Aquaponic System Design and Management

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What is Aquaponics?

Aquaculture

Hydroponics
Why do Aquaponics?
Aquaculture is Limited

- Water quality and quantity
- Growing Season
- Effluent mitigation
- Energy inputs
- Markets
- Feed Costs
- Fry/fingerling availability
- Labor

Where Aquaponics Can Help!
Benefits of Aquaponics

- Nutrient management/effluent mitigation
- Plants grow 2x as fast
- Year round production possible
- 75% smaller footprint
  - Less space required per plant
  - Vertical production allows more efficient use of space
- Prolonged individual plant life
- 90% Less water consumption
- Soil pathogens eliminated
- Plants can be grown at desired height
- No weeding!!!!
Where is aquaponics done?
This means we need environmental control!

- Light
- Temperature
- Humidity/Evaporation
- Air Flow
Design and Construction Considerations
Pumps

- Efficiency is key!
- Use one pump and let gravity do the rest
- Always have a backup pump!!!

**Impeller pumps**
- Inline
- Submersible
- Mag-drive

**Airlift pumps**
- Blower
- Compressor
- See “Paradigm shift with Airlift”

https://learn.extension.org/events/1064
Pipes

- Use opaque, non-collapsible PVC whenever possible
  - Prevent algae growth and flow issues
  - Paint PVC where exposed to sunlight to prolong life
- Glue PVC parts that are under pressure to avoid leaks
  - Drain side can be dry fit together for easy disassembly and cleaning
- Install check valves and Tee’s where appropriate to avoid unwanted siphons
- Oversize pipes to account for bio-fouling
- Make outflow larger diameter than inflow
ADD AERATION WHENEVER POSSIBLE!
Aids in oxygenation and off-gassing of unwanted toxins
Helps fish, plants, and bacteria perform critical biological processes

Aeration options
Diffuser stones
Venturi action
Packed columns
Waterfall action
Water

- Water is heavy!
  - ~8.35 lb/gal
  - 1 kg/L

- Take advantage of gravity flow whenever possible

- Put tanks on the ground or support them adequately with good construction materials
Tanks

Tons of choices!

- Choose the most appropriate tank for the scale of your operation
  - Tank size and shape is dependent on fish and plant species and harvest style
  - 40-gal square tanks are 20% of system volume at ISU

Popular Options

- IBC and HDPE storage tanks
- Livestock tanks
- Above-ground pools
- Poly-tanks (HDPE)
- Fiberglass
- Rubber/Plastic lined structure
Mechanical Filtration

Solids removal is critical to maintaining good water quality and flowing water

- Excessive solids harbor excessive bacteria
- Leftover feed can encourage fungus to grow
- Bio-fouling can clog pipes and lead to system failures

Options

- Filter pads
- Settling chambers/Clarifiers
- Sand and bead filters
- Screen filters
Biological Filtration

Biofiltration is critical for the conversion of toxic ammonia to the nitrate plant fertilizer

- 2-step bacterial process
- Oxygen and high surface area are critical to promoting bacterial processing
  - 1 kg of O₂ used per 1 kg feed
  - 1 kg feed → 0.03 kg ammonia
  - TAN Conversion Ratio
    - At 25°-30°C = 1.0 to 2.0 g/m²/day
    - Need 15 to 20 m²/kg feed/day

- Best to over-size the biofilter

- Options:
  - Trickling biofilter
  - Fluidized bed
  - Rotating contact biofilter
Hydroponic Unit

- Where the plants are grown
- Must maintain moisture and high oxygen concentrations for plant roots

Options:
- Floating raft
- Flood and drain
- Nutrient film technique
- Towers
- Aeroponics
Greenhouses

- Controlled environments culture
  - Take advantage of natural light
  - Control culture temperature of plants and fish
  - Extend/year-round growing season
  - Reduce pest issues
  - Increase food safety

Options:
- High tunnels
  - Least control, Least expensive
- Polycarbonate
- Glass
  - Most control, Most expensive
Supplemental Lighting

- Necessary for winter months and indoor culture
- Efficiency is critical to economic viability
- Light spectrum and photoperiod affects fruiting of plants
  - Seasonality to reproduction and growth habits
    - Basil needs long day length – 16L:8D
    - Lettuce needs short days – 12L:12D
  - Fruiting plants need certain light wavelengths to fruit
    - High pressure sodium lights promote fruiting
    - Florescent lights are fine for leafy greens
- Options:
  - High Pressure Sodium
  - Florescent
  - Halogen
  - Light Emitting Diodes (LED)
Management Considerations
Automation is nice...
...but not necessary
...there is NO substitute for physical inspection
Water Source

HAVE YOUR WATER TESTED BEFORE SETTING UP A SYSTEM!!!

Municipal Water
- May contain chlorine or chloramine – **TOXIC to fish**
- Chloramine must be broken up with a sulfur compound
  - Sodium sulfite or Sodium thiosulfate

Well Water
- May contain pesticides, contaminants, or toxins
- Will likely be low DO and high CO$_2$ – aeration necessary

Rain Water
- Low hardness and may be affected by acid rain
- May need to add ocean salt for fish osmotic balance (0.25 – 1 ppt)

Surface Water
- May contain pesticides, contaminants, or toxins
- **May contain diseases, algae, fungi, fecal coliforms, etc.**
Water Quality

Daily Testing
- Dissolved oxygen (DO)
- Temperature
- pH
- Total ammonia nitrogen (TAN)

Weekly Testing
- Nitrite
- Nitrate
- Phosphorus
- Potassium
- Iron
- Alkalinity
- Calcium hardness

[Image of a scientist in a laboratory setting]
Nutrient Deficiencies

Yellowing, reduced growth rates, and reduced flavor quality can be caused by nutrient imbalances.
Nutrient Supplementation

- **Iron**
  - Chelated Iron (EDTA)

- **Calcium**
  - Agricultural Limestone
  - Calcium Carbonate (CaCO$_3$)
  - Hydrated Lime
  - Calcium Hydroxide (Ca(OH)$_2$)
  - Calcium Chloride (CaCl$_2$)

- **Potassium**
  - Muriate of Potash
  - Potassium chloride (KCl)
  - Potassium Hydroxide (KOH)
Nutrient Supplementation Considerations

- Calculate out how much you’ll need based on active ingredient
  - i.e. – CaCl$_2$ is only 36.1% Calcium

- Use appropriate ingredient based on other chemical parameters like pH and salinity
  - pH affects plants abilities to absorb chemicals (optimal pH 6.5-7)
  - Ca(OH)$_2$ and KOH will raise pH dramatically
  - Too much chloride (>500 mg/L for lettuce) may harm plants

- Not all chemicals dissolve easily and may need to be mixed with water before adding to the aquaponic system
Pest Issues/Control

Biological Control
Disease Issues

Aeromonas

Pythium

Sporangia
Biosecurity

Preventions is best!

- No foreign water, fish, plants, nets, hands, etc.
  - Regular sterilization of surfaces and equipment

Maintaining healthy water

- Regular solids removal
- Ultraviolet light sterilization
  - No harmful byproducts!
  - Most effective in low turbidity water
  - Water must pass 50μm filter first to be effective

- O-Zone sterilization
  - Extremely effective and helps oxygenate water
  - Can be expensive and requires concentrated oxygen
  - POWERFUL OXIDIZER – USE EXTREME CAUTION
Rakocy’s Guidelines for Aquaponic Producers

1. Use a feeding ration for design calculations
2. Keep feed input relatively constant
3. Supplement with calcium, potassium, and iron
4. Ensure good aeration
5. Remove solids
6. Be careful with aggregates
7. Oversize pipes
8. Use biological control
9. Ensure adequate biofiltration
10. Control pH
11. Use only one pump
1. Use a feeding ration for design calculations

- 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.

- Ratio between fish and plants is based on the feeding rate ratio (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/m²/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 m² for a feeding rate ratio of 60 g/m²/day.
2. Keep feed input relatively constant

- **Multiple rearing tanks, staggered production**
  - four tilapia rearing tanks
  - tilapia production cycle = 24 weeks, harvest every 6 weeks
  - restock harvested tank with fingerlings
  - feed input to the system drops by 25 to 30% and then gradually increases to maximum input over 6 weeks
  - one fish rearing tank would decline nutrients by 90% and slowly increase to maximum input over 24 weeks

- **Single rearing tank with multiple size groups of fish**
  - 6-month growout tank would have 6 size groups of fish
  - monthly grading and harvest of fish
  - restock equal number of fingerlings

**Disadvantages**
- Grading is hard on the fish and mortalities result
- Stunted fish remain in the system and waste feed
Plants require 13 nutrients for growth, and fish feed supplies 10 nutrients in adequate quantities.

Limiting Nutrient in Aquaponics

- Calcium
  - Ca(OH)$_2$ - Also raises pH
- Potassium
  - KOH - Also raises pH
- Iron
  - Chelated Iron
4. Ensure good aeration

- The fish, plants and bacteria in aquaponic systems require adequate levels of dissolved oxygen (DO) for maximum health and growth.
  - Maintain DO at >5 mg/liter
5. Remove solids

- It is advisable to remove this solid waste from the flow steam through filtering or settling before it enters the hydroponic component.
  - Approximately 25% of the feed given to fish is excreted as solid waste, based on dry weight.
  - If solids are not removed:
    - Depletes dissolved oxygen
    - Clogs pipes
    - Kills nitrifying bacteria
    - Causes ammonia problems
6. Be careful with aggregates

- Organic solids may tend to clog aggregates such as pea gravel, sand and perlite
  - Creates anaerobic conditions (low DO)
  - Kills plant roots
  - Kills beneficial bacteria
  - Can be mitigated by adding worms to aggregate substrate to process organics
7. Oversize pipes

- Use oversized pipes to reduce the effects of biofouling
  - dissolved organic matter promote the growth of filamentous bacteria
    - restricts flow within pipes
  - Spaghetti tubes will likely clog
  - Tilapia in drain lines reduce biofouling by grazing on bacteria
  - Pipes downstream from solids removal are less likely to clog
  - Lower water temperatures reduce biofouling
8. Use biological control

- Pesticides must not be used to control insects and plant diseases because many are toxic to fish and none have been approved for use in food fish culture.
- Therapeutants for treating fish parasites and diseases may harm beneficial bacteria and vegetables may absorb and concentrate them.
- Biological control methods are the only option for controlling insects and diseases.
9. Ensure adequate biofiltration

- In floating raft culture adequate or excess biofiltration occurs in the raft hydroponic component.
- NFT has less surface area for the attachment of nitrifying bacteria than floating raft, 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

- Nitrification is more efficient at pH 7.5 or higher and practically ceases at pH values less than 6.0.
  - Nitrification decreases pH
  - Base (calcium hydroxide and potassium hydroxide) must be added to neutralize the acid.

- The optimum pH for nutrient solubility is 6.5 or slightly lower.
  - A compromise that pH 7.0 should be maintained in an aquaponic system.

- High pH plants display nutrient deficiencies

- Low pH ammonia accumulates to levels that are toxic to fish
11. Use only 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.
- Have a backup pump available if your primary one goes out.
How does it work?

1 - Fish Culture Tank
2 - Mechanical and Biological Filter
3 - Hydroponic Component
4 - Sump Tank with Pump
5 - Blower
Fish Tanks

- Dimensions – 50x65x74 cm
- Water Volume ~ 158 L (42 gal)
- Directional flow (1” PVC)
- Bottom outflow (1\(\frac{1}{4}\)” PVC)
- Emergency overflow (1\(\frac{1}{4}\)” PVC)
- Aeration via Airstone
  - 8x3x3 cm
- Covers (1 cm plastic mesh)
- Max fish biomass = 120 kg/m\(^3\)
Filter Tanks

- **Dimension** = 56x40x35 cm
- **Water Depth** = 3 cm
- **Biofilter Material Vol.** = 0.063 m³
  - **Bio-Fill™ – 800 m²/m³** → 51.6 m²
- **Solids filter pads**
**Plant Trays**

- Tray Dimension = 83 cm x 76 cm = 0.63 m²
- Inflow manifold = 75 cm x 35 cm
- 3 mm holes, spaced 3.5 cm
Sumps

- 50 gal stock tank
  - ~ 167 L (44 gal) capacity
- 1/3 Horsepower sump pump
- Shunt-valve
- Auto Shutoff
- Auto Refill via head tank
  - Head Tank Vol. = 170 L (45 gal)
- Nutrient supplementation
  - Iron
  - Calcium
  - Alkalinity
Implications of Substrate for Aquaponics

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Study Objectives

1. Collect baseline data
   - Fish
   - Water consumption
   - Nutrients
   - Plant production

2. Compare substrate types
Types of Growout
Nutrient Film Technique (NFT)

Rockwool
NFT Key Characteristics

- Rockwool cubes – 98% Air by volume
- Blocks 10 cm (L) x 10 cm (W) x 7.6 cm (H)
- ~1cm water depth of blocks
- Wicks up water from below
- Tray water volume = 41 L (11 gal)
Flood and Drain/Ebb and Flow
Pea Gravel
Flood and Drain Key Characteristics

- Pea Gravel from local quarry
- Diameter = 0.5 – 1.5 cm
- Flood and drain cycle = 20-30 min
Deep Water Culture
Floating Raft
Floating Raft Key Characteristics

- Water Depth = ~ 15 cm (6 in)
- Tray Volume = ~ 92 L (24 gal)
- Average Flow Rate = 6.3 L/min (1.7 gal/min)
Control – Soil
Soil Control Key Characteristics

- 4” Pots with sterile potting soil
- Submerged water depth at 3 cm
- Nutrient solution 20-20-20
  - applied at 0.2 g/L
- Tray dimensions 179x71x3.5 cm

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Percent by Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Nitrogen (N)</td>
<td>20 %</td>
</tr>
<tr>
<td>Ammonia-N</td>
<td>5.9 %</td>
</tr>
<tr>
<td>Nitrate-N</td>
<td>6.0 %</td>
</tr>
<tr>
<td>Urea-N</td>
<td>8.1 %</td>
</tr>
<tr>
<td>Phosphate (P₂O₅)</td>
<td>20 %</td>
</tr>
<tr>
<td>K₂O</td>
<td>20 %</td>
</tr>
<tr>
<td>B</td>
<td>0.02 %</td>
</tr>
<tr>
<td>Cu</td>
<td>0.05 %</td>
</tr>
<tr>
<td>Fe</td>
<td>0.12 %</td>
</tr>
<tr>
<td>Mn</td>
<td>0.06 %</td>
</tr>
<tr>
<td>Mo</td>
<td>0.0005 %</td>
</tr>
<tr>
<td>Zn</td>
<td>0.05 %</td>
</tr>
</tbody>
</table>
System Characteristics

- Average System Volume =
  - Fish Tanks ~158 L (42 gal)
  - Filter Tanks ~7 L (2 gal)
  - Sump Tanks ~167 L (44 gal)
  - Pipes ~23 L (6 gal)

  Subtotal ~355 L (94 gal)

- Plant Trays:
  - Rockwool ~41 L (11 gal) each * 4 = 164 L (44 gal)
  - Pea Gravel ~35 L (9 gal) each * 4 = 140 L (36 gal)
  - Floating Rafts ~92 L (24 gal) each * 4 = 368 L (96 gal)

<table>
<thead>
<tr>
<th>System Volume</th>
<th>Rockwool NFT</th>
<th>Pea Gravel</th>
<th>Floating Rafts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liters</td>
<td>519</td>
<td>495</td>
<td>723</td>
</tr>
<tr>
<td>Gallons</td>
<td>138</td>
<td>130</td>
<td>190</td>
</tr>
</tbody>
</table>
Lighting

- High Pressure Sodium Lamps
  - 400 watts
  - 1.5 m above tables
  - 2 per bench
  - 8 total

- Photoperiod
  - 16L : 8 D
Species Grown

Nile Tilapia
*Oreochromis niloticus*

Buttercrunch Bibb Lettuce

Italian Largeleaf Basil
Feed Used

- Zeigler Bronze
  - Floating
  - 3.0 MM Diameter
  - 35% Protein
  - 5.0% Fat
  - 4.5% Fiber

Ingredients:
Soybean meal, Wheat, Poultry By-product meal, Hydrolyzed feather meal, Fish Meal, Alfalfa meal, Soy Lecithin, Vitamin and Mineral Mix
Study Design

- **Study Period**
  - November 29, 2012 – January 13, 2013 (45 days)

- Plants germinated 2 weeks prior to stocking

- 40 All-male Tilapia stocked at 110 ± 35g per tank

- Fish Fed twice daily

- Water quality recorded every morning

- Water chemistry analyzed twice weekly

- CaCO$_3$, NaHCO$_3$, and Fe supplemented as needed

- Fish measured monthly
# Winter Water Consumption (gal)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>19 Days</th>
<th>27 Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rockwool</td>
<td>84</td>
<td>146</td>
</tr>
<tr>
<td>Raft</td>
<td>77</td>
<td>145</td>
</tr>
<tr>
<td>Pea Gravel</td>
<td>74</td>
<td>128</td>
</tr>
<tr>
<td>Control - Soil</td>
<td>14</td>
<td>19</td>
</tr>
<tr>
<td><strong>Typical RAS Culture</strong></td>
<td><strong>285</strong></td>
<td><strong>405</strong></td>
</tr>
<tr>
<td>*10% Exchange</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Assuming 150 gallons per system
## Fish Growth

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Individual Wt Gain (g)</th>
<th>Daily Growth (g/day)</th>
<th>%Growth</th>
<th>Biomass Gain (kg)</th>
<th>FCR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floating Raft</td>
<td>67.6</td>
<td>1.83</td>
<td>61</td>
<td>2.01</td>
<td>1.35</td>
</tr>
<tr>
<td>Pea Gravel</td>
<td>73.7</td>
<td>1.99</td>
<td>64</td>
<td>2.20</td>
<td>1.24</td>
</tr>
<tr>
<td>Rock-wool</td>
<td>69.1</td>
<td>1.87</td>
<td>65</td>
<td>2.17</td>
<td>1.23</td>
</tr>
</tbody>
</table>

No real differences in growth
<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Preferred&lt;sup&gt;1,2&lt;/sup&gt;</th>
<th>Pea Gravel</th>
<th>Floating Raft</th>
<th>Rockwool</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia (NH&lt;sub&gt;4&lt;/sub&gt;⁺)</td>
<td>2.2</td>
<td>0.0 - 4.97</td>
<td>0.128 - 2.04</td>
<td>0.088 - 0.856</td>
</tr>
<tr>
<td>Nitrate (NO&lt;sub&gt;3&lt;/sub&gt;)</td>
<td>0.4 - 82.2</td>
<td>20.2 - 24.2</td>
<td>35 - 111</td>
<td>25.3 - 110</td>
</tr>
<tr>
<td>Nitrite (NO&lt;sub&gt;2&lt;/sub&gt;)</td>
<td>0.7</td>
<td>0.08 - 7.54</td>
<td>0.0 - 2.14</td>
<td>0.084 - 1.42</td>
</tr>
<tr>
<td>Alkalinity (CO₃)</td>
<td>113.2</td>
<td>42 - 96</td>
<td>43 - 240</td>
<td>26 - 93</td>
</tr>
<tr>
<td>Calcium (Ca)</td>
<td>10.7 - 82.1</td>
<td>491 - 726*</td>
<td>150 - 780*</td>
<td>452 - 727*</td>
</tr>
<tr>
<td>Phosphorus (P)</td>
<td>0.4 – 15.3</td>
<td>0.807 – 4.97</td>
<td>1.68 – 40.1</td>
<td>1.05 – 6.05</td>
</tr>
<tr>
<td>Iron (Fe)</td>
<td>0.13 – 4.3</td>
<td>0.04 – 0.536</td>
<td>0.145 – 0.688</td>
<td>0.21 – 0.509</td>
</tr>
<tr>
<td>Dissolved Oxygen (DO)</td>
<td>4.0 - 5.0</td>
<td>3.29 - 8.15</td>
<td>2.55 - 8.01</td>
<td>5.0 - 8.2</td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td>29 - 31</td>
<td>19.4 - 27.6</td>
<td>21.2 - 28.8</td>
<td>17.4 - 26.9</td>
</tr>
</tbody>
</table>

* Total Hardness measured

Issues Observed

Caused by lack of flow and low DO
Results
Produce
Basil Produce Weight

The graph illustrates the comparison of basil produce weight across different substrates: Pea Gravel, Floating Rafts, Rockwool, and Soil. 

- Pea Gravel: ab
- Floating Rafts: a
- Rockwool: bc
- Soil: c

The data suggests that Floating Rafts resulted in the highest basil produce weight, followed by Pea Gravel, Rockwool, and Soil.
Lettuce Produce Weight

![Bar chart showing the produce weight for Pea Gravel, Floating Rafts, Rockwool, and Soil. The Pea Gravel category has the highest weight, followed by Floating Rafts and Rockwool, with Soil having the lowest weight. The chart includes error bars indicating variability.]

- Pea Gravel: a
- Floating Rafts: ab
- Rockwool: b
- Soil: b
<table>
<thead>
<tr>
<th>Treatment</th>
<th>Lettuce Ave. % Survival</th>
<th>Lettuce S.D.</th>
<th>Basil Ave. % Survival</th>
<th>Basil S.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rockwool</td>
<td>81%</td>
<td>0.07</td>
<td>66%</td>
<td>0.21</td>
</tr>
<tr>
<td>Pea Gravel</td>
<td>78%</td>
<td>0.21</td>
<td>22%</td>
<td>0.26</td>
</tr>
<tr>
<td>Floating Raft</td>
<td>81%</td>
<td>0.16</td>
<td>59%</td>
<td>0.26</td>
</tr>
<tr>
<td>Soil</td>
<td>88%</td>
<td>0.10</td>
<td>53%</td>
<td>0.21</td>
</tr>
</tbody>
</table>

**No Difference Between Treatments**
Total Basil Tray Production

![Graph showing basil tray biomass production for Pea Gravel, Floating Rafts, Rockwool, and Soil. Rockwool has the highest biomass with A, Pea Gravel and Soil have B.]
Total Lettuce Tray Production

The bar chart shows the total lettuce tray biomass (g) for different substrates: Pea Gravel, Floating Rafts, Rockwool, and Soil. The chart indicates that Rockwool supports the highest biomass, while Floating Rafts support the lowest. The chart also highlights that thelettuce tray biomass was measured to be:

- Pea Gravel: B
- Floating Rafts: B
- Rockwool: A
- Soil: B
Conclusions

- Which substrate is best?...
- Well...what’s your goal?
  - Largest plants
  - Best environment for fish
  - Least water consumption
  - Which earns the most money?

$ $$ $$
### Iowa Retail Prices as of 2/20/2013

<table>
<thead>
<tr>
<th></th>
<th>Lettuce</th>
<th>Basil</th>
<th>Tilapia (fillets)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retail Price ($/kg)</td>
<td>$10.96</td>
<td>$79.02</td>
<td>$15.36</td>
</tr>
</tbody>
</table>

**Average Tilapia Production Value =**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Total Weight per Tank (kg)</td>
<td>5.95</td>
</tr>
<tr>
<td>Fillet Yield (kg) (35% dressout)</td>
<td>2.08</td>
</tr>
<tr>
<td>Retail Value Per Tank ($15.36/kg)</td>
<td>$31.99</td>
</tr>
<tr>
<td>Production Value ($/m³)</td>
<td>$202.48</td>
</tr>
</tbody>
</table>
## Mean Plant Production Value ($/m²)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Lettuce</th>
<th>Basil</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pea Gravel</td>
<td>$50.45</td>
<td>$28.84</td>
<td>$79.29</td>
</tr>
<tr>
<td>Floating Raft</td>
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In March of 2012...
Average Individual Lettuce Produce Weight

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<th>Material</th>
<th>Lettuce Produce Weight (g)</th>
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<tr>
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<td>218.3</td>
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<tr>
<td>Soil</td>
<td>62.5</td>
</tr>
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<td>Pea Gravel</td>
<td>271.1</td>
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<td>Rockwool</td>
<td>210.1</td>
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## Lettuce Production Value

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Average Produce Weight (g)</th>
<th>#/tray</th>
<th>tray area (m^2)</th>
<th>Biomass (kg/m^2)</th>
<th>Retail Value ($/m^2)</th>
<th>Production Value ($/m^2)</th>
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</thead>
<tbody>
<tr>
<td>Floating Raft</td>
<td>218.3</td>
<td>8</td>
<td>0.6</td>
<td>2.91</td>
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<tr>
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<td>0.83</td>
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<td>$9.13</td>
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<tr>
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<td>3.61</td>
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<tr>
<td>Rockwool</td>
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<td>$30.70</td>
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Tilapia Harvest
# Harvest Size and Value

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<th>Treatment</th>
<th>Average weight (g)</th>
<th>Biomass (kg/m^3)</th>
<th>% Fillet Yield</th>
<th>Retail Value ($/kg)</th>
<th>Production Value ($/m^3)</th>
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<td>Pea Gravel</td>
<td>345.2</td>
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<td>Rockwool</td>
<td>376.5</td>
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<td>390.7</td>
<td>44.5</td>
<td>35%</td>
<td>$15.36</td>
<td>$239.28</td>
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Current Research
Implications of Water Exchange for Aquaponics

D. Allen Pattillo and Kailey James
Summer 2013

Channel Catfish

Results still being analyzed

Italian Large-Leaf Basil
Future Directions

- Replicate these experiments and refine results
- Evaluate other species of fish and plants
- Test LED light sources
- Evaluate economics and sustainability of aquaponics for the Midwestern United States
Questions?
Cumulative Water Usage

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<tr>
<td><strong>Density (plants/m²)</strong></td>
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<tr>
<td><strong>Retail Price ($/kg)</strong></td>
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