Challenges and Opportunities for Aquaponics in the College of Tropical Agriculture and Human Resources

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One of the best kept secrets in the University of Hawaii System is the aquaculture research and extension complex that is nestled in the mauka corner of Windward Community College and State Hospital campuses. Beginning in 2009 CTAHR's aquaculture research and extension program began to include aquaponic technologies, which integrates aquaculture and hydroponic food production methods. It is currently being used as a means to address and raise awareness as to what it would take for our island state to become self reliant in producing its own food. A working model based at Windward Community College, also known as the Waimānalo Prototype (*Figure 1*), allows researchers, extension professionals and educators a means to identify the various inputs (e.g., energy, feed, micro-nutrients) and to define ways in which these can all be produced locally and renewably. "What do we do if the boat (imports) stops coming?" is the idiom coined by Richard Ha that is being used to characterize what it would take for the people of our state to live sustainably.

What is the best feed to use in my aquaponic system?

In Hawaii, the fish being grown in aquaponic systems is tilapia because of its tolerance to the various water quality parameters encountered in an aquaponic system. A common question raised by aquaponic producers is what is the best feed to use in my aquaponic system? True to our land grant mission we have done the necessary research at our WCC facility in order to provide a science based recommendation for an aquaponic producer to make an informed decision. Work done by undergraduate Marissa Lee (Molecular Biosciences and Bioengineering) compared the production of tilapia in an aquaponic setting using two commercially available feeds that differed in price, crude protein and crude fat, the results of which are summarized in Table 1. As you would expect the feed that had the higher protein content would also translate into significantly higher levels of nitrogenous waste in the form of ammonia and nitrates and underscores the paradox between aquaculture and aquaponics. While in an aquaculture setting the higher nutrient levels would actually be frowned upon and steps for their remediation would immediately be implemented. However, the higher nutrient levels are the driving force in an aquaponic setting and steps are usually taken to maximize their outputs.

Figure 1. The "Waimanalo Prototype" growing taro located at the Windward Community College Aquaculture/Aquaponics Research facility.

Table 1. Summary of comparing different feeds in the production of tilapia in an aquaponic setting.

Category	Feed 1 (35% Protein 5% Fat)	Feed 2 (45% Protein 16% Fat)
Total Ammonia-Nitrogen (ppm)	0.3 ± 0.5	2.0 ± 1.4
Total Nitrate (ppm)	31.9 ± 14.6	79.8 ± 30.9
Feed Costs ($)	$0.63/lb	$0.77/lb
Food Conversion Ratio (FCR)	0.8	1.1
Survival (%)	98.5%	98.9%
Fish Fat Content (%)	26.1%	33.2%
Harvest Density (Kg/m^3)	10.4	19.0
Net Gain ($)	$8.62	$39.60

The results indicate that the two feeds did not differ in the food conversion ratio or survival of the tilapia being grown. However, the more expensive higher protein higher fat diet did result in a significantly higher fat content implying an improvement in the quality of fish. The rate of growth was also higher using the more expensive feed driving the harvest density to almost twice that observed when using the less expensive feed. The bottom line (e.g., Net Gain) is that just considering feed costs you will make money using either feed. However, you stand to make almost four times the amount when using the more expensive feed because of the resulting faster growth rates. Lastly, did the increase in nutrients result in an improved growth in the plants? There were no differences in growth between the two kinds of lettuce (e.g., Red Sail and Manoa) that were produced. However, a significant difference in growth of Kai Choi (*Figure 2*) was observed using effluent from fish being grown on the more expensive feed. Therefore, the recommendation would be to use the feed with a higher protein and fat content in an aquaponic setting despite it also being more expensive as it will actually result in an overall cost savings in the performance of the fish and some plants.

Figure 2. Marissa Lee with the results of her aquaponics experiment.

Local Sources of Fish Food

The source of fish food remains as one of the greatest challenges facing research and extension professionals as 100% of Hawaii's commercial fish feeds is currently being imported. Under the auspices of a USDA-ARS project by-products from the generation of biodiesel are being investigated as potential resources to produce feed or feed supplements for aquatic organisms. Biofuel residues (e.g., vinasse, glycerin) are being turned into protein biomass via fungal fermentation. This effort is being headed by Dr. Samir Khanal (MBBE) and his working group with the intent of producing enough protein that can be used to formulate fish feed. In addition, work being conducted at our WCC facility focuses on turning protein based byproducts (e.g., whole fish, cafeteria waste) that are being used to produce black soldier fly grubs (Figure 3) that in turn is being used directly as a fish food to support the growth of tilapia and vegetables in the Waimanalo Prototype. This work is still in its infancy but preliminary results show that the tilapia will consume the grubs directly and both efforts clearly provides an opportunity of developing a locally produced source of fish food.

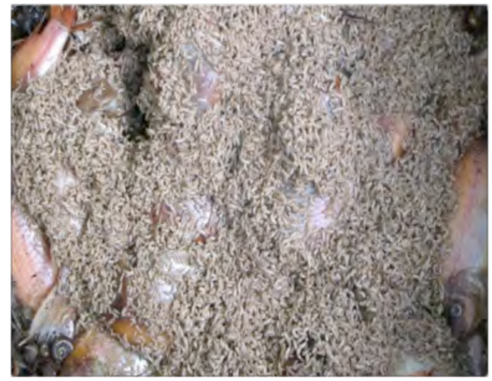

Figure 3. Black soldier fly grubs feeding on tilapia carcasses.

Figure 4. Brewing vermicast tea (top) Ted Radovich administering the tea (middle) and initial results using bak choi (bottom).

Micronutrients from vermicast tea

Fish food is the major source of the macro and micronutrients into an aquaponic system. While the system results in a steady stream of nitrogen it is limited in the amount of certain micronutrients (e.g., potassium, iron) that are key to supporting plant growth. Fortunately for us fish folks we can draw upon the expertise of CTAHR's vast network of experts with plants and our collaborative efforts with Ted Radovich (Tropical Plant & Soil Sciences) and his working group have been fruitful (no pun intended) to say the least. Our initial efforts have been revolving around the utility of using vermicastings as a source of micronutrients as it can be produced locally and consistent with the overall goal of using only homegrown products. Interestingly, the apparent effectiveness of using vermicast tea in a terrestrial setting (Pant et al., 2009) could not be duplicated at our aquaponic research facility (*Figure 4*) indicating that there is still much to be learned regarding the dynamics of nutrient extraction and uptake that are occurring in an aquaponic setting.

Technology Transfer

The work does not stop with just the development of new knowledge but must be linked with the successful transfer of those technologies to appropriate end users. Taking advantage of the fact that aquaponics farming systems can be setup irrespective of soil type, a landscaping company, Maris Garden[1], located in the highly urbanized town of Mililani in central Oahu, is an active private partner in the development of a sustainable commercial aquaponic enterprise producing fresh fish and produce on Oahu. Since the first planting in February of 2010 they have become the largest aquaponic producer of Manoa lettuce in the State (*Figure 5*). Plans to expand and diversify include aquaponically grown tomatoes and cucumbers that is already underway with a prototype system in production. Hand in hand with the diversification of plant products is the expansion and diversification of the fish crops with the recent establishment of a Chinese catfish hatchery. Staff received training from our aquaculture extension faculty in the induction of spawning (*Figure 6*) and the artificial fertilization of ovulated eggs and currently are in the process of rearing the thousands of larvae that were produced. This effort will lead to becoming self reliant in producing seed for further expansion of their Chinese catfish enterprise.

Figure 5. Growbeds of Mānoa lettuce at Maris Garden, Mililani, O'ahu.

Figure 6. Suzanne Lee and Brendon Lau injecting a Chinese catfish female.

Reaching the Next Generation

Educators make up a special stakeholder group and have taken a keen interest in the aquaponic technologies in order to develop Science Technology Engineering and Math (STEM) curriculum. Because aquaponic systems are inherently integrated in a single system both teacher and student can address the goals of a "STEM education" which offers student and teacher alike one of the best opportunities to make sense of the world holistically, rather than in bits and pieces (Lanz, 2009). As put by a science teacher already using aquaponics in the classroom students are able to grasp what were once abstract and challenging concepts (e.g., nitrogen cycle, mass balance, recycling) because they can actually see, touch, hear, smell, and even taste the various segments in an aquaponic setting. It also has become increasing apparent that our country will have a serious shortfall in the number of scientists, engineers, and mathematicians needed to keep the United States in the forefront of research, innovation, and technology and the need to develop

Figure 7: Pearl City Highlands Middle School teachers and administrators practice water quality measurements.

[1] http://www.marisgardens.com/

STEM skills has never been more apparent than it has ever been. Our aquaculture/aquaponics team has already begun to address the requests for technical assistance by collaborating on workshops conducting field site demonstrations at our WCC facility (*Figure 7*) and providing one on one consultation to various teachers involved with establishing systems on their respective campuses. We are hopeful that we will be able to continue to provide the level of assistance that meets with the expectations of the educators given the economic challenges that we are facing.

Hawaiian Homelands

Aquaponics is playing a major role in the area of strengthening communities which is a major part of CTAHR's vision and mission. Working with Ilima Ho and God's Country Waimānalo Homestead Association and Sam Moku formerly with the Department of Hawaiian Homelands, aquaponic systems have been established and being operated on several Hawaiian homesteads. The overall intent of the efforts are to increase self reliance of homeowners to produce their own food. The possibility of establishing cooperatives where families or groups can work together to develop mini enterprises is also being discussed as possible opportunities for economic development (*Figure 8*).

Figure 8: Waimanalo prototype on Kawika Kahiapo's Waimanalo Hawaiian Homestead. Left to right Bradley "Kai" Fox, Clyde Tamaru, Naholo Gramberg and Kawika Kahaiapo.

Growing Food Mending Lives

One community based aquaponic project (Growing Food Mending Lives[2]) that received recognition by Chancellor Virginia Hinshaw is the collaborative partnership between CTAHR, the State Hospital and WCC where three semi-commercial scale prototypes (*Figure 9*) were constructed on hospital grounds. The prototypes are currently operated by 25 patients where mini enterprises have been developed that generate sufficient income that the units are economically self-sustaining. However, there therapeutic value, the main reason for the project, are beginning to be appreciated and according to Tiffany Kawaguchi, director of psychological rehabilita-

Figure 9. Aquaponic unit established at the Hawai'i State Hospital.

[2] http://www.staradvertiser.com/features/20100728_Spiritual_growth.html

tion at HSH, "The aquaponic systems, although still in the 'development stage,' have had a transformative impact on our patient and staff populations alike."

The social aspect of growing your own foods using aquaponics is particularly appealing as gardening no longer is bound to the quality of soil or even the need to have soil. In addition, there are several practical aspects that favor greater adaption of growing plants particularly in an urban setting as it has a relatively small footprint, there are no weeds to deal with and if the grow beds are situated in an appropriate manner (my favorite) there is no need to bend over when working a grow bed. To top things off, the technology is consistent with the Three R's for protecting the environment, (e.g., reduces, reuses and recycles) and people can easily become engaged in this national movement by producing their own food aquaponically. Is this a spark for another green revolution? Can we revitalize agriculture in our state by raising awareness establishing aquaponics as part of the normal curriculum inside the classroom? Certainly it is an opportunity.

Citations

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