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Aquaponics Systems: De-risking the Future of Agriculture

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Introduction

Climate change is the catalyst for growing concerns for food security, water and land scarcity, crop failure, soil degradation, pest and disease patterns and general inadequate protection of ecological systems [1]. Aquaponics has the capacity to curb some of these challenges facing us today.

By 2050, the population is expected to reach 9.6 billion, with more than 75% of that population living in urban areas [2]. New forms of modern agriculture that can accommodate these people will be crucial to the sustainability of our population.

Aquaponics is a sustainable alternative farming technique that combines the processes of aquaculture and hydroponics as outlined in Figure 4. Utilizing the waste produced by fish, nutrients are provided to plants in a close looped system.

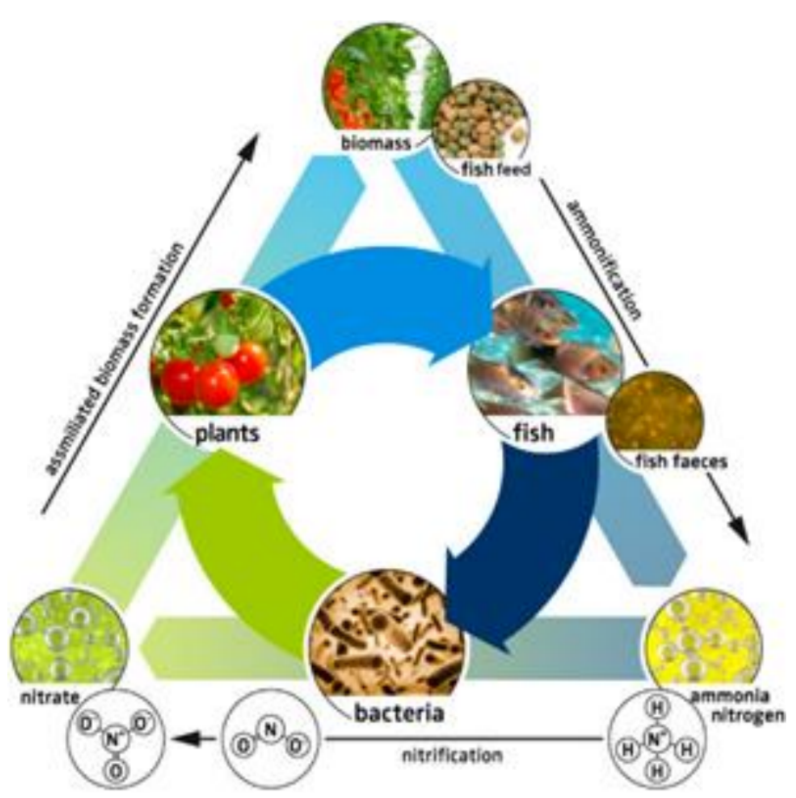


Figure 1: Nutrients cycling in aquaponics [3].

Potential Impact

A major setback in the implementation of commercial aquaponic systems is the potential negative environmental impact that they can cause. Creating a perfect system is difficult because all ammonia from the fish waste would need to be utilized by the plants as depicted in Figure 1. This excess in ammonia can cause a multitude of environmental issues.

- Ammonia is toxic to aquatic organisms
- Even concentrations of 0.02 mg/L of ammonia is lethal to sensitive freshwater fish [5]
- Stream polluted with ammonia could be harmful to livestock
- LC50 for Daphnia Magna (typical water flea) is 0.66 mg/L [5]
- Infestation of fecal coliform bacteria (such as E. Coli) could infect water, plants, and fish
- Nitrogen and phosphorus released from operation leads to excessive algae growth and eutrophication

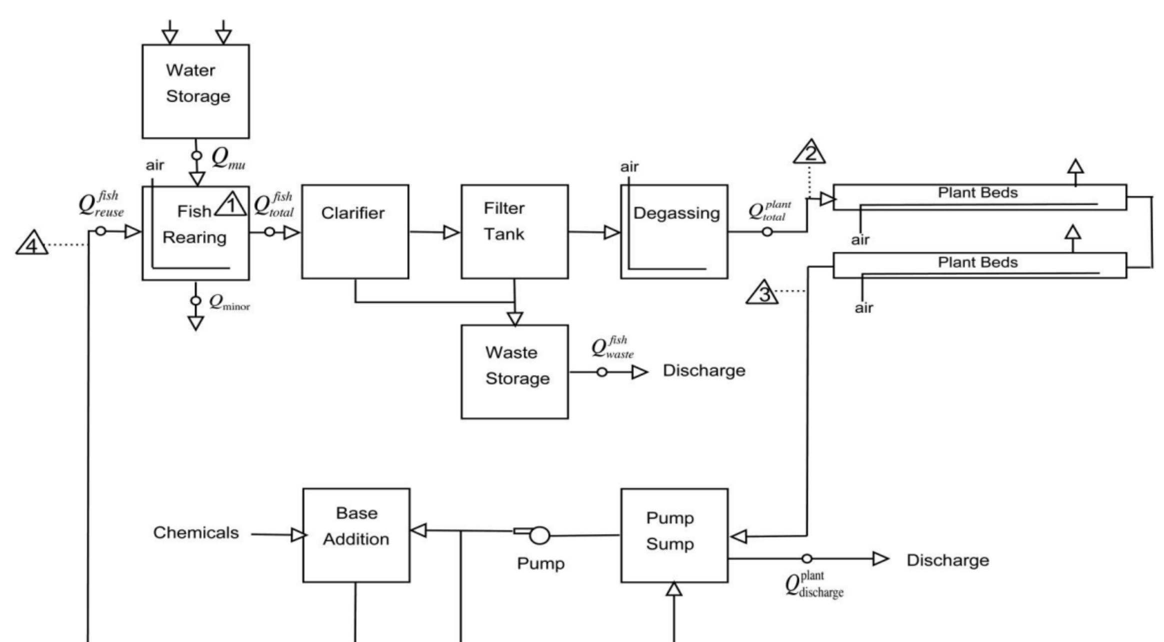


Figure 3: Coupled aquaponics system schematic [3].

Sensitive Unit

Sludge Treatment through Aeration Treatment

- Mechanical removal of suspended solids and improvement of nutrient recycling
- Higher nutrient retention and use of sludge as a fertilizer [3]
- Profitability from high water recovery from the sludge and decreased fertilizations for plants [4]
- Increase self-reliance of system
- Within 14 days of incubation [4]
  - Increased the phosphorus concentration by 330%
  - Potassium concentration by 31%
  - Reduced nitrates concentrations by just 16% compared to 97% in the unaerated treatment

Figure 4: Coupled aquaponics system schematic [3].

Wastewater Treatment through Thermal Distillation

- Minimizes water and environmental (i.e. fertilizer usage) footprint of multi-loop aquaponics system
- Separate volatile solids and water
- Concentrate the hydroponics nutrient solution, while increasing the aquaculture water quality by dilution [5]
- Cleaner water to put back into the system
- Reducing adverse effects on fish health from high nutrient levels in the RAS unit [4]

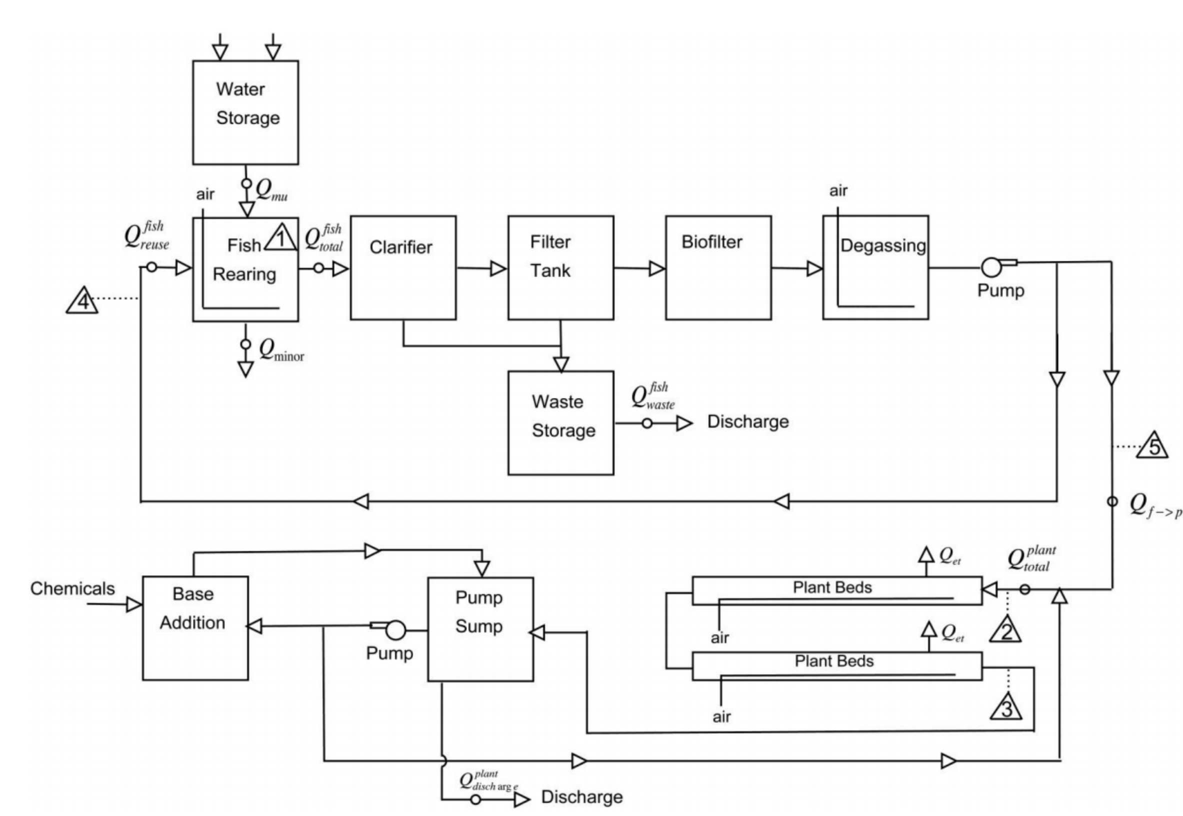


Figure 5: Decoupled aquaponic system [3].

Research

Increasing Profitability

Currently, there are not many large-scale profitable aquaponics operations. However, many aspects of aquaponics are understudied, such as consumer perception, and economic and environmental value of using aquaponics [6]. Better understanding of these factors can help make aquaponics more profitable.

Solubilization

More research needs to be carried out on fish waste solubilization. Not a lot of information is known on the details of solubilization. Wastes from the fish excretion are only partially solubilized [3]. Not all waste can be completely converted into plant biomass. Therefore, a completely decoupled system is a challenge to achieve. Complete conversion of ammonia to nitrates is not easily achievable as there is a delicate balance between fish and plant chemistries.

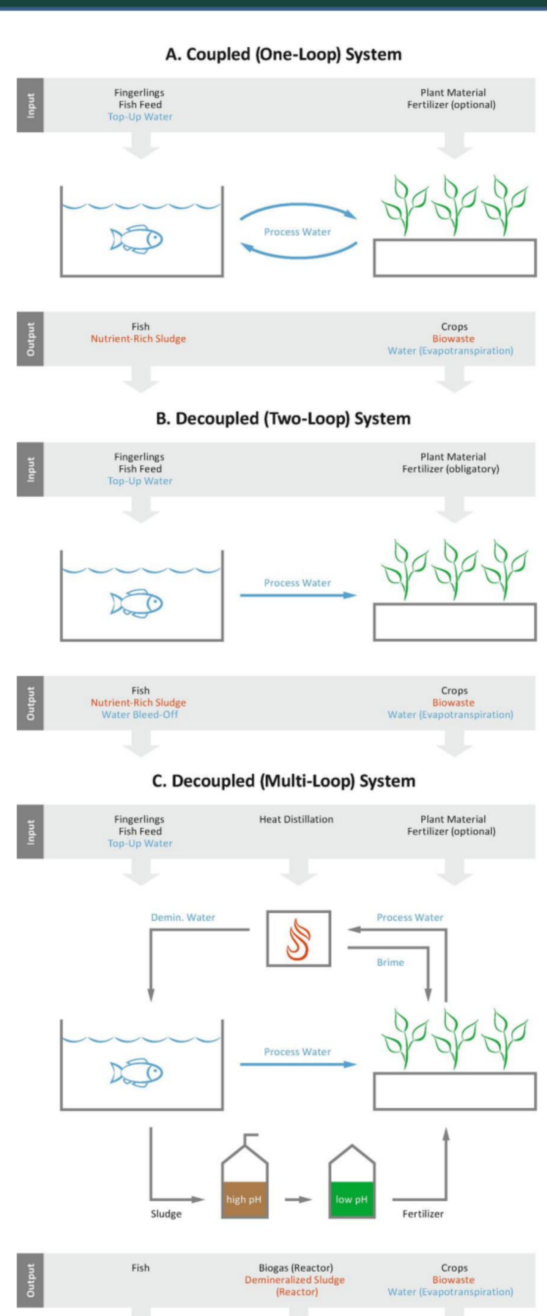
Mineralization

Although there is minimal research on the topic, mineralization could be a great alternative to reducing fish waste and improving the amount of nutrients available throughout the system.

- Implement anoxic environment using the bioleaching abilities of heterotrophic bacteria [3]
- Use of earthworms, that help convert organic waste to water enriching compounds [3]

Waste in the aquaponics system would be greatly reduced and a decoupled system would be a more realistic option [7]. Aquaponics can become more profitable on a larger, industrial scale if a decoupled system is used.

Process Description



Aquaponics Overview

- Hydroponics and aquaculture combination (Figure 2)
  - Hydroponics is the growing of plants in an aqueous, nutrient rich solution without soil [3]
  - Aquaculture is the cultivation of aquatic plants and organisms
- Using ammonia waste produced by fish to provide nutrients to crops for produce production

Coupled System

- Close-looped nutrient cycling (Figure 4)
- Plants utilized as primary water cleansing
- Challenging to meet optimum growth levels for fish and plants [3]

Decoupled, Multiloop System

- Separate the water and nutrient loops of both the aquaculture and hydroponics unit from each other (Figure 5)
- Reuse of sludge and mobilization of nutrients instead of recycling through the system [4]

Figure 2: Different aquaponic systems. (a) is a close looped system, (b) is a decoupled system, (c) is a decoupled multi-loop system. [3]

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