Cost/Benefit Analysis of Aquaponic Systems

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PURPOSE

The purpose of this paper is to analyse the costs and benefits of aquaponic systems designed for home use. However, one can easily extrapolate from this paper the commercial benefits of aquaponic systems in comparison to other ways of farming fish and vegetables.

Furthermore, with climate change (carbon emission), food shortages, water shortages, depleting fish stocks and increasing energy cost becoming critical problems and issues facing the world, one can see that aquaponic systems are one obvious solution to reducing their impacts.

The aquaponic systems used in this analysis are based on:

1. Those available from *Backyard Aquaponics* of Western Australia;
2. Current or most recent cost and price figures in Perth, Western Australia; and
3. Climatic conditions in and around Perth.

This paper does not intend to provide details on how to set up or use aquaponic systems. Interested readers should refer to extensive literatures on this subject available elsewhere.

I like to thank Mr Joel Malcolm, Mrs Faye Arcaro and Mr Carl Schmidt of Backyard Aquaponics, corner Jandakot Road and Berrigan Drive, Jandakot, Western Australia 6164, for the assistance rendered to me in preparing this paper. Unless otherwise stated, all figures used in this paper are provided by them or extracted from their documents.

This paper is dedicated to Mr John Brummell OAM, Coordinator Fusion Horticulture, Canberra ACT. I hope this paper will be of some assistance to him in his worthwhile effort to popularise aquaponics in Australia. In his letter to me, he stated “I am more than convinced that aquaponics is one way to go …. combat climate change …water shortages ….. food shortages…..”.

INTRODUCTION

In an aquaponic system, nutrient-rich waste water from fish tanks is used to provide plant food to vegetables and herbs grown hydroponically in grow beds. Beneficial bacteria in the grow beds convert ammonia to an available form of nutrients able to be taken up by the plants. The removal of nutrients (fish waste, algae and fish feed leftovers) from the water allows the freshly cleaned water to be recirculated back into the fish tank. A series of pipes, irrigation fittings, stands and water pump enable this.

The material inputs to the aquaponic system are essentially fingerlings (young fish), fish feed, seedlings and water (to replace loss in evaporation and transpiration and to produce fish, vegetables and herbs) while nothing is wasted.

Other cost input to the aquaponic system is power supply which is required to run the water pump and air pump.

After installation of the aquaponic system, the major effort involved is the initial establishment of the grow beds and the fish tank with vegetables and fish fingerlings respectively in the first year. Once established, the aquaponic system virtually runs by itself and less than 30 minutes a day is required to keep the system going. This mainly involves feeding the fish daily and occasionally harvesting the fresh vegetables and fish when fully grown.

I use the high ends of the cost figures and the low ends of revenue figures to arrive at the financial benefits. Hence, the return on investment may be considered conservative.

BACKYARD AQUAPONIC SYSTEMS

The main features of the aquaponic systems used in this exercise and derived power consumption and cost figures are summarised in Table 1 below:

Table 1

Backyard Aquaponics System	**The Courtyard**	**The Entertainer**	**The Backyard**	**The Family**	**The Deluxe**
No. of Grow Beds	1	2	3	4	6
Fish Tank Capacity (kL)	1	1	2	3	3
Fingerlings Tank	No	No	No	Yes	500 Litres
Water Pump Capacity (kL/hr)	3.0	3.0	4.5	8.0	8.0
Water Pump Wattage	60	60	65	250	250
Estimated Water Pump Power Consumption pa[1] (KWH)	132	132	142	548	548
Air Pump Capacity (litres per minute)	8	8	8	8	8
Air Pump Wattage	10	10	10	10	10
Estimated Air Pump Power Consumption pa (KWH)	88	88	88	88	88
Total Estimated Power Consumption pa (KWH)	220	220	230	636	636
Estimated Cost of Power pa[2]	**$39**	**$39**	**$41**	**$112**	**$112**

[1] Assume water pump runs for 15 minutes in every hour.

[2] Base on the cost of power in Perth, Western Australia, at 17.61 cents per KWH on 1st August 2009.

FISH

Fish species that are considered suitable for aquaponic systems in Western Australia, derived fish costs and market prices of live fish in Perth are summarised in Table 2 below:

Table 2

Fish Species	Silver Perch	Barramundi	Rainbow Trout	Black Bream	Goldfish
Water	Fresh	Salt or fresh	Fresh	Salt or fresh	Fresh
Growth Time of Year	All year round	**Oct – Mar**	**Apr – Sep**	All year round	All year round
Normal Growth Period (months)	10 – 12	**6 – 8**	**6 – 8**	24	-
Normal Harvesting Growth Size (gms)	500	450 – 500	450 – 500	500	-
Temperature Range	2^0C – 35^0C	15^0C – 39^0C	0^0C – 23^0C	8^0C – 33^0C	
Optimum Temperature Range	20^0C – 30^0C	27^0C	18^0C	22^0C – 24^0C	16^0C – 22^0C
Type of Pelletised Feeds	Floating or Sinking	Floating or Sinking	Floating or Sinking	Sinking	Floating
Approximate Feed Conversion Ratio (Feed : Fish)	2.00 : 1.00	**1.70 : 1.00**	**1.25 : 1.00**	(Not available)	-
Other Feeds	Omnivorous/ plant materials as adults	Carnivorous	Carnivorous	Carnivorous	Algae
Cost of Each Fingerling	$2.00 (8 cm/50gms) $1.00-$1.50 (3-4 cm)	$4.50 (300 gms)	$1.30 (10 cm/50 gms)	$4.00 - $5.00 (300 gms)	$1.30
Approximate Cost of 1 kg of Fish Feed	$3.00	$5.00	$4.00	$	$
Approximate Cost of Feed to Produce 1 Fish[3] (500 gms)	$2.70	$1.70	$2.25	$	$
Total Cost of Feed for 1 Fish (500 gms) plus 1 Fingerling	$4.70	$6.20	$3.55	$	$
Retail Price[4] of 1 Live Fish (500 gms) in Perth (Low End)	$	$12.00	$9.00	$	$

It is clear from the above figures that Rainbow Trout and Barramundi are ideally suited for aquaponics in Perth from their excellent feed conversion ratios, short growth

[3] Larger fingerlings of the respective fish available are used and the difference in weight between the fingerling and the fish is used to derive the fish feed required and hence the cost of fish feed.

[4] These are the lower end of current retail prices of respective live fish in Perth from a phone survey.

periods and complementary growing time in the year. Hence, I prepare this paper based on these two species of fish only.

COSTS

Capital Costs

The initial one time capital cost for each of the Aquaponic System is summarised in Table 3 below:

Table 3

Backyard Aquaponics System	The Courtyard	The Entertainer	The Backyard	The Family	The Deluxe
Price	$1,845	$3,100	$4,995	$7,525	$9,975
Delivery & Installation	$425	$675	$975	$1,300	$1,500
Total Cost	**$2,270**	**$3,775**	**$5,970**	**$8,825**	**$11,475**

Other Costs

Cost of Fish

In costing the fish, it is assumed that the Barramundi will be kept in the warmer months of the year (November – May/June) and Rainbow Trout will be kept in the colder months (April – October).

Table 4

Backyard Aquaponics System	The Courtyard	The Entertainer	The Backyard	The Family	The Deluxe
No. of Barramundi[5] pa	20 – 25 Average: 22	40 – 50 Average: 45	60 – 75 Average: 67	80 – 100 Average: 90	120 – 150 Average: 135
No. of Rainbow Trout pa	20 – 25 Average: 22	40 – 50 Average: 45	60 – 75 Average: 67	80 – 100 Average: 90	120 – 150 Average: 135
Cost of Barramundi at $6.20 each from Table 2 based on Average (High End)	$140	$280	$420	$560	$840
Cost of Rainbow Trout at $3.55 each from Table 2 based on Average (High End)	$80	$160	$240	$320	$480
Total Cost of Fish (Barramundi + Rainbow Trout) pa (High End)	**$220**	**$440**	**$660**	**$880**	**$1320**

[5] Assume fish are raised under favourable conditions, 40-50 fishes (Barramundi and Rainbow Trout, half each) pa per grow bed and each fish weighs 450-500 gms at harvesting.

Cost of Seedlings for Vegetables and Herbs

Table 5

Backyard Aquaponics System	The Courtyard	The Entertainer	The Backyard	The Family	The Deluxe
Cost Estimates of Seedlings pa (High End)	**$60**	**$120**	**$180**	**$240**	**$360**

Cost of Water

Table 6

Backyard Aquaponics System	The Courtyard	The Entertainer	The Backyard	The Family	The Deluxe
Estimated Evaporation and Transpiration Water Loss pa[6] (kL)	0.55	0.55	1.10	1.65	1.65
Estimated Water Consumed by fishes, Vegetables and Herbs pa[7] (kL) (High End)	0.55	1.10	1.65	2.20	3.30
Total Estimated Water Consumption pa (kL) (High End)	1.10	1.65	2.75	3.85	5.95
Estimated Cost of Water[8] (High End)	**$0.70**	**$1.10**	**$1.80**	**$2.50**	**$3.60**

*The statement from Geoff Wilson at Footnote 7 means that about **one kilo of fish and seven kilos of vegetables and/or herbs can be grown for every 22 litres of water which cost less than one cent in Perth**. One can therefore see how small is the quantity and cost of water used in an aquaponic system!*

Summary of Other Costs

[6] This is based on statements "Temperate climate evapo-transpiration water loss in aquaponics has been cut to around 0.15% a day. This means that top up of water each year is about 55% of the total water volume in the system" from Geoff Wilson, Convenor, Aquaponics Network Australia, 17th February 2006.

[7] This is based on the statement "About one tonne of fish and seven tonnes of vegetables or herbs can be grown for every 22 cubic metres (22,000 litres) of water" from Geoff Wilson, Convenor, Aquaponics Network Australia, 17th February 2006. Hence 50 fishes (Barramundi or Rainbow Trout) which weigh around 25 kgs use 550 litres of water.

[8] This is based on cost of water at 0.643 per kL in Perth, Western Australia, on 1st August 2009.

You will note that I have not included the cost on labour provided by the owner of the aquaponic system. As stated earlier, less than 30 minutes per day will be required to keep the system going. This mainly involves feeding the fish.

Table 7

Backyard Aquaponics System	The Courtyard	The Entertainer	The Backyard	The Family	The Deluxe
Estimated Cost of Power (Table 1)	$39.00	$39.00	$41.00	$112.00	$112.00
Estimated Cost Fish + Fingerlings (Table 4)	$220.00	$440.00	$660.00	$880.00	$1,320.00
Estimated Cost of Seedlings (Table 5)	$60.00	$120.00	$180.00	$240.00	$360.00
Estimated Cost of Water (Table 6)	$0.70	$1.10	$1.80	$2.50	$3.60
Total Other Costs	**$320.00**	**$600.00**	**$883.00**	**$1,234.00**	**$1,796.00**

RETURN ON INVESTMENT

Table 8

Backyard Aquaponics System	The Courtyard	The Entertainer	The Backyard	The Family	The Deluxe
Retail Value of Live Barramundi pa at $12.00 each	$264	$540	$804	$1,080	$1,620
Retail Value of Live Rainbow Trout pa at $9.00 each	$198	$405	$603	$810	$1,215
Retail Value of Vegetables and Herbs pa	$800	$1,600	$2,400	$3,200	$4,800
Total Potential Retail Revenue	$1,262	$2,545	$3,807	$5,090	$7,035
Total Potential Net Revenue	$900	$1,900	$2,900	$3,800	$5,200
Pay Back Period (years)	**2.5**	**2.0**	**2.1**	**2.3**	**2.2**

COST/BENEFIT ANALYSIS

The financial analysis shows that the Pay Back Period is approximately the same for the Backyard Aquaponic Systems and is just more than 2 years, especially for those who value fresh vegetables and live fish and are prepared to pay the market prices for them.

In addition, the aquaponic systems have the following benefits:

1. Aquaponic systems use very little water. Hence, they could be used to:
   a. Produce fresh food using very little water; and
   b. Produce fresh food in places which are short of water.
2. The owner can achieve truly sustainable farming in his own backyard.
3. The owner can have ready and immediate access to fresh vegetables and live fish at his backyard when required, i.e. he doesn't have to drive to the shop to buy them.
4. Once established, it requires very little effort and time to run the system – only effort required is to feed the fish daily.
5. The aquaponic system can be set up on a small area around the house and at the backyard, even on places that are deemed too small for home gardens.
6. Just about every household in Australia can have an aquaponic system installed in their house.
7. The owner can be sure of the health quality and freshness of the fish and vegetables that are chemical and pesticide free.
8. Comfortable working height suits disabled as well as elderly people.
9. No chemical fertiliser is used for growing vegetables and/or herbs.
10. No nutrient is wasted in aquaponics.
11. Educational benefits include teaching children how to grow food as well as care for living things.
12. No ongoing soil improvements required, saving time energy and money
13. Raised beds keep plants free from ground dwelling pests.
14. It provides a topic for conversation and entertaining guests at the backyard.
15. The owner contributes to:
    a. conservation of the scarce water resources – only use 10% of water required to grow vegetables on the ground;
    b. environmentally friendly way of growing food;
    c. cost-effective production of food locally;
    d. cost-effective use of energy;
    e. cost-effective use of idle places around the house; and
    f. climate change management.

The aquaponic system will be more cost-effective if fish feed can be cost-effectively produced locally through the use of worm farms and the like.

There is also no doubt that large scale production of fish and vegetables by aquaponic means will result in better return on investment. This can be done locally at a village, town, city or regional level to reduce transport time and cost.

RISK MANAGEMENT

Power Cuts

Fish has a high requirement for clean water and dissolved oxygen. Their survival time is determined by the size of the fish, the temperature of the water, time of day, ammonia and oxygen levels.

Hence, it is necessary to have a back up system to the power supply. This may be in the form of a generator, battery back up, solar or wind power. It is advisable for the owner to have such a backup power supply system in case of a prolonged power cut. All aquaponic systems supplied by Backyard Aquaponics comes with a battery back up to their air pump so that it can continue to run during power cuts of few hours duration each.

Water Cuts

The fish tank of an aquaponic system has to be topped up once a week in Summer. The water sources may be from the bore, scheme or rain.

Water storage may be required for an isolated location, collected in Winter and used in Summer. Water can also be trucked in if required.

There are very few such problems in the Perth Metropolitan area.

Pest

It's best to use "Integrated Pest Management" where predators and parasites are encouraged to visit an aquaponic system and help to keep a natural balance. If treatments are required, they must be fish friendly. As the beds are raised there is less chance of ground dwelling pests.

Hygiene is also important and good management practices minimise the spread of pests and diseases. This includes picking off the caterpillars and feeding them to the fish.

The washing off the soil from plant seedling roots before adding to the system also eliminates most soil borne diseases.

Treatments that may be used include the followings:

- Fungicide and bloom stimulant - Eco-rose $20.00
- Caterpillar treatment - Dipel $18.50
- Traps for aphids and whitefly - $10.00 to $20.00

- Beat-A-Bug Chili and garlic spray - $13.50
- Seasol - Seaweed concentrate - $8.20

Fish Sicknesses and Diseases

Monitoring fish behaviour could be done while feeding fish daily and one can get to know whether the fish are behaving normally or not. Signs of flashing, not eating and/or gulping at the surface are indications that something may not be right.

Management may include simple salt treatments. If only one fish is affected, it should be removed from the system. Fish introduced in stages could be quarantined first. Salt treatments for a family system are less than $10.

Breakdowns

It is advisable to have a spare pump on hand. Maintenance should include period checks to ensure back up system is working.

Establishment

Once an aquaponic system has been set up and the fish tank filled with water, it is advisable that seedlings are planted into the grow beds preceding the addition of fish. Rates for fish stocking densities are 20-25 fish per grow bed and it is best they are advanced fingerlings (around 100mm). The system will go through a natural cycle called nitrification and can be monitored and documented to track whether the system has become cycled. This process can take as little as short 4 weeks dependant on conditions and temperatures. To avoid establishment problem, these advices should be followed as far as possible.

Other Risks

1. Contamination from neighbouring sprays may be avoided by enclosing in a greenhouse to avoid and protect water quality.
2. Vandalism risk can be minimised by construction of fences to keep unwanted visitors away.
3. Birds going for the fish. Protective netting may be set up over the fish tank as well as placing a floating raft at the fish tank to allow fish a place to hide.

CONCLUSION

It is clear that aquaponics is very cost-effective for growing vegetables and raising fish at homes with numerous benefits. Moreover, aquaponics also allow families to individually contribute to overcoming worsening water and food shortages and climate change problems facing Australia and the world.

Furthermore, larger aquaponic systems could be established for villages, towns, regions, etc, to more cost-effectively serve local food needs.

Governments, businesses and individuals alike should therefore support and encourage the use of aquaponics at all levels.

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