Sustainable Food Production Systems

June 25, 2025

Ounísia Santos
LSRE-LCM, School of Technology and Management (ESTG), Polytechnic Institute of Leira




ALiCE ASSOCIATE LABORATORY IN CHEMICAL ENGINEERING

U.PORTO FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO

LSRE LCM LABORATORY OF SEPARATION AND REACTION ENGINEERING LABORATORY OF CATALYSIS AND MATERIALS

Introduction

Climate change

Populational growth

Traditional agriculture

Pressure on water resources

Growing need for food production

Soil pollution and depletion

Soilless production systems offer a promising solution to advance sustainable agricultural practices and improve water management.

Sustainable systems: Aquaponics

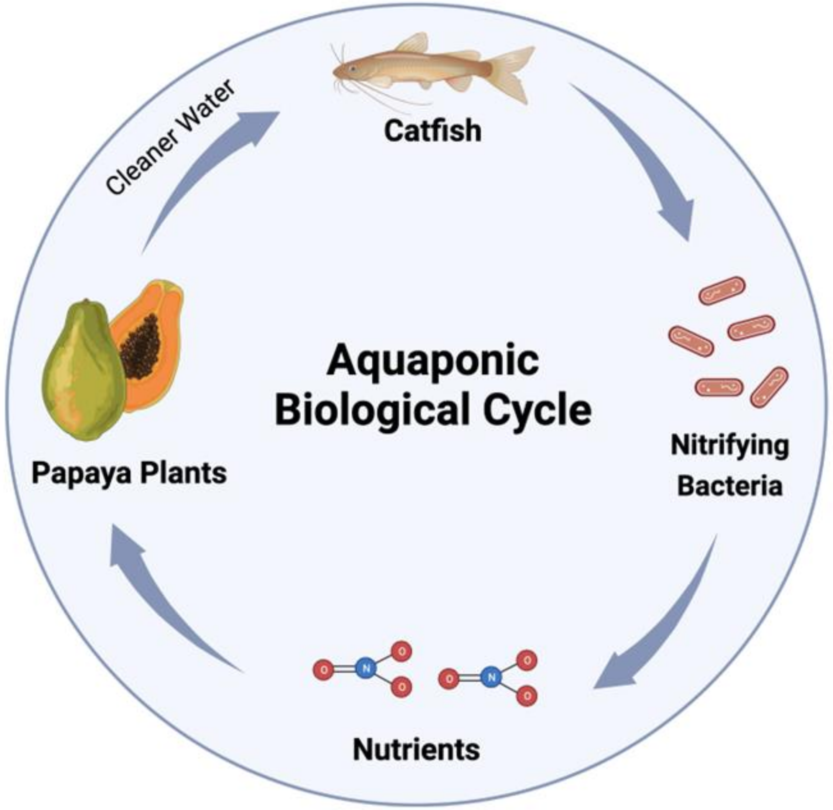
An integrated multitrophic system that combines two food production systems, **aquaculture** and **hydroponics**, in a symbiotic environment where nutrients and water are in recirculation between both subsystems.

Benefits:

- Low water and energy requirements.
- High productivity (fish and plants).
- Minimal chemical use.
- Sustainable.
- Smaller area footprint.
- Possible in urban areas.

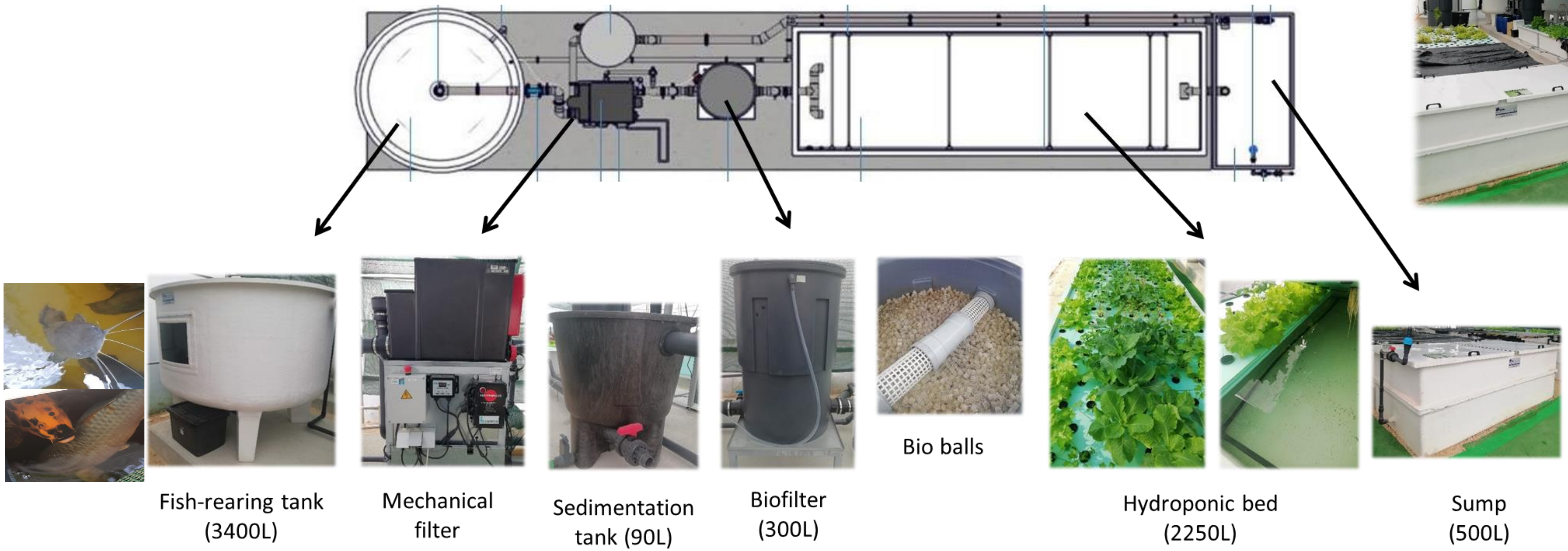
Disadvantages:

- High operating, maintenance, and fish feeding costs.
- Requires an advanced technical background.



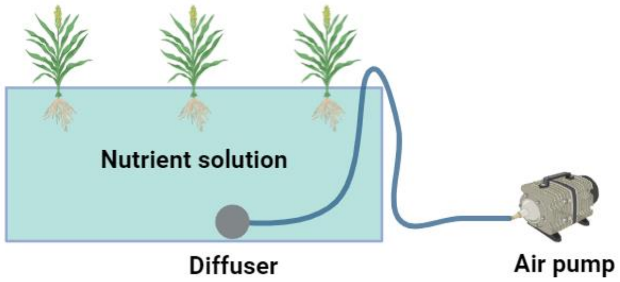
Our Aquaponic systems- LSMI

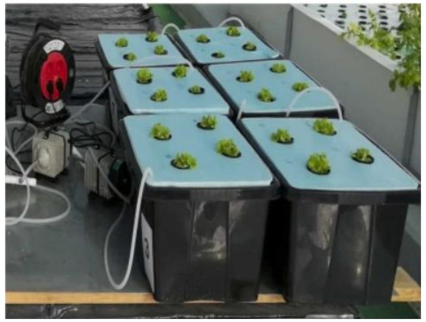
Laboratory of Integrated Multitrophic Systems (greenhouse), Polytechnic of Leiria.



- 3 integrated parallel lines.
- Water and nutrients are recycled in a closed-loop system.
- Aeration is maintained in the fish-rearing tank, biofilter, and deep-water hydroponic bed.

Sustainable systems: Hydroponics





Benefits:

- Do not require soil usage.
- Less water consumption (70–80% compared to soil-based agriculture).
- Precise control of nutrient input and crop monitoring.
- High production efficiency.

Disadvantages:

- High initial costs for materials and equipment.
- Proper disposal of nutrient solutions is crucial to prevent environmental problems.

Wastewater Hydroponic Systems

Wastewater Treatment Plant:
Nutrient-rich urban wastewater.

Hydroponic system:
Nutrient removal from wastewater.
Reduced fertilizer costs and freshwater usage.

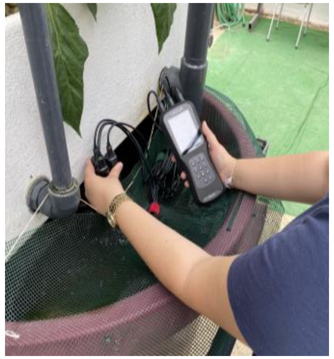

Economically valuable crops.

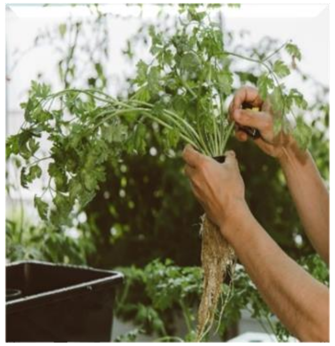
Reduced impacts on natural watercourses associated with wastewater discharge.

Wastewater also contains organic matter, heavy metals, pathogens, and emerging contaminants, making contamination a great concern in these systems.

Monitoring

- **Plants:** Morphological growth, nutritional characterization, toxicity tests, and microbiological and emerging contaminants.
- **Water:** T, pH, EC, TDS, DO, nutrients ($N\text{-}NH_4^+$, $N\text{-}NO_2^-$, $N\text{-}NO_3^-$, $P\text{-}PO_4^{3-}$, Fe,…), organic matter (COD and BOD_5), total coliforms and *E. coli, and* emerging contaminants.
- **Fish:** Feeding and guarantee of well-being.
- **Greenhouse:** Temperature, relative humidity, and light intensity.



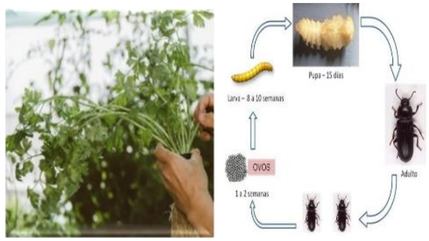



Ongoing Projects

- Hydroponic production of ornamental and fruit plants using urban wastewater.

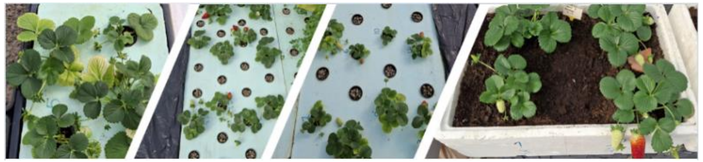
- Sustainable production of papayas in aquaponics.

- Edible aromatic plants production in aquaponics using a partial mealworm supplement in fish feeding.

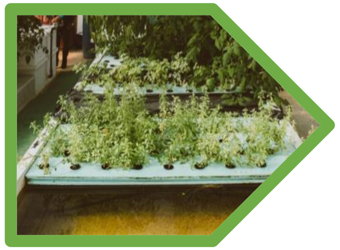


- Implementation of sensors supported by IOT for water quality monitoring.

- Comparative evaluation of aquaponic, hydroponic, and soil systems on yield and antioxidant levels in different fruits and vegetables (e.g., strawberries).



Main results



The aquaponics system implemented was able to produce cultivars of lamb's lettuce and arugula while maintaining low levels of ammonium and optimal levels of nitrates for plant growth, improving nutrient sustainability and reducing nitrogen-rich wastewater production. The antioxidants and polyphenols produced by the plants were shown to correlate with higher viability of human Caco-2 model cells.

Journal of the Science of Food and Agriculture
SCI where science meets business

Research Article | Open Access

Nutrient-efficient catfish-based aquaponics for producing lamb's lettuce at two light intensities

Fernando Sebastião, Daniela C Vaz, Cristiana L Pires, Pedro F Cruz, Maria João Moreno, Rui M M Brito, Luis Cotrim, Nelson Oliveira, Ana Costa, André Fonseca, Maria Rodrigues, Kirill Ispolnov, Raul Bernardino, Judite Vieira

First published: 23 March 2024 | https://doi.org/10.1002/jsfa.13478

The wastewater hydroponic system has the potential to effectively remove contaminants from urban wastewater (minimum removals of 75.2 % BOD_5, 83.1 % COD, 43.4 % P, 44.9 % N, and 90.4 % K). Lettuce plants showed no signs of toxicity in leaf extracts up to a concentration of 1 % (w/v). *E. coli* was not detected on plant leaves, and total coliforms remained within acceptable limits, suggesting a low contamination risk.

ELSEVIER
Agricultural Water Management
Volume 301, 1 August 2024, 108966

Wastewater as a nutrient source for hydroponic production of lettuce: Summer and winter growth

Ounísia Santos [a b], Daniela Vaz [a b c], Fernando Sebastião [a b], Helena Sousa [a b], Judite Vieira [a b]

Conclusions

- ✓ These systems use **water efficiently,** allowing **the production of economically valuable crops** with reduced fertilizer usage.
- ✓ An **added advantage** is **their effectiveness in removing nutrients/contaminants from wastewater**, making them a strong asset for water resource management.
- ✓ They are also used as a **form of citizen science to raise community awareness regarding the efficient use of resources** and alternative production methods applicable to various environments, including urban settings.

Acknowledgements

This work was supported by national funds through FCT/MCTES (PIDDAC): LSRE-LCM, UIDB/50020/2020 (DOI:10.54499/UIDB/50020/2020) and UIDP/50020/2020 (DOI:10.54499/UIDP/50020/2020); and ALiCE, LA/P/0045/2020 (DOI:10.54499/LA/P/0045/2020);

FCT Fundação para a Ciência e a Tecnologia
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR

REPÚBLICA PORTUGUESA

Contacts:
ounisia.santos@ipleiria.pt
Judite.vieira@ipleiria.pt

ALiCE ASSOCIATE LABORATORY IN CHEMICAL ENGINEERING

U.PORTO FEUP FACULDADE DE ENGENHARIA UNIVERSIDADE DO PORTO

SRE CM LABORATORY OF SEPARATION AND REACTION ENGINEERING LABORATORY OF CATALYSIS AND MATERIALS