

Flocponics: The future of Sustainable Fish and Vegetable Farming



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INTRODUCTION

As the population is expected to reach 9.7 billion by 2050, the demand for safe and healthy food is rapidly increasing, driven by the growing number of people who create greater demand for food. Thus, meeting the dietary requirements of a growing population will create a significant strain on existing food sources, particularly those that depend on water and land for their production; this is compounded by the additional pressure being placed on those same resources due to the increasing global demand for food. Many parts of the world are still having to deal with issues like hunger and malnutrition, while in other parts of the world, obesity rates are rising at an alarming rate; consequently, a growing population is creating a highly complex, global food security situation (Conijn et al., 2018; Byerlee and Fanzo, 2019). There is a critical need for the development of innovative food production technologies that provide consumers with high-quality nutrition with minimal negative impact on the environment, a goal that new aquaculture methods will help achieve (Thilsted et al., 2016).

Aquaculture is now the fastest-growing source of animal protein and contributes to the world's fish supply (FAO, 2020).



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A significant percentage of aquaculture production worldwide comes from extensive (such as pond systems) or intensive cage-style systems, which can create negative consequences to the environment, such as water quality degradation and excessive nutrient loading (eutrophication). There are developments taking place within modern-day aquaculture that address environmental degradation through the use of closed and resource-efficient methods of managing aquatic organisms (Tucker & Hargreaves, 2012). Recirculating aquaculture systems (RAS) and biofloc technology (BFT) represent two prominent examples. RAS uses mechanical and biological filtration to recycle water and maintain optimal conditions for fish growth, whereas BFT relies on the stimulation of beneficial microbial communities to assimilate nitrogenous wastes directly within culture tanks. Both systems offer controlled environments, high water-use efficiency, and predictable production cycles.

Integrated multi-trophic systems have gained increasing attention as a sustainable alternative, offering nutrient recycling, reduced waste discharge, and diversified production. Advancements in aquaponic design have led to variations such as decoupled systems, multi-loop configurations, algae-based systems and biofloc-integrated systems.

Flocponics represents one of the most recent innovations in this field. Defined as the integration of biofloc-based aquaculture with hydroponic plant production (Pinho *et al.*, 2021). Flocponics is an alternative type of aquaponics system where RAS is replaced by a system based on BFT. This approach leverages the nutrient-rich microbial flocs generated within BFT systems to support plant growth, potentially enhancing nutrient recycling efficiency, reducing water and fertilizer inputs, and improving overall system sustainability. This emerging agricultural model offers a promising solution to the

environmental, technical, and economic challenges faced by traditional aquaculture.

The need for flocponics?

The need for Flocponics arises from the limitations and challenges encountered in traditional Aquaponics, particularly through the integration of Biofloc Technology (BFT) to enhance resource efficiency, fish health, and overall sustainability.

Firstly, it addresses the problem of unbalanced plant nutrition by using microbial biofloc sludge as a concentrated, complete biofertilizer, ensuring plants receive essential micronutrients often missing in clear-water aquaponics. Secondly, it greatly improves water quality and system stability by having the dense microbial flocs perform in-situ biofiltration, quickly removing toxic ammonia and nitrite directly in the fish tank, which can reduce the need for external filtration components. Finally, Flocponics benefits aquaculture by providing fish with the flocs as a protein-rich natural feed supplement, lowering reliance on costly external feed, enhancing the overall Feed Conversion Ratio (FCR), and supporting higher, more intensive fish stocking densities while maintaining the system's highly efficient, closed-loop water conservation model.

How does flocponics work?

The process starts in the biofloc fish culture tank, where fish are cultured in conditions that promote the development of a diverse microbial population. Nitrogenous waste is added to the culture water by fish excreta, uneaten feed, and other organic materials. By managing the carbon-to-nitrogen ratio appropriately, heterotrophic microorganisms incorporate inorganic nitrogen and organic matter into microbial biomass. These microorganisms agglomerate with organic particles and other microorganisms to form bioflocs (Crab *et al.*, 2012; Dauda, 2020).

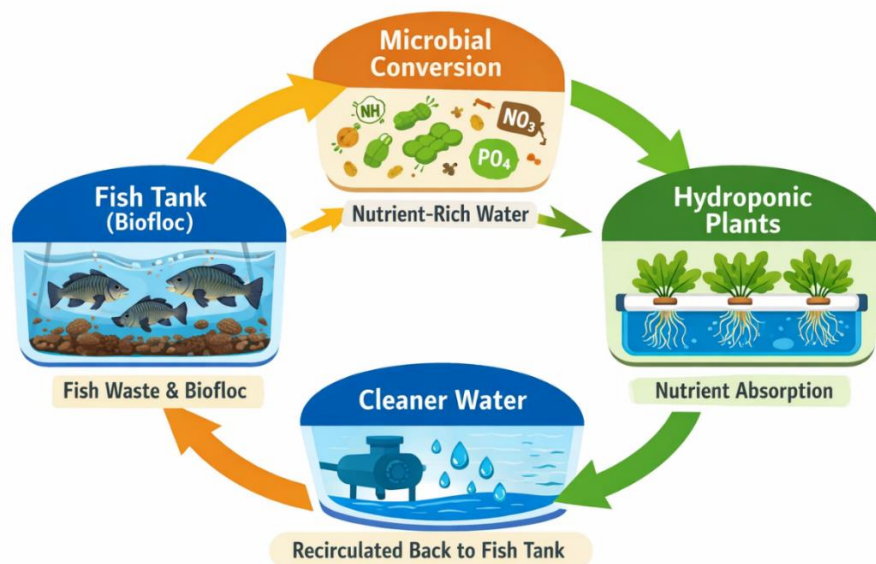
Bioflocs therefore play an important dual role in the system. First, the microbial

community helps manage water quality by assimilating nitrogenous wastes into microbial biomass. Secondly, the microbial flocs thus produced can be an additional source of nutrients for the cultured fish. This microbial pathway enables some of the nutrients from feed and fish metabolism to stay in the production system instead of being immediately excreted as waste. The nutrient-rich water from the biofloc unit is then linked to the hydroponic plant-production component. They grow plants without soil and the roots are exposed to water containing dissolved nutrients. The plants absorb the nutrients present in the water and use them to grow and develop. This way, plant production provides an alternative route for nutrient recovery resulting from fish culture (Pinho *et al.*, 2022).

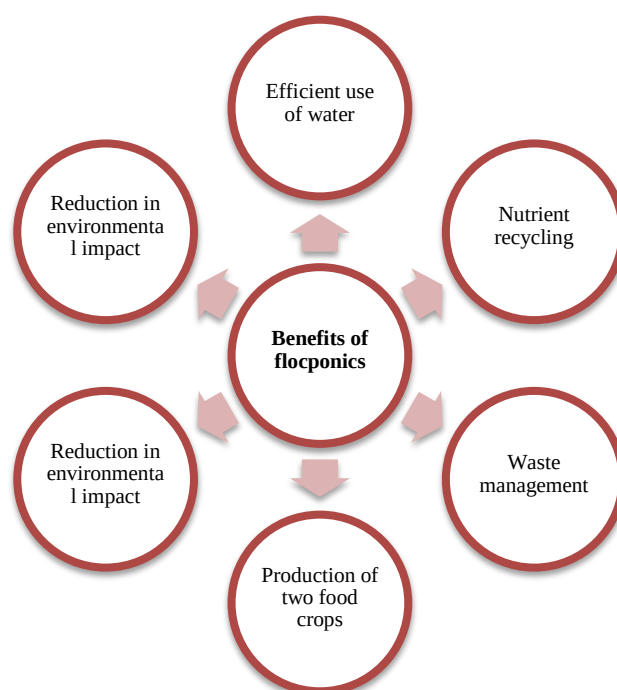
After nutrient uptake by the plants and other biological processes, the water can be

recirculated within the integrated system. This creates a circular pathway in which nutrients move from fish feed to fish waste, from waste to microbial biomass, and subsequently to plant production. The principle is to minimize the loss of resources and improve the efficiency with which nutrients and water are utilized.

The working principle of Floconics can thus be described as a three-way interaction between fish, microorganisms and plants. Fish produce nutrients thru feeding and metabolism. Microorganisms convert and incorporate these nutrients into biofloc. Plants take up part of the available nutrients for their own growth. The integration of these processes gives us the chance to produce fish and vegetables, while at the same time recycling nutrients and reducing waste discharge.



Benefits of floponics



Floponics combines the resource-efficient biofloc technology with the nutrient-recovery capability of hydroponic plant production, offering several potential advantages. Rather than treating fish waste as a waste product to be disposed of, Floponics seeks to recover and reuse nutrients within the production cycle. This integrated approach can increase the efficiency of water and nutrient use and yield both fish and vegetables from the same system.

CONCLUSION

Floponics represents a promising step toward the development of sustainable and integrated food-production systems by bringing together fish farming, biofloc technology, and hydroponic vegetable cultivation. Its ability to recycle nutrients, reduce water consumption, utilize limited land efficiently, and produce both animal and plant foods makes it an attractive alternative to conventional farming

practices. The integration of microbial processes with plant uptake can improve resource-use efficiency while reducing nutrient losses and environmental impacts. However, the long-term success of floponics depends on careful management of water quality, microbial balance, stocking density, plant nutrition, and production costs. Continued research is needed to optimize system design, identify suitable fish and vegetable combinations, improve economic viability, and develop practical management protocols for farmers. Overall, floponics has significant potential to contribute to food security, resource conservation, and environmentally sustainable agriculture, particularly in regions facing increasing pressure on land and water resources. With appropriate research, innovation, and farmer-oriented technologies, floponics could play an important role in shaping the future of integrated and circular aquaculture-vegetable production.

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