Aquaculture Webinar Series

Introduction: David Cline, USAS President Elect
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Aquaponics: How to Do It Yourself

Presented by:

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Fisheries & Aquaculture Extension
Iowa State University - NCRAC

Aquaponics
Recirculating Aquaculture
Pond Management
Local foods
Aquaculture Business Development

NATIONAL
Aquaculture
ASSOCIATION

North Central Regional Aquaculture Center
NCRAC
What is Aquaponics?

- Integration of:
  - Aquaculture
  - Wastewater treatment
  - Hydroponics
- Artificial ecosystem
- Closed-loop agriculture
- Low environmental impact
- High yield
Benefits of Aquaponics
Nutrient Management

- Effluent mitigation for EPA compliance
- Reduce expense of effluent filtration
- Maintains high water quality for fish
Enhanced Plant Growth

- 2x plant growth rate of soil
- Prolonged individual plant life
- Year-round production in controlled environments
Value of Plants

- Plants make up more than 75% of aquaponic production value
- Frequency and consistency of plant production aids in marketing & cash flow
Reduced Footprint

- Less space required per plant
- Vertical production allows more efficient use of space
Reduced Water Consumption

- Recirculating Aquaculture Systems
  - 5-15% daily exchange

- Aquaponics
  - 1.4% daily exchange

- Water lost in waste purging

- Potential co-products

Reduced Water Consumption
Romaine Lettuce Comparison

- Irrigated Agriculture (California)
  - 10-35 gal/m²/day

- Aquaponics
  - 2-3 gal/m²/day
  - 78-94% water savings


http://keepcaliforniafarming.org/produce/california-lettuce/
Reduced Soil Pathogens

- Most soil pathogens eliminated
- Enhanced plant growth without stress

http://forums.gardenweb.com/discussions/2090164/what-is-this-soil-pathogen-fungus
Reduced Labor Cost

- Efficiency of combined business model
- Potential for automation
- Plants can be grown at desired height
- No weeding!!!
Aquaponic Management Considerations
TEMPERATE CLIMATES

• Extreme shifts in temperatures between seasons
• Affects plants, fish, and bacterial community
• Climate control can help
• Consider seasonal production
FISH - PLANT COMBINATIONS

- Consider
  - Temperature
  - Light Conditions
  - Salinity
  - Nutrient requirements

- Water Quality Tolerance
- Market Outlets/Preference
- Availability
- Price and Economic Viability
Feed ration & System design calculations

• For a raft hydroponic system the optimum ratio varies from **60 to 100 g/m²/day.**
  • **35% Protein Feed**

• For example:
  • 1,000 g feed per day will fertilize 16.7 m² for a feeding rate ratio of 60 g/m²/day.
Fish Food has an Impact on Water Quality

- 1 kg Feed
- 0.25 - 1.0 kg Oxygen
- 0.18 - 0.4 kg Alkalinity
- 0.25 - 0.5 kg Waste Solids
- 0.35 – 1.38 kg CO$_2$
- 0.025 - 0.055 kg NH$_3$ & NH$_4$
Solids Removal

• 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
Mechanical Filtration

- Minimal clogging and automatic cleaning are ideal, but expensive

Options
- Filter pads
- Settling chambers/Clarifiers
- Sand and bead filters
- Screen filters
Water Quality

Daily Testing
- Dissolved oxygen (DO)
- Temperature
- pH

Twice Weekly Testing
- Total ammonia nitrogen (TAN)
- Nitrite
- Nitrate
- Alkalinity

Twice Monthly Testing
- Phosphorus
- Iron
- Calcium hardness
- Potassium
Biofiltration

- **Surface Area**
  - Living Space for the Nitrifying Bacteria
  - Competition for that Space

- **Food**
  - ammonia or nitrite
  - > 0.07 mg / L

- **Good Living Conditions**
  - Dissolved Oxygen going into the biofilter >4 mg/L
  - pH 7.2 – 8.8
  - Alkalinity > 200 mg / L as CaCO₃
Table 1. Relative percentage of total ammonia nitrogen (TAN) in the toxic, unionized form at a given temperature and pH

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Aeration

• The fish, plants and bacteria in aquaponic systems require adequate levels of **dissolved oxygen** maximum health and growth.

  • Maintain DO at **>5 mg/liter**
Feed Consistently

**Feed = Fertilizer**

- Multiple rearing tanks, staggered production
  - four tilapia rearing tanks
  - Stock & Harvest every 6 weeks
  - All-in/all-out production (per tank)
**Feed Consistently**

- 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

<table>
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<th>Stock</th>
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<th>Harvest &amp; Stock</th>
<th>Stock</th>
<th>Harvest &amp; Stock</th>
<th>Harvest &amp; Stock</th>
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</table>
Plants provide critical filtration!!

Single rearing tank with multiple size groups of plants

• 6-week growout time for plants will require
• Harvest plants weekly or bi-weekly
• restock equal number of seedlings
SOW SEEDS
- Week 1
- Week 2

TRANSPLANT
- Week 3
- Week 4
- Week 5
- Week 6

HARVEST
Optimal pH
6.5 to 7.2
Fish feed provides 10 out of 13 macro and micro nutrients

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

- **Calcium**
  - Calcium Carbonate (CaCO3)
  - Calcium Hydroxide (Ca(OH)2)
  - Calcium Chloride (CaCl2)

- **Potassium**
  - Potassium chloride (KCl)
  - Potassium Hydroxide (KOH)
Nutrient Deficiencies

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

Deficiencies related to source water and feed additives.
Sludge Management

• 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
Prevent Biofouling

• Use **oversized pipes** to reduce the effects of biofouling
• dissolved organic matter promote the growth of filamentous bacteria restricts flow within pipes
Prevent Biofouling

• Spaghetti tubes will likely clog - avoid

• Juvenile tilapia in drain lines reduce biofouling by grazing on bacteria

• Lower water temperatures reduce biofouling

• Periodic pressure flushing
Non-Toxic Pest 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.
PEST CONTROL

• Few safe treatments
• Prevention is best
• Consider biologicals
  • Parasitic wasps, lacewings, ladybugs...
• Diatomaceous earth
• Bt for caterpillars
Limit Electrical Usage

• Take advantage of gravity
• Lower likelihood of water flow imbalance
• Lower energy usage
• Take advantage of vertical growing opportunities
  • Maximize profit per square foot
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
Filter Tanks

• Biofilter Material
  Vol. = 0.063 m³
  • Bio-Fill™
  • 800 m²/m³
  • Total filtration surface area ~ 51.6 m²
• Solids filter pads
Plant Trays

- 30” x 32”
- 0.62 m²
Sumps

- Water Collection
- Pumping
- Nutrient supplementation
  - Iron
  - Calcium
  - Alkalinity
Species Grown

Nile Tilapia
*Oreochromis niloticus*

Barramundi
*Lates calcarifer*

Money-Maker Tomato

Italian Large leaf Basil

Buttercrunch Bibb Lettuce
Standards - Fish

• Tilapia

• Trout
Trends – Fish

• Koi
• Yellow Perch
• Barramundi
• Sturgeon
• Grass Carp (Triploid)
• Redclaw Crayfish
• Freshwater Prawn
Standards - Plants

- Lettuce
- Basil
- Herbs
- Tomatoes
- Cucumbers
- Strawberries
Trends - Plants

• Microgreens
• Edible Flowers
• Stevia
• Bok Choi
• Medicinal Herbs
Standards – Plant Growing Methods

- Floating Rafts
- Media Beds (flood & drain)
- Nutrient Film Technique (NFT)
Trends – Plant Growing Methods

- Vertical Growing Systems
- Stacked floating rafts
Standards – Systems

- Freshwater Aquaponics
- Balanced Nutrient Systems
- Feed in = Plant Uptake

Diagram:

1 - Fish Culture Tank
2 - Mechanical and Biological Filter
3 - Hydroponic Unit
4 - Sump Tank with Pump
5 - Aerator/Blower
Trends – Systems

- Decoupled Aquaponic Systems
- Independent RAS & Hydroponic Systems
- Saltwater Aquaponics
- Possible shrimp & salt-tolerant plants
Standards - Environments

• Outdoors
• Glass Greenhouse
• Basement/Garage
Trends - Environments

- Storefronts
- Warehouse
- High-Tunnel Greenhouse
- Polycarbonate Greenhouse
- Urban Settings
- Schools
Standards - Lighting

• Sunlight
• Fluorescent
• High Pressure Sodium (HPS)
Trends - Lighting

• Light Emitting Diode (LED)
• Induction

http://www.agtus.org/knowledgebase/
Trends – Electricity Source

• Solar


• Wind

http://cleantechnica.com/2014/04/21/real-innovation-wind-energy/
Trends – Heat Source

- Geothermal
- Solar
- Biological (compost)


http://smallfarms.cornell.edu/2012/10/01/compost-power/

https://en.wikipedia.org/wiki/Geothermal_heat_pump
Additional Products

- Composting worms
- Compost/worm castings
- Compost Tea
- Mushrooms
- Fish Emulsion
- Carbon Credits??
- Others??
CANNOT AQUAPONICS PROFIT?

Depends on:

• Facility Costs
• System Costs
• Operational Costs
• Revenue Streams
• Do your due diligence!
TECHNO-ECONOMIC ANALYSIS

a) Capital and operational expenditures
b) Potential revenues
c) Break-even points

http://suntrace.de/typo3temp/pics/fb74fc6358.jpg
T.E.A. OF AQUAPONICS

System boundary and flowchart
**PRODUCTION ASSUMPTIONS**

All calculations based on operational data collected during 2012-2013

Italian large leaf basil
(_Ocimum basilicum_)

Nile tilapia
(_Oreochromis niloticus_)
## T.E.A. OF AQUAPONICS

### Key Assumptions for three scales

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<th>10 X ISU</th>
<th>300 X ISU</th>
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<td>Capacity</td>
<td>Grow bed area(m²)</td>
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<td>75.6</td>
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<td>Model</td>
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<td>Fish tank</td>
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Maximum fish biomass is 120 kg/m³
As size increases, annual cost per unit area decreases exponentially (economies of scale) due to increased production efficiencies.
Annual system profits with various basil prices (for a constant tilapia sales price of $9 /kg)
Annual system profits with various basil prices (for a constant tilapia sales price of $9/kg)
CONCLUSIONS

• Economies of scale apply

  operation size, ↓ cost per unit produced, ↑ overall profitability

• Aquaponics should be profitable when:
  • Grow bed area > 75 m²
  • Basil price @ $60/kg ($27/lb)
SUPPLEMENTAL LIGHTING

• Necessary for winter months and indoor culture
• Efficiency is critical to economic viability
• Light spectrum and photoperiod affects fruiting of plants
## Economic Assessment

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<th>Category</th>
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<th>HPS</th>
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<td>Dry</td>
<td>Wet</td>
<td>Dry</td>
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<td>Ave. Harvest wt. (g/plant)</td>
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<td>Grow period (d/harvest)</td>
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<tr>
<td>Harvests/y (#/y)</td>
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<td>Plants/tray (#/tray)</td>
<td>16</td>
<td>16</td>
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<tr>
<td>Area/tray (m²)</td>
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<td>Ave. Total wt./tray (g/tray)</td>
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<td>Ave. Mass/area (g/m²)</td>
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<td>Ave. Biomass produced (g/y/m²)</td>
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<td>Light cost ($/y/tray)</td>
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<td>Market price ($/kg)</td>
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### LED Wet Basil

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<td>Wet Basil Value ($/m²/yr)</td>
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<td>$405</td>
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<td>Net Benefit ($)</td>
<td>$434.89</td>
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<td>$47.63</td>
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WHO IS RESPONSIBLE FOR SAFE FOOD?

• Producers
• Handlers
• Processors
• Food Suppliers
• Consumers

www.fightbac.org
INTRODUCTION

• Food safety is a concern
  • little is known about foodborne diseases in aquaponics systems

• Foodborne diseases
  • Annually responsible for 48 million illnesses (1 in 6 Americans)
  • Result in $77 billion economic burden annually

• Specific concern with aquaponics
  • Proximity of fish culture water to edible plant culture

http://dhhs.ne.gov/publichealth/EPI/Pages/Foodborne.aspx
INTRODUCTION

• Fish generally not regarded as a food safety threat in aquaponics
  • Temperatures of culture water are low
  • Thought that establishment of pathogens may be promoted however
    • (e.g. *Escherichia coli* or *Salmonella* spp.)

• Potential for survival and growth is really unknown

• Evaluation of this assumption is needed
FOOD SAFETY THREATS

Painter et al. 2013
WHY IS PRODUCE RISKY?

1. Raw
2. Wrinkly
   • High Surface Area
3. Sticky
   • Covered in Wax
GOOD AGRICULTURAL PRACTICES

GAPs help reduce contamination risks for:

• Soil
• Water
• Hands
• Surfaces

GAPs include:

• Food Safety Plan

PM 1974A – On-farm Food Safety: Guide to Good Agricultural Practices (GAPs)
http://store.extension.iastate.edu/Product/On-farm-Food-Safety-Guide-to-Good-Agricultural-Practices-GAPs
Food Safety Plan

What goes in a food safety plan?

1. Production steps
2. Hazard analysis
3. Control points
4. Monitoring strategies
5. Adjustment protocols
6. Documentation
Fish Harvest

• Rapidly cool the core body temp to below 37⁰ F using an ice bath
• Store fish on ice until processed
• Be aware of regulations associated with seafood processing
• Iowa Department of Inspections and Appeals
GOOD HARVESTING TECHNIQUE:
With *washed* hands, or washed hands covered with clean disposable gloves, touch *only* the produce when harvesting.

DO NOT touch the raft or the water underneath the raft during harvesting. That contaminates your hands or gloves with bacteria, which can then contaminate the produce.

For the same reason, *DON’T* touch the root system or growing cup when harvesting.

Plant Harvest

• Rapidly cool plant to food-safe temp. ASAP!
• Clean produce appropriately
• Store plants under proper temps until consumed
• Be aware of regulations associated with processing
• Iowa Department of Inspections and Appeals
Contact Info:

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- www.NCRAC.org
- http://www.nrem.iastate.edu/fisheries/
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Questions about this webinar series should be directed to brentoncontact@iastate.edu