Ten Guidelines for Aquaponic Systems

By James Rakocy

I want to extend my congratulations to Rebecca Nelson and John Pade for the creation of Aquaponics Journal and their sustained effort in maintaining this highly informative periodical for 10 years. They have provided a tremendous service to aquaponic enthusiasts and have been very instrumental in the advancement of this exciting new industry. To signify their achievement, I compiled a list of 10 guidelines for aquaponic systems. They are not listed in their order of importance. All of them are important.

1. Use a feeding rate ratio for design calculations

In a correctly designed and balanced aquaponic system the ratio between fish and plants is based on the feeding rate ratio. The feeding rate ratio is the amount of feed fed to the fish daily per square meter of plant growing area. For a raft hydroponic system the optimum ratio varies from 60 to 100 g/m^2/day. For example, if the fish are being fed 1,000 g per day on average, the area devoted to hydroponics production should be 16.7 m^2 for a feeding rate ratio of 60 g/m^2/day. Conversely, if 200 m^2 are devoted to plant production, then the fish tanks, tank volumes, fish stocking rates, and production schedules should be manipulated in such a way as to achieve average daily feed input to the system of 20,000 g (44 lbs) if a feeding rate ratio of 100 g/m^2/day is desired. The optimum feeding rate ratio depends on many factors such as type of hydroponic system, plants being cultivated, chemical composition of source water and percentage of system water lost during solids removal. The optimum feeding rate ratio for a nutrient film technique hydroponic system is roughly 25% of the ratio used for a raft system.

2. Keep feed input relatively constant

There are two methods for keeping feed input to an aquaponic system relatively constant. One method involves the use of multiple fish rearing tanks and staggered production. The UVI aquaponic system has four tilapia rearing tanks. The production cycle for tilapia requires 24 weeks. The tilapia in each tank are at different stages of grow so that one of the four tanks can be harvest every 6 weeks. When a tank is harvested and restocked with fingerlings, the overall feed input to the system drops by 25 to 30% and then gradually increases to maximum input over 6 weeks. Although feed input and nutrient levels fluctuate, the fluctuation is moderate. With only one fish rearing tank in an aquaponic system, upon harvest and restocking the feed input would decline by 90% and slowly increase to maximum input over 24 weeks. Nutrient levels would be low at stocking and excessive at harvest, resulting in poor plant performance.

Another method to maintain relatively constant feed input is to stock the sole fish rearing tank with multiple size groups of fish. Using tilapia and a 6-month growout period as an example, the fish rearing tank would have 6 size groups of fish. Each month a grader bar would be pulled through the tank to remove the largest fish. An equal number of fingerlings would be restocked after each partial harvest. The feeding rate would fluctuate only moderately during each monthly cycle. This system is very conservative of space and reduces capital costs, but there are two disadvantages. Grading the entire fish population monthly is hard on the fish and causes a minor amount of mortality. Stunted fish escape capture and remain in the system for a long time, which represents a waste of feed.

3. Supplement with calcium, potassium and iron

Plants require 13 nutrients for growth, and fish feed supplies 10 nutrients in adequate quantities. However, levels of calcium, potassium and iron in aquaponic systems are generally too low for good plant growth and must be supplemented. In the UVI system, calcium and potassium are supplemented by adding basic compounds (calcium hydroxide and potassium hydroxide) to adjust pH. Iron is added as a chelated compound, a compound in which iron is attached to an organic structure that prevents it from precipitating out of solution.

4. Ensure good aeration

The fish, plants and bacteria in aquaponic systems require adequate levels of dissolved oxygen (DO) for maximum health and growth. DO levels of 5 mg/liter or higher should be maintained in the fish rearing tank and in the water surrounding plants roots. It is also essential to maintain healthy populations of nitrifying bacteria, which convert toxic levels of ammonia and nitrite to relatively non-toxic nitrate ions. Ammonia is secreted by fish mainly through their gills. One genus of bacteria (*Nitrosomonas*) converts ammonia to nitrite while another genus of bacteria (*Nitrobacter*) converts nitrite to nitrate. Oxygen is required for these chemical transformations, a process known as nitrification.

5. Remove solids

Approximately 25% of the feed given to fish is excreted as solid waste, based on dry weight. However, the wet weight of solid waste is considerably greater. It is advisable to remove this solid waste from the flow steam through filtering or settling before it enters the hydroponic component. If solids are not removed, they will adhere to plant roots, decrease oxygen levels as they decay and affect the uptake of water and nutrients. Excess solids will also have an adverse effect on nitrifying bacteria. Moreover, as solids decompose, oxygen is consumed and ammonia is produced.

6. Be careful with aggregates

Aggregates such as pea gravel, sand and perlite are excellent media for growing plants in hydroponic systems. However, the solid organic matter generated in aquaponic systems can clog aggregate media and channelize water flow. Water will not flow through the clogged areas, which will become anaerobic (without oxygen) as the organic matter decomposes, thereby killing plant roots. Even if particulate organic matter is removed from the flow stream prior to entering the hydroponic component, aquaponic system water contains substantial amounts of dissolved organic matter that promote the growth of bacteria and other organisms. Bacteria growth also results during the nitrification process. Accumulated dead and living bacteria can also clog aggregate media. If aggregate media is used, generally the fish stocking rate and organic loading rate (feed) must be reduced.

7. Oversize pipes

Use oversized pipes to reduce the effects of biofouling. The same principle that applies to aggregate media applies to pipes. High levels of dissolved organic matter in aquaponic systems promote the growth of filamentous bacteria inside pipes and restrict flow. Spaghetti tubes for water delivery to individual plants will most likely clog, stopping the flow completely. Even 4-inch drain lines from fish rearing tanks can restrict water flow partially due to biofouling, causing rearing tank water levels to rise. In the UVI system, a few tilapia in the clarifiers have access to the drain lines and keep them free of biofouling by swimming through them and grazing on the bacteria. Pipes that are located downstream from the solids removal component and biofilter are less likely to clog because the dissolved organic matter has been removed or reduced through biological activity in the biofilter. Lower water temperatures reduce biofouling.

8. Use biological control

Pesticides must not be used to control insects and plant diseases in aquaponic systems because many are toxic to fish and none have been approved for use in food fish culture. Similarly, most therapeutants for treating fish parasites and diseases should not be used in an aquaponic system because they may harm beneficial bacteria and vegetables may absorb and concentrate them. Biological control methods are the only option for controlling insects and diseases. Fortunately, biological control is the subject of intense investigation, and new methods are becoming available. The use of hardy fish species such as tilapia and best management practices prevents fish disease and parasite problems.

9. Ensure adequate biofiltration

After removing solids, the next stage in the treatment process of a recirculating system is biofiltration or the oxidation of ammonia to nitrate by nitrifying bacteria. In the UVI system, adequate biofiltration occurs in the raft hydroponic component. In fact, when the optimum feeding rate ratio is maintained, there is excess water treatment capacity. In aquaponic systems using nutrient film technique, the hydroponic component has less surface area for the attachment of nitrifying bacteria, and a biofilter is needed. Biofilters are also used in aquaponic systems with fish that require excellent water quality. Biofilters add a safety factor for species less hardy than tilapia.

10. Control pH

pH is referred to as the master variable because it controls many other water quality variables. One of the most important variables is the process of nitrification. Nitrification is more efficient at pH 7.5 or higher and practically ceases at pH values less than 6.0. Nitrification is an acid producing process that continually decreases pH. Therefore pH must be measured daily, and base (calcium hydroxide and potassium hydroxide) must be added to neutralize the acid. pH also affects nutrient solubility. The optimum pH for nutrient solubility is 6.5 or slightly lower. A compromise must be reached between nitrification and nutrient solubility, and therefore it is recommended that pH 7.0 should be maintained in an aquaponic system. If pH is too high, nutrients precipitate out of solution, plants display nutrient deficiencies, and growth and production decreases. If pH is too low, ammonia accumulates to levels that are toxic to fish and a different set of nutrients precipitate out of solution with similar detrimental effects of plant grow and production. Therefore, monitor and control pH.

Bonus

A wise man once said that aquaculture systems should be designed with one pump. His exact words were, "One God, one country, one pump" That man was Dean Farrell, former owner of Seagreenbio in Palms Spring, California. His entire fish farm of a few hundred thousand pounds of tilapia required just one 13-hp pump. Similarly an aquaponic system should be designed with just one pump. Pump the water from the lowest point in the system to the highest point, have these points close to each other, and let the water flow through the rest of the system by gravity. The one-pump rule saves money and aggravation.