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Aquaponics

Feeding the world – with fish poo!

Key words
aquaponics
aquaculture
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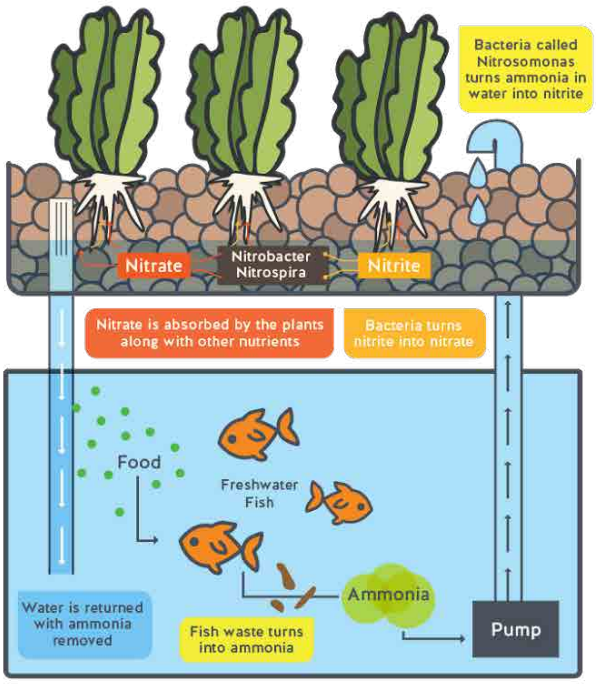
nitrogen cycle

Living organisms have an essential need for nitrogen to build proteins and nucleic acids (such as DNA). Most modern, intensive agricultural systems rely on heavy inputs of nitrogen fertilisers. Producing these requires large amounts of fossil fuels, and so there is an urgent need for more sustainable methods to source nitrogen for crops. Aquaponics is a potential solution that could help minimise the environmental costs of producing enough food to feed the growing population.



A basic aquaponics system

What is aquaponics?

Put simply, aquaponics is the combination of aquaculture (farming aquatic animals or plants) with hydroponics (growing plants without soil). A problem with conventional aquaculture, such as commercial fish farms, is that waste excretions from the animals accumulate in the water and can reach toxic levels. In aquaponic systems, the water containing these excretions is fed to hydroponically grown crops to provide a source of nitrogen (see diagram, left). Instead of using soil, the crops are either grown in a substrate, such as gravel or coconut fibre, or suspended so that their roots grow into pipes or a tank containing running water.

However, the plants cannot use the waste products directly and so require an intermediate organism to break them down first. Hence, the waste water from the fish enclosure is first pumped to a tank containing the bacteria *Nitrosomonas* and *Nitrobacter* which convert the wastes to nitrite and then nitrates as part of the nitrogen cycle (the processes which transfer nitrogen between living organisms and the environment). The water is then pumped to the plants, which filter out the waste products. Afterwards the water is returned to the fish tank, creating a self-sustaining cycle. Because the water is effectively recycled, the plants in an aquaponic system need considerably less irrigation than conventionally grown crops (as low as 2%). Growing the crops hydroponically also reduces the risk of soil-borne plant diseases, reducing the need to apply toxic chemicals.

The basic principles of aquaponics have been practised for thousands of years: one of the earliest examples is the chinampas (floating islands) developed by the Aztecs. Here, plants were grown on stationary or moveable islands in the lake shallows, and were fed using waste water dredged from the canals of the surrounding cities.

Where will it work?

A key advantage of using aquaponics is that it can be adapted to a wide range of climates and agricultural systems. It is particularly popular in Asia and Australia, and is growing in popularity in the USA and in Europe. Because of the low water demands, aquaponics can even be done in urban spaces or land that would otherwise be unproductive, such as rooftops or warehouses (see Box right). There is also a huge variety of plant/fish combinations that can be used. Green leafy vegetables, such as lettuce, spinach and herbs grow particularly well in aquaponics systems, as these typically have low-medium nutrient requirements. Plants that need higher levels of nutrients (e.g. tomatoes, cucumbers and peppers) can also be grown however these may require a higher density of fish.

Crops growing using aquaponics at the WeGrow.Social Project at the University of Sheffield

One of the most popular fish species for aquaponics systems is Tilapia, a fast-growing, edible fish that can be harvested for food. In Britain, where the climate is too cold to use Tilapia outside a greenhouse, freshwater fish such as carp, rainbow trout and perch are used instead or ornamental fish such as goldfish. As for the bacteria, *Nitrosomonas* and *Nitrobacter* are naturally abundant in the environment and will generally seed themselves into a standing body of water.

The Bristol Fish Project

The Bristol Fish project is one example of an urban-based aquaponics system, being located inside a warehouse formerly used for spraying paint on cars. Alice-Marie Archer, founding director of the project, says, "We work with critically endangered *Anguilla anguilla* (European eels) as part of international conservation efforts and we plan on growing wasabi and watercress. As a community-supported farming model, people can get involved at different levels with the day to day farming. We also teach aquaponics so that other communities can start their own projects."

Newly installed tanks at the Bristol Fish Project; elvers (young eels) ready to grow

Challenges and opportunities

Given that aquaponics could help us to grow more food without fertilisers, why is it not more commonplace? Hamish Cunningham, a Professor at the University of Sheffield explains that because aquaponics is a 'three-way balanced ecosystem', it

can be tricky to get all the elements exactly right. The basic inputs are water, oxygen, light, fish food and electricity to pump and oxygenate the water. However, many other factors can affect the system, including the air and water temperature, the pH, the humidity level and the water flow rate.

It takes real skill and knowledge to keep an aquaponic system working effectively. Currently, aquaponic farms require regular maintenance to check the physical conditions and the health of the fish and plants. As part of the WeGrow.social team, who are investigating new methods to grow sustainable food locally, Hamish is developing ways to automatically monitor and control the conditions in aquaponics systems. One of their latest creations is the WaterElf, a micro-controller with built-in sensors that can monitor various parameters including the pH, temperature, water depth, light and humidity levels. If the conditions change, the WaterElf can activate 16 electrical sockets, which can be connected to fans, pumps, lights, etc., to make sure the conditions stay within a certain range. Technology such as the WaterElf could eventually allow aquaponics systems to be grown with minimum supervision.

The WaterElf - a device that automatically monitors conditions in aquaponic systems

Another factor to consider is the cost: currently, it is no cheaper to use aquaponics than conventional agricultural methods, mainly due to the need to supply fish food. But scientists are investigating whether waste food could be used to feed the fish instead. One potential method uses the larvae of black soldier flies. As Hamish explains, "The larvae are voracious eaters and consume food waste very quickly, producing a protein which is appropriate for fish diets." The initial cost of setting up an aquaponics system can be high but it is possible to construct systems using recycled materials, such as former shipping containers or even old bathtubs.

Finally, lack of knowledge and awareness is also a barrier to aquaponics becoming more commonplace. However aquaponics farmers are starting to form virtual hubs where they can advise one another and exchange ideas. Meanwhile, there is an increasing number of aquaponics demonstrations and courses which the public can visit to see how it works.

Growing resilience

In a world facing increasing uncertainty due to climate change, rapidly growing populations and environmental degradation, aquaponics could help to increase the resilience of our food supplies. "One of the most interesting and useful things we can do is to start growing more food locally so that we have supply chains that are under our control and more predictable in the face of chaos and confusion," says Hamish. It has already been demonstrated that aquaponics can be a powerful means to help communities improve food security.

Eman Nofal collects vegetables from her rooftop garden in the Gaza Strip, part of an aquaponics scheme developed by the United Nations.

One example concerns the Gaza Strip, an area of great conflict and poverty between Israel and Egypt. Here, the Food and Agriculture Organisation of the United Nations has been installing rooftop gardens connected to fish tanks. These have helped to provide a source of fresh vegetables and protein for some of the most impoverished families and are particularly suitable for female-headed households as they require little physical effort to maintain.

Given the many challenges that humanity faces, it's likely that we will need a whole range of approaches to secure the harvests of tomorrow, rather than a single magic 'silver bullet'. But aquaponics certainly looks like a promising method that deserves to be taken up more widely.

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Look here!

Have a look at Aquaponics in action:

Bioaquafarm: 'The biggest aquaponic trout farm in Europe', near Bristol: *http://bioaquafarm.co.uk/*

The Incredible Aqua Garden, Todmorden, West Yorkshire: *https://incredibleaquagarden.co.uk/*

Humble by Nature, near Monmouth in the Wye Valley in South Wales, and run by the BBC presenter Kate Humble: *http://www.humblebynature.com/*