Int. J. Agriworld, Vol. 6[1] January 2025
©2020 SVPSS, India
Online ISSN: 2582-7537
Journal's URL:http://www.svpss.in/ijaw
DOI: https://doi.org/10.51470/IJAW.2025.06.01.16
Received 02.09.2024 Revised 15.12.2024 Accepted 08.01.2025
REVIEW ARTICLE **OPEN ACCESS**

Aquaponic: A Sustainable Farming Review

Swatantra Pratap Singh* and Aman Kumar
Quantum School of Agriculture Studies, Quantum University Roorkee, Uttarakhand
***Corresponding E. mail:** swatantra.agr@quantumeducation.in

Abstract

The need to produce more food is growing along with the global population, placing more strain on natural resources like water, land, and nutrients. As a result, it is critical to discover sustainable and more efficient ways to produce food. Neither environmentally sustainable nor adequately addressing the concerns, the present strategies for increasing food supply fall short. It is essential to adopt technologies that will enable us to achieve maximum productivity while using the fewest resources in order to address these problems. Scientists are experimenting with a method called aquaponics in order to accomplish this aim. Using hydroponics and aquaculture to grow fish and crops without the need for soil, aquaponics is an environmentally beneficial method of producing food. Fish and plants live in a low-cost symbiotic relationship. Fish and plants are raised together in aquaponics systems, which were developed many years ago by populations in ancient China and Mexico. How is this possible? The process by which bacteria transform fish waste into plant-nutrients is the solution. Utilizing this nutrient, the plants purify their waste, which may subsequently be used to raise fish and begin the cycle again. Water conservation is one of the distinct benefits of an aquaponics system over a typical irrigation system, however. Reusing water between the plant bed and habitats helps preserve water. Aquaponics also offers the advantage of organic plant fertilization via the use of dissolved fish water. Less water quality monitoring was necessary when using plants as a natural substitute for conventional filters. While aquaponics has advanced significantly in recent years, there are still a number of important problems that need to be properly resolved.

Keywords: Agriculture, Sustainable farming, Organic fertilizer, and Water conservation.

Introduction

Agriculture has the fastest potential development in terms of food production. It is also recognized as the most efficient and promising source for protein synthesis worldwide. Considering that India is the world's second most populous tropical nation, it is imperative to provide a nutritious diet to its growing population. With the "Natural Mission for Protein Supplement Scheme," the Indian government is increasing the quantity of protein that people eat. However, the expanding human population has encroached on agricultural land due to a shortage of housing, which has serious implications for agricultural productivity that impacts not only India but the whole globe. The rapid expansion of the human population places strain on the planet's environment and resources. Food production is becoming increasingly difficult as a result of human activities, including pollution, deforestation, and climate change. To address these issues and enhance food production and consumption for the world's expanding population, new and innovative approaches are required. Therefore, it is essential to focus on alternate farming techniques that might provide a larger output in a shorter quantity of space and time. Aquaponics is a cutting-edge method and system for producing food in the future (Rakocy, *et al.,* 2004*;* Pantanella, *et al.,* 2010).

Fish may be raised in large numbers in comparatively small amounts of water owing to the recirculating systems. These devices can purify and repurpose hazardous waste-free water. Multiple uses of water lead to the accumulation of organic debris and non-toxic nutrients. These metabolic by-products do not need to be squandered if they are used to feed secondary crops with a profit margin or to improve primary fish production systems. "Integrated systems" are those that use products from the production of the main species to produce other crops. This integrated

system is referred to as a "aquaponics system" whether the fish are raised in watery secondary crops or if soil plants are produced alongside them. This is a cheap, environmentally beneficial symbiotic relationship between fish and plants. Soluble nutrients that are either directly excreted by fish or result from the microbial degradation of fish excrement cause plants to develop rapidly. Based on this criterion, culinary herbs are the best option, as they grow much more quickly and have a greater market value (Rakocy, *et al.,* 2012; Endut, *et al.,* 2010).

Application of aquaponics

Aquaponics is a special type of farming that produces more plants than fish, while simultaneously improving fish farming.

Sustainable source of nutritious food: A closed-loop system, such as aquaponics, uses less water and does not require chemical fertilizers. This enables the production of nutritious organic food even in harsh climates and ecologically sensitive places.

Increased crop yields: Plants may develop quicker and generate more when fed fish excrement continuously, which is not possible in traditional farming.

Year-Round Farming: Plants may be cultivated year-round in aquaponics systems because they are managed inside, independent of weather. This is advantageous for regions with severe winters or less productive soils (Love, *et al.,* 2017; Blidariu, *et al.,* 2011).

Beyond Food Production

Education and Research: Schools and universities may employ aquaponic systems to educate biology, ecosystems, and sustainable farming. Researchers also utilize it to investigate the interactions between plants and fish and create new aquaponics techniques.

Community Development: Biology, ecology, and sustainable farming may all be taught at schools and universities using aquaponic systems. It has also been used by scientists to study the interactions between plants and fish and to create new aquaponics methods.

Environmental Protection and Restoration: Wastewater may be cleaner and less harmful to the environment by using aquaponics. In addition, they can be used to reconstruct damaged ecosystems and to build artificial reservoirs (Blidariu, and Grozea, 2012; Buzby, and Lin, 2018).

Specific Uses

Home System: Installing a modest aquaponic system in your house or yard allows the production of attractive plants, medicinal plants, and food.

Urban Farming: Because aquaponics requires less room, it is appropriate for urban areas. This enabled town with little land to obtain fresh food.

Commercial production of fish and vegetables: Vegetables and fish can be produced commercially using large aquaponic systems. When there is a strong market for food produced nearby, this might be a lucrative venture. Therefore, aquaponics is a sustainable and adaptable technique rather than merely fish farming or farming (Pantanella, *et al.,* 2013; Rakocy, *et al.,* 1998).

Fig.1: Research and Education purposes

Fig.2: Aquaponics system for home

Mechanism of Aquaponics

Although aquaponics has a rather complex mechanism, they create an artificial environment that is beneficial to the growth and development of plants and fish alike. This is a synopsis of the operation of the aquaponics.

Fish Tank: The fish tank is the first component of the closed loop that constitutes the aquaponics system. Fish, including tilapia, guppies, and trout, were grown in this tank. In addition to absorbing nutrients from their diet, fish expel waste, mostly ammonia.

Filtration and Nitrification: Ammonia from the fish tank is converted to nitrite by microorganisms in the

© Int. J. Agriworld, INDIA

biofilter. The nitrite is then changed by other bacteria into nitrate, a nutrient that is vital to plants

Hydroponics: The plants are grown in a hydroponic system using nitrate-rich water, shielding their roots from dirt. Plant roots obtain nutrients from water, and the plants take up unnecessary salts from the water.

Plant growth: The plant growth region receives nitrate-rich water. Nitrates and other nutrients are absorbed by plants from the water, which enables them to develop and flourish. Additionally, plant roots purify water by filtering out extra solid waste.

Water Recycling: This cycle is then completed when the water from the hydroponic system returns to the fish tank. Water is not wasted because it is always circulated throughout the system (Rakocy, *et al.*, 1998&2004).

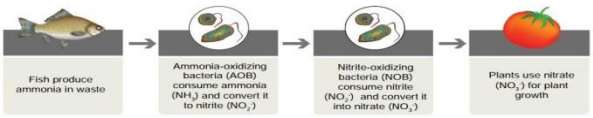

Fig.4: Filtration and Nitrification

Types of Aquaponics

Based on their structures and different advantages, aquaponics can be categorized into three types.

• Media Based Grow Bed
• Deep Water Culture (DWC)
• Nutrient Film Technique (NFT)

Media based grow bed

• A hydroponic trough filled with inert substrate that functions as both a microbial substrate and root support is a media-based growth bed.

• Lava rocks, gravel, or clay pellets are used as growth materials in a growing bed that holds plants. The growth medium helps maintain a healthy root environment and provides plant roots with physical support.

• Media based aquaponics systems are extensively used because of their adaptability, simplicity in installation and upkeep, and capacity to accommodate an extensive range of plant species (Resh, 2012; Bailey, *et al.*, 2020).

Basic component of media based grow bed

1. Volcanic Gravel
2. Limestone
3. Packing Foam

Flood and drain

• Before the nutritional solution is flushed away, plant roots are exposed to it for hours at a time.

• The roots obtain oxygen via their recurring submersion in water and subsequent exposure to air.

• Automated siphons (bell siphons) exist (Endut, *et al.*, 2010; Goddek, *et al.*, 2019).

Advantages and disadvantages of media based grow bed

Advantages:

• It is easy to assemble and maintain reasonable costs.

• Fits various types of plants, ranging from big fruiting plants to leafy greens not much cleaning are necessary.

• You may modify the media-based configuration to meet your requirements.

• Suitable for home gardening, hobby purposes, and commercial farming (Rakocy, *et al.*, 1998; Bailey, *et al.*, 2020).

Disadvantages:

• A high-quality medium may come with a high price tag.

• Over time, the medium's pore spaces might clog, resulting in inadequate anaerobic conditions for plants.

• The system type in question is often inappropriate for commercial use because of its reduced productivity and challenges associated with large-scale adoption.

• Because media beds are heavy, a strong, rigid framework is required (Goddek, *et al.*, 2019; Fitzsimmons and Love, 2011).

Deep Water Culture (DWC):

Deep-water culture (DWC) is a common aquaponics technique, also referred to as the floating method or raft system. It entails hanging plant roots straight in nutrient-rich, constant-flow fish tank water (Endut, *et al., 2009;* Rakocy, *et al.*, 2004).

How it works:

1. ***Fish tank:*** Holds goldfish, koi, or tilapia. Plants obtain nutrients from their excrements.
2. ***Growbed:*** A water-filled container, approximately 20 cm deep, in which plants are placed on PVC or Styrofoam rafts that float.
3. ***Water pump:*** Water is constantly moved from the growth bed to the fish tank, feeding the roots of the plants with nutrients and oxygen.

4. Air stones: These are essential for the health of fish and plants because they provide oxygen to water.

5. Grow medium (optional): To support and increase the surface area of beneficial bacteria in net pots, some gardeners use clay pellets or coccoir (Resh, 2012; Rakocy, *et al.*, 1998).

© Int. J. Agriworld, INDIA

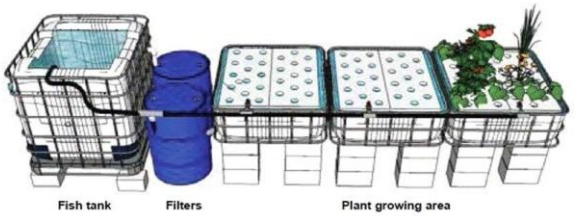

Fig.5: deep water culture

5.2 Advantages:

High rate of plant growth: Plants develop quickly when they have direct access to the nutrients and oxygen in the water.

Effective water use: Since there is no water lost due to drainage or evaporation, it is perfect for areas with limited water resources.

Low maintenance: Compared to other aquaponics techniques, the system needs very little care once it is set up.

Space-saving: More plants may be grown in a less space because to the vertical arrangement.

Appropriate for beginners: It's an excellent place for novice aquaponics lovers to start because of its comparatively easy setup and operation. (Goddek, *et al.*, 2019; Endut, *et al.*, 2010).

5.3 Disadvantages:

Restricted plant selection: Not every plant can survive on damp roots all the time. Herbs and leafy greenery are usually more effective. Power disruptions may be dangerous; as backup electricity is vital because continuous water flow is necessary.

Root-sensitive: Roots may suffer harm if oxygen concentrations fall or the quality of water declines. Crucial to monitor the quality of the water must be tested and adjusted often to keep fish and plant populations at their ideal levels.

Possibility of fish escape: Ensure there is a tight cover over the growing bed to prevent fish from leaping out (Bailey, *et al.*, 2020; Pantanella, *et al.*, 2013*).*

5. Nutrient Film Techniques:

A thin film or layer of nutrient-rich water is continuously poured over the roots of plants using the Nutrient Film Technique (NFT) aquaponic growth technique, providing the plants with a steady supply of nutrients and oxygen. NFT is a potent tool in aquaponics that maximizes the development of a variety of plants, including vegetables, herbs, and tiny fruits (Resh, 2012). The NFT aquaponics system is renowned for its effective use of fertilizers and water. This is because the nutrient-rich water from the fish tank may be efficiently captured by the NFT channels and sent directly to the roots of the plants. In addition to improving the pace of development and general health of plants, this technique helps clean the aquatic habitats of fish (Fitzsimmons and Love, 2011).

6.1 How nutrient film techniques work:

A shallow stream of nutrient-rich water runs down the bottom of the NFT aquaponics system when water is pushed with a tiny even flow from the bio-filter into the growing pipes. Plants were inserted into holes positioned at the tops of the growing pipes. The water returned to the fish tank after leaving the growing pipes (Tyson and Simonne, 2018). Inside the growing pipes, plants start to form root systems as they consume nutrient-rich water. Prior to the water returning to the fish tank, the roots were further purified and filtered. The cycle is completed when the water entering the fish tank overflows over the exit pipe and returns to the mechanical filter. Because the water in the NFT continually flows from the fish tank, the Nutrient Film technology does not require flood and drain time, in contrast to the media-based system (Fitzsimmons and Love, 2011; Goddek, *et al.*, 2019).

6.2 Advantages and disadvantages of NFT:

Advantages:

1. ***Effective nutrient delivery (NFT)***: aquaponics systems provide a very effective way to supply nutrients directly to plant roots, accelerating development and increasing harvests.

2. Water Conservation: By recirculating water and reducing waste and evaporation, the NFT technology conserves water.

3. Oxygenation: Water that flows via NFT channels gives the roots oxygen, which prevents water logging and encourages stronger root systems.

4. Space-Efficient: NFT systems are an excellent option for urban and indoor aquaponic installations because they are appropriate for farmers with limited space.

5. Scalability: NFT systems are scalable, meaning that they can be readily adjusted to changing requirements and spatial limitations. This allowed them to support a wide range of plant types and volumes. (Blidariu and

© Int. J. Agriworld, INDIA

Grozea, 2011; Somerville and Cohen, 2018).

Disadvantages:

1. The roots may block the channels, and water-dangling roots are beneficial to the health of the plants. Bigger roots, on the other hand, have the potential to obstruct the channels as the plants become larger, depriving other plants of water and perhaps leading to nutritional deficiencies.
2. The temperature of water is affected by temperature variations owing to the very thin layer of water that passes through the NFT channels.
3. A failed pump may drastically reduce yield; without access to water, plants will quickly wilt or die.
4. Can only grow a certain number of plants: Small vegetable plants and leafy greens thrive in an NFT system, while bigger plants with.
5. Large variations in root systems: Water poured through the tubes has a swift temperature change. These are not appropriate for NFT. (Pantanella, *et al.*, 2013; Goddek, *et al., 2019*)

Plants in Aquaponics

Vegetables	Fruits & Flowers	Herbs
Lettuce	Strawberry	Basil
Beans	Watermelon	Thyme
Squash	Banana	Cilantro
Broccoli	Marigold	Sage
Pepper	Rose	Lemongrass
Cucumber	Sunflower	Wheatgrass
Peas	Zinnias	Parsley

Fish in Aquaponics

• Tilapia (*O. niloticus*)
• Catla (*Catla catla*)
• Rohu (*Labeo rohita*)
• Common carp (*Cyprinus carpio*)
• Silver carp (*Hypophthalmichthys molitrix*)
• Grass carp (*Ctenopharyngodon idella*)
• Goldfish (*Carassius auratus*)
• Barramundi (*Lates calcarifer*)
• Perch (*Anabas testudineus*)
• Channel Catfish (*Ictalurus punctatus*)
• Trout (*Oncorhynchus mykiss*)
• Salmon (*Salmo salar*)
• Grey mullet (*Mugil cephalus*)
• Freshwater Prawn (*Macrobrachium rosenbergii*) [Blidariu, and Grozea, 2011; Somerville, and Cohen, 2018].

Water Quality in Aquaponics

• **pH** - 6.5–8.5
• **DO** - 4–8 mg/liter
• **Temperature**
Tropical fishes - 22–32°C
Cold-water fishes - 10–18 °C
• **Ammonia and nitrite** - 0 mg/l
• **Light** - Indirect natural light (Rako, *et al.,* 1998).

Fish Health Management

• Fish feed - Pellets are highly recommended
- 2-3 times a day, but don't overfeed
• Stocking density - Recommended stocking density.
• Observations - Fish behavior and appearance (Understand the signs and symptoms of stress, disease and parasites) [Bailey, *et al.,* 2020].

Pros and Cons of Aquaponics

Pros

- ✓ An intense and sustainable method of food production.
- ✓ One nitrogen source (fish food) yields two agricultural outputs (vegetables and fish).
- ✓ Outstandingly water-efficient.
- ✓ Plant growth may occur without soil.
- ✓ Does not use chemical pesticides or fertilizers.
- ✓ Better production quality and yields.
- ✓ Greater biosecurity and reduced dangers from external pollutants.
- ✓ Greater production control results in reduced losses.
- ✓ Applicable to non-arable terrain, such as sandy, salty islands, damaged soil, and deserts.
- ✓ Generates less waste (Rako, *et al.,* 1998; Somerville and Cohen, 2018).

Cons

• High starting expenses in comparison to the cultivation of vegetables in soil.
• Every farmer must understand the creation of plants, microorganisms, and fish in order to succeed.
• Requirements for fish and plants don't always line up exactly.
• Not advised in locations where plants and fish cultivated there cannot get the proper temperature ranges.
• Errors or mishaps may result in a disastrous system failure.

© Int. J. Agriworld, INDIA

• Requires steady availability to energy and fish and plant seeds. Needs to be closely watched to avoid any problems from developing (Somerville and Cohen, 2018; love *et al.,* 2015).

Conclusion

A cutting-edge and quickly developing agricultural technique, aquaponics smoothly combines hydroponic gardening with recirculating aquaculture systems (RAS). Fish and plants coexist in a symbiotic habitat thanks to this effective system. Aquaponics provides a sustainable method of producing food by using the waste that fish make to feed the plants, which then clean and filter the fish's water. It not only encourages environmental sustainability but also increases fish and plant productivity, which could completely change how we grow food in the future.

REFERENCE

Bailey, D.S. *et al.,* (2020). Aquaponics for Urban Food Systems: Challenges and Opportunities. *Sustainability*, vol. 12, no. 14, pp. 1-17.

Blidariu, F., and Grozea, A. (2012). Aquaponics for Sustainable Development: A Promising Educational Tool. *Environmental Engineering and Management Journal*, vol. 11, no. 8, pp. 1417-1423.

Blidariu, F. and Grozea, A. (2011). Increasing the Economic Efficiency and Sustainability of Indoor Fish Farming by Means of Aquaponics – Review. *Animal Science and Biotechnologies*, vol. 44, no. 1, pp. 1-8.

Buzby, K.M. and Lin, S.Y. (2018). Community Aquaponics: A Step-by-Step Guide to Raising Vegetables and Fish Together. *New Society Publishers*.

Endut, A. *et al.,* (2009). A Review of Aquaponic Systems: Hydroponics and Aquaculture Integration. *Journal of Applied Aquaculture*, vol. 21, no. 4, pp. 282-301.

Endut, A. *et al.,* (2009). A review of aquaponic systems: Hydroponics and aquaculture integration." *Journal of Applied Aquaculture*, vol. 21, no. 4, pp. 256-282.

Endut, A. *et al.,* (2010). A study on the optimal ratio of plant to fish for water recirculation aquaponics system. *Journal of Applied Aquaculture*, vol. 22, no. 4, pp. 315-326

Endut, A. *et al.,* (2010). Design and Development of Automatic Bell Siphon System for Small Scale Aquaponic. *International Journal of Engineering and Technology*, vol. 2, no. 2, pp. 111-115.

Endut, A., Jusoh, A., Ali, N., Wan Nik, W.B., & Hassan, A. (2010). A study on the optimal hydraulic loading rate and plant ratios in recirculation aquaponic system. *Bioresource technology*, 101(5), 1511-1517.

Fitzsimmons, K., and Love, D.C. (2011). Aquaponics - Integration of Hydroponics with Aquaculture. *Cooperative Extension Service, College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa*.

Goddek, S., *et al.,* (2019). Aquaponics Food Production Systems: Combined Aquaculture and Hydroponic Production Technologies for the Future." *Springer*.

Goddek, S., *et al.,* (2017). Challenges of Sustainable and Commercial Aquaponics. *Sustainability*, vol. 9, no. 10, pp. 1-21.

Goddek, S., Joyce, A., Kotzen, B., Burnell, G.M. & Esteban, M. Á. (2019). The Current Status of Aquaponics—A Review. *Journal of the World Aquaculture Society*, 50(4), 589-613.

Love, D.C., Fry, J.P., Li, X., Hill, E. S., Genello, L., Semmens, K., & Thompson, R.E. (2015). Commercial aquaponics production and profitability: Findings from an international survey. *Aquaculture*, 435, 67-74.

Love, D.C., *et al.,* (2011). A role for research in advancing integrated aquaculture and agriculture systems. *Frontiers in Ecology and the Environment*, vol. 9, no. 4, pp. 209-214.

Love, D.C., *et al.,* (2017). Comparative Analysis of Environmental Impacts of Aquaculture and Agriculture in the U.S. *Environmental Science & Technology*, vol. 51, no. 7, pp. 3896-3905.

Pantanella, E., Cardarelli, M., Colla, G., Rea, E., Marcucci, A., & Zaccheo, P. (2010). Aquaponics vs. hydroponics: production and quality of lettuce crop. *Acta horticulturae*, (927), 887-893.

Pantanella, E., *et al.,* (2013). Aquaponics: A System for Sustainable Food Production. *Food Research International*, vol. 54, no. 1, pp. 359-371.

Rako, J.E., *et al.,* (1998). Aquaponic Integration of Hydroponic Plant Production with Recirculating Fish Culture. *Proceedings of the 4th International Symposium on Tilapia in Aquaculture*, vol. 200, pp. 451-459.

Rakocy, J.E., Bailey, D.S., Shultz, R. C., & Thoman, E.S. (2004). Aquaponic production of tilapia and basil: Comparing a batch and staggered cropping system. *Aquaculture engineering*, 28(1-2), 69-81.

Rakocy, J.E., Bailey, D.S., Shultz, R.C. (2012). Aquaponic production of tilapia and basil: comparing a batch and staggered cropping

 © Int. J. Agriworld, INDIA

system. *Aquaculture International*, 20(3), 1-13.

Rakocy, J.E., *et al.*, (2012). Aquaponic Production of Tilapia and Basil: Comparing a Batch and Staggered Cropping System. *Acta Horticulturae*, vol. 927, pp. 71-78.

Rakocy, J.E., et al., (2004). Aquaponics: Integration of Hydroponics with Aquaculture. *Cooperative Extension Service, College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa*.

Resh, H.M. (2012). Hydroponic Food Production: A Definitive Guidebook for the Advanced Home Gardener and the Commercial Hydroponic Grower. *CRC Press*.

Somerville, C., and Cohen, M. (2018). Aquaponics as a Sustainable Food Production System: A Case Study in Israel. *Aquaculture International*, vol. 26, no. 3, pp. 753-769.

Suhl, J., *et al.*, (2016). Investigating aquaponics: A system dynamics approach. *Sustainability*, vol. 8, no. 5, pp. 1-20.

Tyson, R., and Simonne, A. (2018). Introduction to Aquaponics. *University of Florida, Institute of Food and Agricultural Sciences*.

CITATION OF THIS ARTICLE

Singh, S.P. and Kumar, A. (2025). Aquaponic: A Sustainable Farming Review, *Int. J. Agriworld*, 6 [1]: 16-22.

IJAW