FIRST RESULTS OF A SEMI-PRACTICE COMBINATION OF TOMATO AND FISH GROWTH

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Content

- About INAGRO (institute)
- About INAPRO (project)
- Results Inapro aquaponic experiments at Inagro
Inagro: a short introduction
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Inagro mission

Inagro delivers the appropriate advice at the right time in the most appropriate way to the farming and horticultural sector with a due focus of attention going out to economy, ecology and society.

Inagro is a sustainable organisation that places a premium on networking whilst pursuing a reputation of excellence.
Inagro structure

The technical crop departments
- Arable farming
- Open Air Horticulture
- Covered Horticulture
- Animal Production
- Organic Farming

Knowledge centres
- Soil & fertilisation
- Water
- Crop protection
- Environmental health
- Energy
- Innovation

Laboratory

Society & Environment Department
Inagro staff

STAFF

A solid educational background in agriculture, either at Master level for the researchers or at Bachelor or technical level for the technical staff is usually a secure foundation for a career with Inagro. In fact, quite a few members of staff have their roots in the agricultural and the horticultural sector. Inagro’s staff policy is aimed at ensuring the continuous in-service training of the organisation’s human capital.

32.5 FTE
Support staff

71 FTE
Researchers & agricultural extension officers

75.5 FTE
Technical staff
Inagro infrastructure
The INAPRO project
This project has received funding from the European Union’s Seventh Framework Programme for research, technological development and demonstration under grant agreement no 619137
INAPRO: Innovative aquaponic production

<table>
<thead>
<tr>
<th>Proposal full title:</th>
<th>Innovative model &amp; demonstration based water management for resource efficiency in integrated multitrophic aquaculture and horticulture systems</th>
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<tbody>
<tr>
<td>Work Programme Topic</td>
<td>Water innovation demonstration projects</td>
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<tr>
<td>Coordination</td>
<td>Forschungsverbund Berlin e.V. – Leibniz Institute of Freshwater Ecology and Inland Fisheries (IGB)</td>
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<tr>
<td>Project duration</td>
<td>01.01.2014 – 31.12.2017</td>
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</table>
Project objectives of INAPRO

- combining fish and vegetable production within an innovative aquaponic system
- using water & nutrients by value added chains and reducing emissions
- INAPRO-system as modular and scalable facilities, adaptable to local conditions
- Testing, optimization and validation under different conditions by rural & urban demo-objects
Combining aquaculture and hydroponic culture

**Aquaculture**
- high environmental impacts (emissions)
- intense use of water resources
  - recirculating aquaculture system (RAS), BUT 5 to 10% vol. of nutrient rich waste water/day

**Hydroponic**
- high specific demands of nutrients
- high demand of freshwater

**Aquaponics**
- waste water by RAS
  - plant nutrition
  - plant irrigation
Aquaponics – conventional systems

- Resource efficiency $\rightarrow$ Environmental friendly $\rightarrow$ Sustainable food production
- Small/medium scale $\rightarrow$ Local food production, mostly backyard (hobby) systems

**BUT:** fish and plants require different water qualities (pH, nutrients) $\rightarrow$ low yields!

- **single recirculation aquaponic system (SRAPS)**
  - 10-20% vol. freshwater/day
Hightech INAPRO aquaponic system

- **double recirculation aquaponic system (DRAPS)** -> optimal conditions for both parts
  gain in efficiency and economy of water (1-3% vol./day) and nutrients (NO$_3$, P, CO$_2$), NO waste water!

**Aquaculture (RAS; A)**

- **Mechanical filter (2)**
- **Fish tanks (1)**
- **Pump sump (5)**
- **Biofilter (4)**
- **3-chamber-pit (6)**
- **Fresh water**
- **Sludge**
- **Fertilizer (7)**

**Hydroculture (B)**

- **Condensed water (10)**
- **Plant gutter (9)**
- **Nutrient solution tank (8)**
- **one-way valve!**
- **regain of evaporated water!**
The INAPRO concept
INAPRO a new concept for aquaponics

**Improves sustainability by**
- drastic reduction of water use (1-3% vol./day or even lower) by regain of plant evaporated water, use of alternative energy and waste heat!

**Increases productivity by**
- using DRAPS instead of SRAPS for aquaponics allows fish production as in conventional RAS but provides also optimum conditions for hydroponic units

**Reduces environmental impacts by**
- lowering drastically emissions of nutrient (N, P) rich fish waste water that is used for hydroponics and plants are even a net sink for CO$_2$ released by fish

INAPRO transfers “tomatofish” into application!
INAPRO work packages (WP)

WP 1: Concept and modelling

WP 2: Design and development of components and modules

WP 3: Integration and testing

WP 4: Demonstration of the INAPRO system at different geographical locations: Germany and Belgium, Spain, China

WP 5: Dissemination and exploitation
The INAPRO research facility

Completion: January 2015
INAGRO experiments
within the INAPRO project
Task Inagro in WP 4: demonstration projects in rural areas

Testing and optimization of water and nutrient exchange
Fish → tomatoes

“Early in the project a comparison will be installed of tomato grown on
(1) nutrient solution made with aquaculture enriched water and
(2) standard nutrient solution made with rain water + tap water.”
Task Inagro in WP 4

This setup can, together with the experimental unit at IGB, deliver system data for the development and test of models and concepts. The facility can be run as control before building the 3 other rural farms and can be extended later.
Combining aquaculture and tomato
Characteristics of Inagro aquaculture

Fish: pike perch
(Sander lucioperca)

Recirculating system (RAS)

Water source: superficial well water (5-10 m)
(EC = 0.8 mS/cm contains Na (25-30 ppm), NO₃ (40 ppm) and Ca (120 ppm))
Details of the Inagro RAS

Well water

Biological filter

drum filter

Removed solids to bio-digester

Rinsing water aquaculture = Source water tomatoes

EC = 0.90 mS

NH$_4$ → NO$_3$

Excess to sewage (NO$_3$ limit = 150 mg/L)
Characteristics of the tomato cultivation

Greenhouse compartment of 320 m²
Variety: truss tomato Foundation (Bayer–Nunhems)
Substrate: rockwool
Reuse of drainage water
Experimental set-up tomato greenhouse

Standard nutrient solution: made with rain water + 20% tap water

Experimental plots: 10 plants = 4.4 m²

Tomato planting: January 6th

Start fishwater usage: April 3rd

Harvest: 30/03 – 4/11
Treatment 1: standard nutrient solution

Rain water (80%) + tap water (20%)

EC = 0.35 mS

Mixture (+ drain to 1.0 mS/cm)

Nutrient solution (3 mS/cm)

Rockwool slab

computer
Treatment 2: = fish water based nutrient solution

- Nutrient solution (3 mS/cm)
- Mixture (+ drain to 1.3 mS/cm)
- EC = 0.90 mS

Drain

Rinsing water aquaculture

Rockwool slab

Computer

NPK
Parameters monitored

- Plant growth and development
- Tomato yield and quality
- Nutrient concentrations in the substrate (rockwool)
Results
Fish water: nutrient content

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Content (mmol/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>7.70 – 8.00</td>
</tr>
<tr>
<td>NO$_3$</td>
<td>0.50 – 2.50</td>
</tr>
<tr>
<td>SO$_4$</td>
<td>0.80 – 1.35</td>
</tr>
<tr>
<td>PO$_4$</td>
<td>0.05 – 0.10</td>
</tr>
<tr>
<td>K</td>
<td>0.20 – 0.30</td>
</tr>
<tr>
<td>Ca</td>
<td>3.00 – 4.40</td>
</tr>
<tr>
<td>Mg</td>
<td>0.65 – 1.00</td>
</tr>
</tbody>
</table>
Causes of EC rise:
addition of NaCl for disease prevention (*Costia*) when adding new, young fishes

Evolution EC fish water (mS/cm)
Treatment 2: fish water based nutrient solution

Problem of EC rise

Problem 1 = reuse of drain becomes impossible (EC>1.3 mS/cm)

Problem 2: less room for addition of needed nutrients

Drain

Rinsing water aquaculture

EC = 0.90 mS

EC = 1.80 mS!

Nutrient solution (3 mS)

Mixture (+ drain to 1.3 mS)

Rockwool slab

EC = 0.90 mS

Nutrient solution (3 mS)
Remediation of EC rise of fish water

Adaptation of settings:

6-14/08: dilution of the fish water with 50% rain water

=> EC falls from 1,8 to 1,2 mS/cm.
Disadvantage: higher water consumption of the aquaponics system = opposite of project objective!

After 14/08: increase of EC nutrient solution from 3,0 to 3,8 mS/cm
+ increase of drain addition level from 1,3 to 2,0 mS
Evolution EC in rockwool slabs (mS/cm)

After 14/08: increase of EC in aquaponic slabs
Evolution Na$^+$ and Cl$^-$ in slabs (mmol/L)

**Na**

- Drain aquaponics
- Accumulation in slabs
- Fish water
- Drain standard

**Cl**

- Drain aquaponics
- Accumulation in slabs
- Drain standard
Nutrient content in the slabs was quite equal for both Standard and Aquaponic systems, with exception for Na and Cl.
Tomato yield

Aquaponic system
Standard system

kg/m²

30.03 19.04 9.05 29.05 18.06 8.07 28.07 17.08 6.09 26.09 16.10

Standaard Vis
Tomato yield and quality

Yield

• Standard system: 48.4 ± 1.71 kg/m²
• Aquaponic system: 49.5 ± 1.05 kg/m²

difference not significant (t.test, p = 0.7842 – 4 repl.)

Blossom end rot

• Standard s.: 0.36% ± 0.19%
• Aquaponic s.: 0.14% ± 0.19%

difference not significant (t.test, p = 0.2121)
Conclusion

At the management conditions of the experiment, use of aquaculture rinsing water for hydroponic tomato production was very well possible.
Points to improve

- Aquaculture system has high level of water consumption: much water is added in order to obtain fish water that can be released into the sewage system (NO$_3$<150 ppm)
- Periodic addition of NaCl to the aquaculture disables the possibility of reusing drainagewater in the hydroponic system
Adaptations for experiment 2016

Monitoring of water flows:
• Fish water to sewage
• Tomato drainage water to sewage

Aquaculture:
no longer pursuing release into sewage. Less water addition for rinsing, resulting in higher nitrate content and higher EC. Installation of a water storage tank to bridge periods with little demand by the tomato plants.
Adaptations for experiment 2016

Aquaculture:
Try out other products for disease control instead of NaCl.
Peroxides?

Future:
replace well water, containing Na, by other water source, free of Na.
Thank you for your attention