Aquaponics: The integration of recirculating aquaculture and hydroponics

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As the title suggests, aquaponics is the integration of two, separate, established farming technologies - recirculating fish farming and hydroponic plant farming. All aquaculturists know that fish release waste in two forms; solids and dissolved gasses. In a recirculating situation, solids are removed quickly from the system. However, the dissolved proportion remains within the water in the system. If left unchecked, these dissolved wastes will build up in the system to a point where some water must be exchanged. The exchange of system water within recirculating systems is required because, if left to build up, several situations harmful to the fish may result, such as osmotic stress from a high dissolved salt concentration.

The release of a waste stream of water from a recirculating aquaculture system (RAS) is probably the number one environmental impact of the system. In addition, in countries such as Australia, water is becoming a commodity that is in short supply and water prices are rising all the time.

The obvious way to counteract these two disadvantages, wastewater release and a requirement for new water, is to find a way to utilize the waste nutrients that are accumulating within the RAS. Historically, many RAS farmers have looked to bacterially mediated methods to counteract salt accumulations. This methodology basically consists of creating a chamber in-line to the RAS water flow in which anaerobic bacteria are grown. These anaerobic bacteria utilize nitrate as a food source and metabolize it to release nitrogen gas as an end prduct. Then the nitrogen gas is bled out of the system, thus counteracting waste nutrient buildup from nitrogenous compounds. However, the metabolism of feed by the fish also produces other waste nutrients, which sometimes cannot be converted to a gaseous form by the anaerobic digester and, therefore, remain within the system.

A better approach to removing waste nutrients is to expose them to something that will utilize the entire suite of nutrients produced with the RAS. This is where plants and hydroponics come into the picture.

Hydroponics is the water-based culture of terrestrial plants. Many people will be familiar with hydroponic tomatoes and lettuce, inasmuch as they are readily available in supermarkets. In fact, many of the vegetables we eat can be produced hydroponically. In some countries, The Netherlands for instance, hydroponics is becoming a principle method for the production of fresh vegetable produce. Hydroponic producers go to great lengths and expense to provide a profile of nutrients perfect for the vegetable crop being grown. The nutrients used in hydroponics are inorganic salts that are purchased and added to the water.

Aquaponics simply makes the connection between the fact that RAS fish farming produces waste nutrients and hydroponics utilizes nutrients for plant production. Because both systems are water-based, integration is a logical step.

A challenge of this integration is that fish do not produce the perfect nutrient profile for plant culture. This is because fish feed is formulated for efficient fish growth and not for efficient plant growth. Research has been going on with regard to this for approximately 30 years. The approach that has been adopted until recently was that nutrients should still be allowed to accumulate in aquaponic systems because this gives the plants access to the limiting nutrients.

I have recently finished a four-year study of aquaponics at RMIT University in Melbourne, Australia. I decided to take a different approach to this problem inasmuch as I wanted the highest efficiency possible from the aquaponic system in terms of removing as much nutrient from the RAS water as possible. My research centered on examining a number of parameters within the aquaponic system and optimizing them to achieve the end point of removing as much nutrient as possible. My optimization studies demonstrated that it is possible to remove close to 100 percent of the waste nutrients within a RAS by utilizing hydroponic plant production as the nutrient removal method.

I have now built a small, commercial scale aquaponic system outside of Melbourne to further this research and to try and prove the commercial viability of aquaponic integration. We have now run this system for 18 months in a start up phase situation, meaning that we are only at about 40 percent of system capacity in terms of fish and plant production.

This commercial enterprise has allowed me to draw the following conclusions for aquaponics within Australia at a commercial scale:

- The system has run for 18 months and we have not released any wastewater; conductivity at present is around 850 µS/cm which is equivalent to a nitrate level of approximately 100 ppm,
- Replacement water lost via plant evapotranspiration, amounts to an average of 80 L/day. This equates to 0.4 percent of system volume per day for a 20,000 L system,
- Up to 50 kg of plant material is produced per week on a

daily fish feed ration of approximately 800g and,

- We produce two crops; fish and plants, which gives us two income streams from one input (fish feed).

Advantages of aquaponics are:

- Little water use,
- Zero environmental impact, no wastewater discharge,
- The production of two income-producing crops,
- Very small environmental footprint, high density farming and,
- Ability to be located close to end users, lowering transportation costs.

I am sure the list goes on, but the above listed advantages are exceptional in their own right.

There are specific management procedures required to integrate fish and plant production for maximum yields. However, fish farmers are in a perfect place to adopt aquaponic technologies and methodologies because they already have a good understanding of water chemistry, the key factor to success.

Any plant that can be cultured in hydroponics can be grown aquaponically. Research by myself and others has shown that aquaponically grown plants grow as well as, or better than, those grown hydroponically. This is because a complex ecosystem is created in aquaponic systems. This ecosystem contains chemicals excreted by the fish that are advantageous to the plants and vice versa. It is a truly amazing sight to see a hot house full of healthy plants that are growing on the nutrients provided by fish culture.

As all recirculating fish farmers appreciate, there now exists an economic reality to RAS farming; an economy of scale is involved. This means that a certain amount of fish needs to be produced for the enterprise to be successful and profitable. At present, in Australia this amounts to a minimum of approximately 1 t of fish produced per week. Because of this, RAS has quickly become an enterprise for those with large amounts of startup capital. This means that small-scale operators effectively have been excluded from RAS fish culture.

My business has been set up with a simple approach: if fish production can be self sustaining economically with fish sales covering the cost of running the business, then nutrients for plant production are provided basically for free and plant sales represent clear profit. In my system, the running costs include the following:

- Power
- Fish feed
- Buffers
- Seedling production

While we are not realizing large profits at present, the small amount of fish we produce adequately cover the running costs of the business and plant sales amount to clear profit. When we reach full production, the business should realize at least US$87,868 in profit per year. This may seem small, however, this will be achieved off a land area the size of a standard tennis court, with around two days work per week!

This is not to say that aquaponics doesn't have an application in large business models. I am presently in discussions with people who are interested in supplying nutrient to a plant production area of approximately 30 hectares! Surprisingly, this area of plant production will only require a relatively small amount of fish production. In addition, by adopting aquaponic technology, the business will negate the legal, environmental and economic problems associated with wastewater release and freshwater supply.

Who can adopt aquaponic methodologies? Any existing RAS growing freshwater fish may adopt aquaponic technology. This is easily achieved by adding the appropriately sized hydroponic component to the RAS and adopting the appropriate management principles. In the case of large, economically viable RAS, this means that additional profits are realized on top of the profits already being realized by the fish operation.

Hydroponic farmers who also have all the skills and knowledge to run an aquaponic system also may adopt aquaponics as a system for fish and plant production. In this case, farmers are often attracted initially by the economic benefits; nutrients are provided for free! Large hydroponic farms have a large cost associated with the purchase of the nutrient salts needed for production. In addition, aquaponics negates the problems of waste nutrient disposal that hydroponic farms presently have to deal with.

Hydroponic and RAS farmers often ask me, what about being able to manipulate the nutrient profile so I can meet the different nutrient requirements that vrious plant species need? This is an area of aquaponics that I have been concentrating on. I am now confident that I have developed management techniques and methodologies that enable me to manipulate nutrient profiles to whatever the specific plant being cultured requires.

If the peoples of the world are fair dinkum (an Australian term meaning "serious ") about caring for their global environment, then the future of aquaponics will be secure, because to my mind, it is one of only a few farming systems that are presently available to truly meet the requirements of environmental sustainability.

Notes

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Attention all WAS members —

Please join us at the annual WAS Business Meeting to be held in conjunction with WORLD AQUACULTURE 2009 in Veracruz, Mexico.

The meeting will be held Monday, May 25, 4 to 5 p.m. in Room Olmeca #7 in the World Trade Convention Center.