



Floponics: An Integrated and Sustainable Aquaculture Technology

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<https://doi.org/10.5281/Vettoday.18096748>

Introduction

The global population is rapidly growing and has surpassed 8.2 billion people as of late 2025, and it is expected to reach 9.7 billion by 2050, thereby increasing the demand for safe and nutritious food. Sustainable food production has thus become a major challenge. Ensuring adequate access to nutritious food for this expanding population is a major global challenge, particularly under current conditions of natural resource scarcity (Ghosh *et al.*, 2024). Many countries still struggle with hunger and food insecurity, while others face rising rates of obesity and malnutrition. Therefore, investment in and research on sustainable food production technologies that provide nutritious food while minimizing the use of natural resources are urgently needed. Ensuring adequate access to nutritious food for this expanding population is a major global challenge, particularly under current conditions of natural resource scarcity. Many countries still struggle with hunger and food insecurity, while others face rising rates of obesity and malnutrition. Therefore, investment in and research on sustainable food production technologies that provide nutritious food while minimizing the use of natural resources are urgently needed (Habib *et al.*, 2025). Modern closed aquaculture systems, such as Recirculating Aquaculture Systems (RAS) and Biofloc Technology (BFT), have been developed to effectively address these challenges. In RAS,

water is continuously treated, filtered, and reused, thereby maintaining optimal water quality and reducing environmental impacts (Zimmermann *et al.*, 2023). Integration with hydroponic systems results in aquaponics, where nutrients derived from fish culture water are recycled to promote plant growth. Additionally, Biofloc Technology (BFT) transforms fish waste into beneficial microbial protein, enhancing feed efficiency while simultaneously improving water quality.

Floponics

Floponics, derived from the terms “flocculation” and “hydroponics,” is an integrated aquaculture system that combines fish farming with hydroponic plant production through the use of suspended microbial flocs as a nutrient source. This creates a single, synergistic ecosystem in which both fish and plants mutually benefit from shared water and nutrient cycling. The term “Floponics” was first introduced by Pinho *et al.* (2022), who described it as an alternative form of aquaponics previously referred to as “BFT + aquaponics” or “BFT + hydroponics.” In this system, traditional recirculating aquaculture system (RAS) components are replaced with a biofloc technology (BFT) subsystem, where plants

function as natural biofilters, removing dissolved nutrients from the culture water. Floponics offers enhanced nutrient recycling efficiency and improved waste reduction capacity compared to standalone RAS or BFT systems (Raza *et al.*, 2025). In floponics, fish are cultured in biofloc tanks, and the nutrient-enriched effluent is recirculated to support plant growth in a soilless hydroponic medium, effectively integrating the nutrient film concept commonly associated with RAS. Within this system, nitrogenous wastes are transformed into bioavailable nutrients by complex microbial consortia, making them readily accessible for plant uptake. Although current scientific attention has largely focused on plant productivity within floponics, the technology holds significant potential for broader aquaculture applications. It can be adapted for the commercial production of high-value aquatic species such as Pacific white shrimp, Nile tilapia, and catfish, thereby offering a sustainable and resource-efficient alternative to conventional intensive aquaculture systems (Hwang *et al.*, 2025)

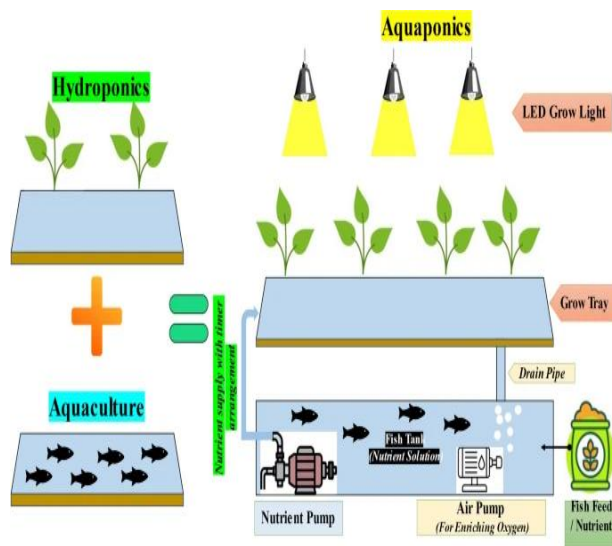


Figure. 1 Overview of the integrated aquaponics system combining aquaculture and hydroponic plant production.

Floponics: System Layout and Design

Floponics is a relatively new system, and researchers have tested different designs to understand how it works best. Most studies use coupled systems, where water continuously circulates between biofloc fish tanks and hydroponic plant units, while fewer studies use decoupled systems, where water flows one-way as needed. For plant production, Nutrient Film Technique (NFT) and Deep Water Culture (DWC) are the most commonly used methods, though it is still unclear which performs better. Biofloc tanks vary greatly in size, and excess suspended solids are usually removed using settling tanks or filters to protect plant roots and oxygen levels. Overall, the lack of standardized designs shows that floponics is still evolving, with optimal system ratios and layouts yet to be established.

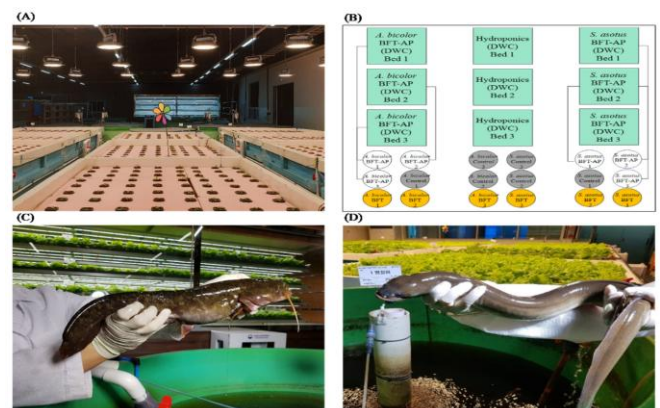


Figure 2. Integrated aquaponics system showing plant beds with *A. bicolor* and *S. asotus* and fish rearing setup.

Maintaining Water Quality and Recycling Nutrients

Biofloc Technology (BFT) is becoming popular in fish and shrimp farming because beneficial microorganisms naturally clean the water and recycle nutrients. These microbes convert toxic ammonia into safer forms or

microbial biomass, helping maintain good water quality with minimal water exchange. In floponics systems, studies show that most water quality parameters remain safe for fish and shrimp, even when biofloc volume is lower than recommended. Although hydroponic plants prefer slightly acidic water, many floponics systems operate at near-neutral pH without negatively affecting plant growth. Managing suspended solids is important, as excess particles can reduce nutrient uptake by plant roots, requiring a balance between fish and plant needs. Overall, floponics efficiently recycles nutrients from fish feed, and the use of plants as natural filters further reduces nitrogen and phosphorus levels, improving sustainability and reducing environmental pollution.

Productive results

Only the experiments that statistically analysed the plant and fish or shrimp growth and provided sufficient data to compare the productive performance were considered in the descriptions below. In general, the FLOCponics studies were conducted mainly by aquaculture researchers. Despite this, twenty-four trials were performed to evaluate plant production and twelve trials tested animal growth in FLOCponics systems.

Plants production

In floponics, nutrient-rich water from biofloc fish systems is used to grow plants. Research so far shows mixed results—some studies report better growth, some similar, and a few show lower yields—mainly due to differences in nutrient levels and management. Leafy vegetables like lettuce and salicornia are commonly studied, while fruiting crops like tomato may suffer from lower nutrients after fish harvest. Plant quality is generally good, but issues such as yellowing leaves, poor growth, and leaf burn can occur due to biofloc buildup, high water pH, nutrient imbalance, and competition between microbes and plants. With proper

nutrient and waste management, floponics has great potential to become a highly productive and sustainable system for future farming.

Animal production

Most floponics research focuses on Nile tilapia and Pacific white shrimp because they grow well in biofloc systems and can tolerate high suspended solids and nitrogen. Tilapia can even consume bioflocs directly, improving growth and feed efficiency. Studies have tested factors like carbon sources, salinity, and plant management, but results on growth differences are mixed. Currently, fish and shrimp yields in floponics are lower than in commercial biofloc or RAS systems because connecting hydroponics reduces biofloc levels, limiting natural food and microbial activity. However, better system design and proper solids management can improve production, making floponics a promising and sustainable option for integrated fish and vegetable farming.

Sustainable Aquaculture with Floponics

Sustainable aquaculture produces healthy food in ways that are environmentally friendly, economically viable, and socially beneficial. Floponics, combining biofloc and aquaponics, is a promising new approach that grows fish and vegetables together using minimal water and low environmental impact. While full scientific sustainability assessments are still lacking, early evidence shows it can provide fresh, pesticide-free food, improve food security, and support small farmers. Technical challenges remain, but with proper research and system design, floponics has strong potential to become a commercially successful and fully sustainable food production system.

Challenges of Floponics System

- ❖ Floponics integrates fish farming and hydroponic vegetable cultivation, combining multiple fields like microbiology, water science, aquaculture, engineering, and agriculture.
- ❖ Its complexity requires good technical knowledge to operate successfully.
- ❖ Limited research has been done; many questions about design, management, and long-term performance remain unanswered.
- ❖ Main challenges are technical, affecting sustainability and economic profitability. Key issues include controlling water quality, nutrient balance, microbial activity, and system design.
- ❖ Similar challenges were once faced by Biofloc Technology (BFT), which is now fully commercialized.
- ❖ With continuous research, technical improvements, and field testing, floponics has the potential to become a highly sustainable, eco-friendly, and profitable integrated farming system.
- ❖ Addressing current challenges today can help make floponics an important technology for future food security.

Conclusion

Floponics is still in its early development stage, with few studies and no standard system design. Fish and plant production results are inconsistent, mainly due to differences in system setup and solid waste management. Controlling bioflocs is critical to ensure optimal conditions for both fish and plants, and better filtration or decoupled system designs are recommended. Floponics is especially suitable for farmers already using Biofloc Technology, as adding hydroponics helps recycle nutrients, diversify products, and improve sustainability. While it may not significantly boost fish growth, it makes farming more eco-friendly, profitable, and aligned with circular economy principles. With further research, improved design, and commercial trials, floponics has strong potential as a sustainable solution for integrated fish and vegetable production.

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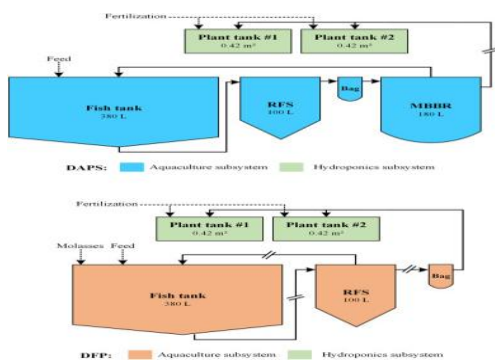


Figure 3. Schematic diagram of Floponics system showing integration of aquaculture and hydroponics subsystems.

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