
- Use recommended stocking density and feeding rates

Cultivation of vegetables

Lettuce (*Lactuca sativa*)

- **pH**: 6.0–7.0
- **Plant spacing**: 18–30 cm (20–25 heads/m2)
- **Ready to harvest**: 24–32 days (longer for some varieties)
- **Temperature**: 15–22 °C (flowering over 24 °C)
- **Light exposure**: full sun (light shading in warm temperatures)
- **Plant height and width**: 20–30 cm; 25–35 cm
- **Recommended aquaponic method**: NFT and DWC
- It is estimated that 45.3 kg (100 pound) of fish will produce sufficient nitrogen for 4050 lettuce or 540 tomato plants when they are fed with 3% of their body weight (Fig. 10 and Fig.11).
  (Richard Tysno, 2013. University of Florida.)

Fig 10: Lettuce grown in aquaponic system

Fig 11: Lettuce grown in aquaponic system

Tomato (*Solanum lycopersicum*)

- **pH:** 5.5–6.5
- **Plant spacing:** 40–60 cm (3–5 plants/m^2)
- **Germination time and temperature:** 4–6 days; 20–30 °C
- **Growth time:** 50–70 days till first harvest.(mostly determinate are used)
- **Optimal temperatures:** 13–16 °C night, 22–26 °C day
- **Plant height and width:** 60–180 cm; 60–80 cm
- **Recommended aquaponic method:** media beds and DWC (Fig.12 and Fig.13).

Fig 12: Tomato grown in aquaponic system

Fig 13: Tomato grown in aquaponic system

Cucumbers
pH: 5.5–6.5
Plant spacing: 30–60 cm (depending on variety; 2–5 plants/m^2)
Germination time and temperature: 3–7 days; 20–30 °C
Growth time: 55–65 days
Temperature: 22–28 °C (day), 18–20 °C (night); highly susceptible to frost.
Light exposure: full sun
Plant height and width: 20–200 cm; 20–80 cm
Recommended aquaponic method: media beds; DWC

Parsley
pH: 6–7
Plant spacing: 15–30 cm (10–15 plants/m^2)
Germination time and temperature: 8–10 days; 20–25 °C
Growth time: 20–30 days after transplant Temperature: 15–25 °C
Light exposure: full sun; partial shade at > 25 °C
Plant height and width: 30–60 cm; 30–40 cm
Recommended aquaponic method: media beds, NFT and DWC

Eggplant
pH: 5.5–7.0
Plant spacing: 40–60 cm (3–5 plants/m^2)
Germination time and temperature: 8–10 days; 25–30 °C
Growth time: 90–120 days
Temperature: 15–18 °C (night), 22–26 °C (day); highly susceptible to frost
Light exposure: full sun
Plant height and width: 60–120 cm; 60–80 cm
Recommended aquaponic method: media beds

Companies involved in India
- Urba grow Aquaponics, Kolkata.
- India Aquaponics, Chandigarh.
- Mahindra Agri Solutions Limited (MASL), Mohali.
- Nanninode Aquaponics RDC, Perumatty, Kerala.

References

1. Anantharaju K Mohapatra, Pillai BR, Rajesh Kumar, Devraj, Majhi D. Growth and survival of climbing perch, *Anabas testudineus* in Nutrient Film Technique (NFT) Aquaponics system. International journal of fisheries and aquatic studies. 2017; 5(4):24-29.
2. Diver S. Aquaponics -Integration of Hydroponics and Aquaculture. Appropriate Technology Transfer for Rural Areas (ATTRA), Fayetteville, AR FAO, 2010.
3. Graber A Junge R. Aquaponic systems: nutrient recycling from fish waste water by vegetable production. Desalination. 2009; 246:147-156.
4. Harry Ako, Adam Baker. Small-scale lettuce production with hydroponics or aquaponics. Sustainable agriculture. SA-2.
5. Hamid Roostaa R, Mohsen H. Effects of foliar application of some macro- and micro-nutrients on tomato plants in aquaponic and hydroponic systems. Scientia Horticulturae. 2011; 129:396-402.
6. Jonas Johansson F, Leslie Paul R, Roger D Finlay. Microbial interactions in the mycorrhizosphere and their significance for sustainable agriculture, FEMS Microbiology Ecology. 2004; 48(1):1-13.8.
7. Lennard WB, Leonard BV. A comparison of three different hydroponic subsystems (gravel bed, floating and nutrient film technique) in an Aquaponic test system. Aquaculture International. 2006; 14:539-550.
8. Mc Murtry MR, Sanders DC, Cure JD, Hodson RG, Haning BC, Amand PC. Efficiency of water use of an integrated fish and vegetable co-culture system. Journal of the World Aquaculture Society. 1997; 28:420-428.
9. Nelson RL. Aquaponic Food Production. Nelson and Pade Inc. Press, 2008, 218.
10. Piedrahita RH. Reducing the potential environmental impact of tank aquaculture effluents through intensification and recirculation. Aquaculture. 2003; 226:35-44.
11. Rakocy JN, Masser MP, LosordoT M. Recirculating aquaculture tank production system: Aquaponics - integrating fish and plant culture. Southern regional aquaculture centre. SRAC. 2013; 454:1-16.
12. Roosta H, Mohsenian Y. Effects of foliar spray of different Fe sources on pepper (*Capsicum annuum* L.) plants in aquaponic system. Scientia Horticulturae. 2012; 146:182-191. Sawyer, Colorado aquaponics.
13. Shanbhag R, Ashram V. Effect of Aquaponics system on yield of Polyhouse cucumber (Multistar Variety), 2013.