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Economics of Aquaponics

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Aquaponics in many respects is not a new technology, but the interest in growing fish and plants in an integrated, indoor system has grown rapidly in recent years. In 2012, there were 21 states that reported at least one aquaponics farm (USDA-NASS 2013), with a total of 71 aquaponics farms reported across the United States. Aquaponics farms represented 2 percent of all aquaculture farms. Of these, 75 percent had sales less than $25,000, as compared to 48 percent of pond-based operations that had sales less than $25,000. Another 14 percent had sales of $25,000 to $49,000, and 11 percent had sales of $50,000 or more. By comparison, 60 percent of pond-based operations had sales of $50,000 or more. Thus, while there is growing interest in aquaponics, most of these operations are quite small. In 2012, Florida had the most aquaponics farms (20 percent), followed by Wisconsin (10 percent), Arizona (8 percent), New York (8 percent), and Hawaii (7 percent). The average size of an aquaponics farm was largest in Hawaii (4,741 gallons), followed by Arizona (3,208 gallons), and then Wisconsin (2,004 gallons). The aquaponics farms in Florida were much smaller, with an average size of 537 gallons.

The very small size of aquaponics farms would seem to indicate that most are operated as a type of lifestyle choice or hobby, returning perhaps some supplemental revenue, rather than as full-time aquaculture businesses. This distinction is important in a discussion of the economics of aquaponics. Individuals who engage in aquaponics as a type of home gardening activity will not need to pay as close attention to costs and revenue as those who plans to support their families from aquaponics.

Aquaponics includes a wide variety of systems, plants, and fish that are combined in a variety of ways. Each system has different types and levels of costs and returns. In spite of the variability, there are three general types of systems: raft or deep water culture systems, nutrient film systems, and systems based on media-filled beds. Raft culture typically is preferred for commercial operations, while the nutrient film technique (NFT) used for hydroponics is restricted to certain types of plants (like leafy green vegetables) that do not have large, heavy root systems. Both raft and NFT systems require that solids be removed. Media-filled beds are more commonly used for home-based aquaponics gardening and require lower stocking rates than those used in raft systems.

Key Economic Considerations

Key economic considerations for any type of business include: 1) the overall investment required to construct facilities and to purchase necessary equipment; 2) the annual costs to operate the system; and 3) realistic estimates of market prices, the degree of competition in the markets to be targeted, and realistic estimates of revenue to be received. Estimating the amount of investment required is likely the easiest step when starting an aquaponics unit. Cost estimates for a greenhouse are readily available and costs for the various types of tanks, PVC, pumps, and filters are readily available from supply stores. Careful thought must go into planning for all necessary components of the business.

Annual costs to operate the system become a bit more difficult to estimate, given that many of these systems are quite new with few comprehensive analyses of their costs and returns over time. Very conservative estimates must be used, particularly for the pounds of fish that can be raised, the volume of vegetables that can be produced, and the risks involved. Power outages in the winter can result in total loss of a tilapia crop, for example. Infestations of diseases or parasites can be difficult because only

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biological controls can be used in aquaponics units, as chemicals may kill the other crops integrated into the system. It is important to underestimate somewhat the growth and yield of fish and plants and to slightly overestimate the costs. Such a conservative approach is more likely to result in a successful business plan.

The most challenging aspect of managing an aquaponics operation is to develop a realistic, accurate, and workable marketing plan. Raising fish indoors is two to three times more expensive than raising fish in open ponds. Thus, a profitable aquaponics operation will need to seek out and develop a market that will pay a higher-than-average price for the crop. An in-depth understanding of the level and type of competition in the market place is essential. For example, an individual who raises lettuce in aquaponics will need to compete with lettuce sold in Wal-Mart, in other grocery stores, and at farmers' markets. Why would an individual buy aquaponically grown lettuce, especially if it is more expensive than other types? The seller must have a clear answer to that question to be competitive.

A second marketing consideration is that the type of high-end market that will pay a premium price will also entail greater marketing costs. For example, if the freshness of the produce is a main reason for a top chef to pay a premium price for aquaponically raised herbs, that chef may want frequent deliveries to ensure that freshness. Frequent deliveries will require additional personnel, vehicles, and associated mileage expenses.

Labor requirements must also be considered. An aquaponics system requires frequent attention. Even on a small scale, aquaponics systems are complex because of their multiple components and requirements. Disease prevention, water level control, and preventing rodents and other problems require inspection and care of the system throughout the day, 7 days a week. Harvesting and packing vegetables are also quite labor intensive. Tokunaga et al. (2015) estimated that labor costs were 46 percent of total operating costs and 40 percent of total annual costs. This is quite high compared to other forms of aquaculture and prospective aquaponics managers must be certain to have an adequate supply of labor to cover these needs.

Estimates of Production Costs

The literature on the economics of aquaponics is sparse, with much of the early literature based primarily on hypothetical situations. Without realistic farm data, such projections often are overly optimistic because they lack details on expenses beyond the obvious expenses of fingerlings, feed, and utilities. However, unexpected expenses are incurred daily, from screens that clog, pumps that fail, or storms that cause damage.

The plan for an aquaponics business must also consider the percentage of the produce that will not be sold, whether this is due to insect or other damage or to times of inadequate sales that result in wasted produce. Such costs frequently are omitted from hypothetical cost analyses.

Table 1 lists estimates of production costs reported from literature that has begun to emerge on aquaponics production. Some of these take the important step of estimating the relative contribution to profitability of each crop and comparing these to prevailing market prices. The costs reported in Table 1 for aquaponically grown lettuce, tomatoes, and basil support the frequently heard anecdotes that vegetable production in aquaponics can be profitable. As shown in Table 1, the production costs of these three crops were 30 percent to 83 percent lower than the market prices reported. Basil was an especially profitable crop, given the high prices that tend to be charged for fresh herbs. However, the fish portion of the aquaponics system was not profitable, with the production costs of tilapia less than market price in only one study, and either higher or essentially the same in the others. This also is consistent with anecdotal reports that the fish portion of aquaponic systems tends to be a net loss, with profits primarily from the vegetable portion.

Table 1. Estimated costs of production of plants and fish raised in aquaponics as compared to relevant market prices (various sources).

	Literature source				
	Baker (2010)	Bailey et al. (1998)	Rakocy & Bailey (1998)		Tokunaga et al. (2015)
Location	Hawaii	Virgin Islands	Virgin Islands		Hawaii
Plant type	lettuce	lettuce	lettuce	basil	lettuce
Production cost	\$1.50/lb	\$11.14–\$12.40/case[a]	\$6.15/case	\$0.75/lb	not calculated
Market price	not reported	\$20/case	\$20/case	\$10.20/lb	\$2.15/lb
Fish type	tilapia	tilapia	tilapia	tilapia	tilapia
Production cost	\$4.99/lb	\$3.17–\$3.78/lb	\$1.46/lb	\$2.50/lb	not calculated
Market price	not reported	\$2.50/lb	\$1.46/lb	\$2.50/lb	\$5.00/lb

[a]A case of lettuce typically contains 24 heads of lettuce.

Fixed costs as a percentage of total costs in aquaponics were much lower than for many other types of aquaculture, ranging from 8 percent to 13 percent in the studies cited in Table 1. The comparatively low percentage of fixed costs indicates that economies of scale may not be as strong as they are in other forms of aquaculture because there are relatively fewer fixed costs to spread across greater volumes of production.

Before expanding an aquaponics business, the size of the market must be carefully considered. Expansion may require investment in specialized packing and chilling facilities that would proportionately increase fixed costs. However, high-value markets required for premium pricing tend to be smaller in volume. Care must be taken not to expand production beyond the quantity that can be sold at premium prices.

Economic Feasibility of Aquaponics in the U.S.

Given the overall sparseness of economic data and the inconsistency of the economic feasibility metrics used in existing literature, no clear conclusions can yet be reached as to the overall economic feasibility of aquaponics in the U.S. Table 2 summarizes what has been reported in terms of the total investment required, annual net returns (annual profit), and internal rate of return (IRR)/modified internal rate of return (MIRR) (long-term profitability of the investment). Total investment costs ranged from $58,760 to $1,020,536, depending on the scale of the operation. Annual net returns (a measure of estimated annual profit) ranged from annual losses of more than $11,000 to a profit of $278,038 (for a hypothetical large-scale system). The smaller scale systems had annual net returns that ranged from $4,222 to $30,761. Rates of return on the investment (IRR and MIRR) ranged from 0 percent to 27 percent. Of the studies reported, Tokunaga et al. (2015) is the only one based entirely on a detailed cost analysis of commercial operations. Their analysis showed an MIRR of 7.36 percent, as compared to a cost of capital of 6 percent, demonstrating economic feasibility. The Tokunaga et al. (2015) profits are lower than those of a number of other studies, but it is not uncommon for analyses with data from commercial farms to show lower levels of profitability than analyses based on hypothetical or experimental data.

Several studies (Bailey et al. 1997; Holliman et al. 2008) show that the fish portion of an aquaponics system was not profitable, but crops like lettuce and basil grown in aquaponics can be very profitable. Thus, it is important to carefully assess the owner's objectives with an aquaponics system. Considering only profitability, the hydroponic production of vegetables and other plants may be more profitable than the aquaponics production of fish. However, if the owner has other reasons for investing in aquaponics, the relative costs and returns from both the fish and the vegetable parts of the system should be considered when planning.

The studies that show greater profitability of aquaponics systems tend to be those located in areas such as the Virgin Islands and Hawaii, where fresh produce is very expensive. For an aquaponics farm to be profitable, it is imperative that a market willing to pay a premium price be found. The aquaponics business will need to compete with other locally grown and organic produce already supplied to those same markets, and an effective marketing strategy to compete successfully with those existing products must be developed.

Love et al. (2015), in an international survey of aquaponics growers, found a significant relationship between sales of non-food products from aquaponics farms and the farms' profitability. Start-up aquaponics growers may want to explore revenue sources other than just the vegetables and fish produced from aquaponics to enhance economic feasibility.

Table 2. Estimated investment costs, profitability, and returns on investment of aquaponics (various sources).

Literature source	Location	Total investment cost ($)	Profitability		
			Annual net returns ($)	Internal rate of return	Modified internal rate of return
Bailey et al. (1998)	Virgin Islands				
Large scale		$1,030,536	$278,038	22%	n.a.
Small scale		$285,134	$30,761	11%	n.a.
Chaves et al.	Scotland	$58,760	$16,701	27%	n.a.
Holliman et al. (2008)	Alabama				
Catfish		$70,640	-$11,579	n.a.	n.a.
Tilapia		$70,640	$4,222	n.a.	n.a.
Rupasinghe and Kennedy (2010)	Australia	n.a.	n.a.	0%–57%	n.a.
Tokunaga et al. (2015)	Hawaii	$217,078	n.a.	n.a.	7.36%

The Love et al. (2015) survey also showed that aquaponics locations in USDA Zones 7–13 in the U.S. were more profitable. This is thought to be related to the reduced risk of losses associated with cold weather, power outages, and utility costs.

Savidov (2004) identified several sources of production risk in aquaponics systems, particularly in the first year of operation. Prospective growers should plan for a steep learning curve as they learn to manage the complexities of several crop systems that are linked to each other and that affect one another. Among the reported sources of loss in the first year of operation were high fish mortality, nutrient deficiencies during startup, selection of cultivars not well suited to aquaponics conditions, root rot, and flooding of the facility due to problems controlling water levels.

Savidov (2004) also discussed food safety concerns expressed by consumers over aquaponics produce. In that consumer survey, respondents expressed concerns about bacterial counts in the water, whether there was adequate testing and monitoring of bacterial counts, and whether bacteria from the fish production unit would get into the vegetables. Aquaponics growers must be aware of these concerns and ensure that the vegetables and fish supplied are free of harmful substances. These concerns are more common among the types of high-end consumers who will be more willing to pay the premium prices required. Such consumers tend to be more conscious of health issues related to the produce they buy.

Summary and Conclusions

The growing popularity of aquaponics has prompted some analyses of the economics of these systems. The few studies developed to date show good potential for aquaponically produced vegetables to be profitable, with the fish portion possibly breaking even or incurring a net loss. Premium prices in high-end markets will be necessary for aquaponically produced vegetables and fish to be profitable. Additional costs and risks associated with these complex systems must be analyzed carefully before investing in aquaponics.

Suggested Readings

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