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Aquaponics:

refers to any system that combines conventional aquaculture (raising aquatic animals such as snails, fish, crayfish or prawns in tanks) with hydroponics (cultivating plants in water) in a symbiotic environment. In normal aquaculture, excretions from the animals being raised can accumulate in the water, increasing toxicity. In an aquaponic system, water from an aquaculture system is fed to a hydroponic system where the by-products are broken down by nitrifying bacteria initially into nitrites and subsequently into nitrates that are utilized by the plants as nutrients. Then, the water is recirculated back to the aquaculture system.

As existing hydroponic and aquaculture farming techniques form the basis for all aquaponic systems, the size, complexity, and types of foods grown in an aquaponic system can vary as much as any system found in either distinct farming discipline

A commercial aquaponics system:

An electric pump moves nutrient-rich water from the fish tank through a solids filter to remove particles the plants above cannot absorb. The water then provides nutrients for the plants and is cleansed before returning to the fish tank below.

Parts of an aquaponic system:

Aquaponics consists of two main parts, with the aquaculture part for raising aquatic animals and the hydroponics part for growing plants. Aquatic effluents, resulting from uneaten feed or raising animals like fish, accumulate in water due to the closed-system recirculation of most aquaculture systems. The effluent-rich water becomes toxic to the aquatic animal in high concentrations but this contains nutrients essential for plant growth.[15] Although consisting primarily of these two parts, aquaponics systems are usually grouped into several components or subsystems responsible for the effective removal of solid wastes, for adding bases to neutralize acids, or for maintaining water oxygenation.

Typical components include:

Rearing tank: the tanks for raising and feeding the fish

Settling basin: a unit for catching uneaten food and detached biofilms, and for settling out fine particulates

Biofilter: a place where the nitrification bacteria can grow and convert ammonia into nitrates, which are usable by the plants.

Hydroponics subsystem: the portion of the system where plants are grown by absorbing excess nutrients from the water.

Sump: the lowest point in the system where the water flows to and from which it is pumped back to the rearing tanks.

Depending on the sophistication and cost of the aquaponics system, the units for solids removal, biofiltration, and/or the hydroponics subsystem may be combined into one unit or subsystem,[15] which prevents the water from flowing directly from the aquaculture part of the system to the hydroponics part.

By utilizing gravel or sand as plant supporting medium, solids are captured and the medium has enough surface area for fixed-film nitrification. The ability to combine biofiltration and hydroponics allows for aquaponic system, in many cases, to eliminate the need for an expensive, separate biofilter.

Live components:

An aquaponic system depends on different live components to work successfully. The three main live components are plants, fish (or other aquatic creatures) and bacteria. Some systems also include additional live components like worms.

A Deep Water Culture hydroponics system where plant grow directly into the effluent rich water without a soil medium. Plants can be spaced closer together because the roots do not need to expand outwards to support the weight of the plant.

Plant placed into a nutrient rich water channel in a Nutrient film technique (NFT) system

Spinach seedlings, 5 days old, by aquaponics

Plants:

Plant placed into a nutrient rich water channel in a Nutrient film technique (NFT) system
Many plants are suitable for aquaponic systems, though which ones work for a specific system depends on the maturity and stocking density of the fish. These factors influence the concentration of nutrients from the fish effluent and how much of those nutrients are made available to the plant roots via bacteria. Green leaf vegetables with low to medium nutrient requirements are well adapted to aquaponic systems, including chinese cabbage, lettuce, basil, spinach, chives, herbs, and watercress.

Spinach seedlings, 5 days old, by aquaponics
Other plants, such as tomatoes, cucumbers, and peppers, have higher nutrient requirements and will do well only in mature aquaponic systems with high stocking densities of fish.

Plants that are common in salads have some of the greatest success in aquaponics, including cucumbers, shallots, tomatoes, lettuce, chilis, capsicum, red salad onions and snow peas. Some profitable plants for aquaponic systems include chinese cabbage, lettuce, basil, roses, tomatoes, okra, cantaloupe and bell peppers.

Other species of vegetables that grow well in an aquaponic system include watercress, basil, coriander, parsley, lemongrass, sage, beans, peas, kohlrabi, taro, radishes, strawberries, melons, onions, turnips, parsnips, sweet potato, cauliflower, cabbage, broccoli, and eggplant as well as the choys that are used for stir fries.

Filtered water from the hydroponics system drains into a catfish tank for re-circulation

Fish (or other aquatic creatures):

Freshwater fish are the most common aquatic animal raised using aquaponics due to their ability to tolerate crowding, although freshwater crayfish and prawns are also sometimes used.
There is a branch of aquaponics using saltwater fish, called saltwater aquaponics. There are many species of warmwater and coldwater fish that adapt well to aquaculture systems.

In practice, tilapia are the most popular fish for home and commercial projects that are intended to raise edible fish because it is a warmwater fish species that can tolerate crowding and changing water conditions. Barramundi, silver perch, eel-tailed catfish or tandanus catfish, jade perch and Murray cod are also used. For temperate climates when there isn't ability or desire to maintain water temperature, bluegill and catfish are suitable fish species for home systems.

Koi and goldfish may also be used, if the fish in the system need not be edible.

Other suitable fish include channel catfish, rainbow trout, perch, common carp, Arctic char, largemouth bass and striped bass.

Bacteria:

Nitrification, the aerobic conversion of ammonia into nitrates, is one of the most important functions in an aquaponic system as it reduces the toxicity of the water for fish, and allows the resulting nitrate compounds to be removed by the plants for nourishment. Ammonia is steadily released into the water through the excreta and gills of fish as a product of their metabolism, but must be filtered out of the water since higher concentrations of ammonia (commonly between 0.5 and 1 ppm)[citation needed] can impair growth, cause widespread damage to tissues, decrease resistance to disease and even kill the fish. Although plants can absorb ammonia from the water to some degree, nitrates are assimilated more easily, thereby efficiently reducing the toxicity of the water for fish. Ammonia can be converted into safer nitrogenous compounds through combined healthy populations of 2 types of bacteria: Nitrosomonas which convert ammonia into nitrites, and Nitrobacter which then convert nitrites into nitrates. While nitrate is still harmful to fish due to its ability to create methemoglobin, which cannot bind oxygen, by attaching to hemoglobin, nitrates are able to be tolerated at high levels by fish.

High surface area provides more space for the growth of nitrifying bacteria. Grow bed material choices require careful analysis of the surface area, price and maintainability considerations.

Operation:

The five main inputs to the system are water, oxygen, light, feed given to the aquatic animals, and electricity to pump, filter, and oxygenate the water. Spawn or fry may be added to replace grown fish that are taken out from the system to retain a stable system. In terms of outputs, an aquaponics system may continually yield plants such as vegetables grown in hydroponics, and edible aquatic species raised in an aquaculture. Typical build ratios are .5 to 1 square foot of grow space for every 1 U.S. gal (3.8 L) of aquaculture water in the system. 1 U.S. gal (3.8 L) of water can support between .5 lb (0.23 kg) and 1 lb (0.45 kg) of fish stock depending on aeration and filtration.

Ten primary guiding principles for creating successful aquaponics systems were issued by Dr. James Rakocy, the director of the aquaponics research team at the University of the Virgin Islands, based on extensive research done as part of the Agricultural Experiment Station aquaculture program.

1-Use a feeding rate ratio for design calculations
2-Keep feed input relatively constant
3-Supplement with calcium, potassium and iron
4-Ensure good aeration
5-Remove solids
6-Be careful with aggregates
7-Oversize pipes
8-Use biological pest control
9-Ensure adequate biofiltration
10-Control pH

Feed source:

As in most aquaculture based systems, stock feed often consists of fish meal derived from lower-value species. Ongoing depletion of wild fish stocks makes this practice unsustainable. Organic fish feeds may prove to be a viable alternative that relieves this concern. Other alternatives include growing duckweed with an aquaponics system that feeds the same fish grown on the system, excess worms grown from vermiculture composting, using prepared kitchen scraps, as well as growing black soldier fly larvae to feed to the fish using composting grub growers.

Plant nutrients:

Like hydroponics, a few minerals and micronutrients can be added to improve plant growth. Iron is the most deficient nutrient in aquaponics, it can be added through mixing Iron Chelate powder with water. Potassium can be added as potassium sulfate through foliar spray. Less vital nutrients include epsom salt, calcium chloride and boron. Biological filtration of aquaculture wastes yield high nitrate concentrations, which is great for leafy greens. For flowering plants with high nutrient demands, it is recommended to introduce supplemental nutrients such as magnesium, calcium, potassium, and phosphorus. Common sources are sulfate of potash, potassium bicarbonate, monoammonium phosphate, etc. Nutrient deficiency in wastewater from fish component (RAS) can be completely masked using raw or mineralized sludge, usually containing 3–17 times higher nutrient concentrations.

RAS effluents (wastewater and sludge combined) contain adequate N, P, Mg, Ca, S, Fe, Zn, Cu, Ni to meet most aquaponic crop needs. Potassium is generally deficient requiring full-fledged fertilization. Micronutrients B, Mo are partly sufficient and can be easily ameliorated by increasing sludge release. The presumption surrounding 'definite' phyto-toxic sodium levels in RAS effluents should be reconsidered – practical solutions available too. No threat of heavy metal accumulation exists within the aquaponics loop.

Water usage:

Aquaponic systems do not typically discharge or exchange water under normal operation, but instead, recirculate and reuse water very effectively. The system relies on the relationship between the animals and the plants to maintain a stable aquatic environment that experience a minimum of fluctuation in ambient nutrient and oxygen levels. Plants are able to recover dissolved nutrients from the circulating water, meaning that less water is discharged and the water exchange rate can be minimized. Water is added only to replace water loss from absorption and transpiration by plants, evaporation into the air from surface water, overflow from the system from rainfall, and removal of biomass such as settled solid wastes from the system.
As a result, aquaponics uses approximately 2% of the water that a conventionally irrigated farm requires for the same vegetable production. This allows for aquaponic production of both crops and fish in areas where water or fertile land is scarce. Aquaponic systems can also be used to replicate controlled wetland conditions. Constructed wetlands can be useful for biofiltration and treatment of typical household sewage.The nutrient-filled overflow water can be accumulated in catchment tanks, and reused to accelerate growth of crops planted in soil, or it may be pumped back into the aquaponic system to top up the water level.

Energy usage:

An aquaponics system that uses downwards movement of water and greenhouse light to reduce energy consumption.

Aquaponic installations rely in varying degrees on man-made energy, technological solutions, and environmental control to achieve recirculation and water/ambient temperatures. However, if a system is designed with energy conservation in mind, using alternative energy and a reduced number of pumps by letting the water flow downwards as much as possible, it can be highly energy efficient. While careful design can minimize the risk, aquaponics systems can have multiple 'single points of failure' where problems such as an electrical failure or a pipe blockage can lead to a complete loss of fish stock.

Fish stocking:

In order for aquaponic systems to be financially successful and make a profit whilst also covering its operating expenses, the hydroponic plant components and fish rearing components need to almost constantly be at maximum production capacity. To keep the bio-mass of fish in the system at its maximum (without limiting fish growth), there are 3 main stocking method that can help maintain this maximum.

Sequential rearing: Multiple age groups of fish share a rearing tank, and when an age group reaches market size they are selectively harvested and replaced with the same amount of fingerlings.[15] Downsides to this method include stressing out the entire pool of fish during each harvest, missing fish resulting in a waste of food/space, and the difficulty of keeping accurate records with frequent harvests.

Stock splitting: Large quantities of fingerlings are stocked at once and then split into two groups once the tank hits maximum capacity, which is easier to record and eliminates fish being "forgotten". A stress-free way of doing this operation is via "swimways" that connect various rearing tanks and a series of hatches/moving screens/pumps that move the fish around.

Multiple rearing units: Entire groups of fish are moved to larger rearing tanks once their current tank hits maximum capacity. Such systems usually have 2–4 tanks that share a filtration system, and when the largest tank is harvested, the other fish groups are each moved up into a bigger tank whilst the smallest tank is restocked with fingerlings. It is also common for there to be several rearing tanks yet no ways to move fish between them, which eliminates the labor of moving fish and allows each tank to be undisturbed during harvesting, even if the space usage is inefficient when the fish are fingerlings.

Ideally the bio-mass of fish in the rearing tanks doesn't exceed 0.5 lbs/gallon, in order to reduce stress from crowding, efficiently feed the fish, and promote healthy growth.

Disease and pest management:

Although pesticides can normally be used to take care of insects on crops, in an aquaponic system the use of pesticides would threaten the fish ecosystem. On the other hand, if the fish acquire parasites or diseases, therapeutants cannot be used as the plants would absorb them. In order to maintain the symbiotic relationship between the plants and the fish, non-chemical methods such as traps, physical barriers and biological control (such as parasitic wasps/ladybugs to control white flies/aphids) should be used to control pests.

The most effective organic pesticide is Neem oil, but only in small quantity to minimize spill over fish's water.