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Fish and Plant Growth in Aquaponic and its Water Quality Parameter

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Abstract

Aquaponics, a symbiotic integration of aquaculture and hydroponics, presents a promising solution to address the challenges posed by population growth, urbanization, environmental degradation, and economic constraints in food production. As a vital source of animal protein, aquaculture plays a crucial role in meeting global food demands. However, conventional aquaculture practices often encounter issues such as water pollution, resource inefficiency, and high production costs. Aquaponics offers a holistic approach by utilizing the waste from fish farming to fertilize plants, which, in turn, purify the water for the aquatic organisms. This study aims to optimize aquaponic systems for efficient and sustainable food production. It encompasses various aspects, including system design, theoretical frameworks, practical implementation, ideal environmental conditions, and management strategies. Additionally, the study explores suitable combinations of aquaculture and horticulture species, ensuring compatibility and maximizing productivity. By achieving a balance between nutrient cycling, water conservation, and ecological integrity, aquaponic systems strive to produce high-quality organic food while minimizing environmental impacts and operational costs. Ultimately, this research seeks to advance the development and adoption of aquaponics as a viable solution for future food security challenges.

***Key words*:** Aquaponics, Climate change, Low-cost, Plant growth, Water quality

Aquaponics, a symbiotic integration of hydroponic plant cultivation with recirculating aquaculture, offers a promising solution to address contemporary challenges in food production, particularly in the face of rising food shortages and the demand for nutritious sustenance [1-2]. Originating as a relatively novel approach, aquaponics has garnered attention as a multifaceted system with the potential to revolutionize agriculture, especially for impoverished farmers residing in climate-vulnerable regions [3]. The core concept of aquaponics revolves around creating a closed-loop ecosystem where plants and fish mutually benefit from each other's presence. Fish, typically species such as tilapia, carp, or bluegill, are cultivated within the system, providing nutrient-rich water through their waste [4]. This nutrient-rich water serves as a natural fertilizer for the hydroponically grown plants, which absorb and utilize these nutrients for growth, effectively purifying the water in the process. In this way, aquaponics maximizes resource efficiency by recycling water and nutrients, while simultaneously producing both protein-rich fish and nutrient-dense vegetables [5]. Aquaponic systems can be tailored to meet various needs and preferences, including the choice of fish species. While some opt for fish suitable for consumption, others may prefer ornamental fish like Koi, adding an aesthetic dimension to the setup. The design of the fish tank, often constructed with materials providing good visibility, can enhance the visual appeal of the aquaponic environment.

At the heart of many aquaponic setups utilized by home or amateur growers is the media bed system. This system employs a medium, such as gravel or lightweight clay balls, to support plant growth, mirroring the function of traditional soil. This medium facilitates the cultivation of a wide range of plants, including vegetables, fruits, and root vegetables, enabling growers to diversify their produce [6]. While the media bed system is popular among small-scale growers, other types of aquaponic systems, such as the Nutrient Film Technique (NFT) [7] and deepwater cultures (DWC) [8], are favored at larger scales. These systems, although less common among home growers, offer advantages in terms of scalability and efficiency. However, they may have limitations in accommodating plants with larger root systems, such as cucumbers, tomatoes, and beans, which thrive better in media bed systems.

The adoption of aquaponics holds significant promise in addressing food insecurity and malnutrition, particularly in vulnerable communities. By leveraging low-cost pond aquaponic systems, farmers can achieve greater food security by meeting daily dietary needs for both fish and vegetables. Moreover, aquaponics represents a climate-resilient agricultural practice, offering adaptability to changing environmental conditions. Aquaponics stands as a dynamic and adaptable agricultural system that not only addresses food shortages but also promotes sustainability, resource efficiency,

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and resilience in the face of climate change. Through continued research, innovation, and implementation, aquaponics has the potential to play a pivotal role in shaping the future of food production and security on a global scale.

By using a variety of culture techniques, it is able to cultivate both vegetables and fish in a small space at a low cost [9]. This method of exploiting an aquaculture site for vegetable production has been implemented in Bangladesh to meet the country's growing nutrition requirement in polyculture ponds [10]. Concerns about pollution in affluent countries have sparked interest in Aquaponic as a viable method for removing aquaculture wastes while producing high-value plants [11]. India's agriculture faces new challenges as total agriculture land shrinks, population growth accelerates, and weather becomes more complex and unpredictable [12], highlighting the development of new crop production systems such as Aquaponic [13].

Previous studies have studied the implementation of such techniques in Bangladesh, where integrated culture has been passed down from generation to generation. [14] investigated in the Mymensingh district of Bangladesh to explore if raft and rack-based vegetable culture in polyculture was feasible. By installing IFCAS (Integrating Floating Cage Aqua geoponics System) in the Barisal region, [15] investigated how this technology fits into the socioeconomic state of farmers and physical qualities of the pond.

In this study, we attempt to implement the Aquaponic technique mentioned in the above studies to the rural regions of Chhattisgarh. The main objective of the study is to enable local farmers to improve their income through the combined cultivation of vegetable as well as fish breeding & Skill development, create awareness among the small farmers, which would also help to improve the food security for the local farmers. Additional steps were taken to improve the integrated culture system in order to boost production and lower the structure's building costs. An attempt was made to find suitable fish species, lucrative culture types, and suitable density of fish culture for maximum production. More products is needed to improve stocking density for tilapia monoculture in floating Bio Floc Integrated with Aquaponic replication, while the system's simplicity, ease of management, and low equipment cost make it an appealing option.

MATERIALS AND METHODS

The study was conducted in the Nandkathi and Arsnara Village of Durg, Chhattisgarh. The duration of the study was for 180 days, from 1 Sep. 2022 to 28 Feb.2022. Bamboo-split was used to build a three-square-meter (1.5 m by 1.5 m) frame. A rectangular nylon net with a brick weight in four corners constitute the cage frame's bottom. There was a horticulture area on three sides of the cage. A horizontal trellis was created above the cage to accommodate climbing plants. One of the four sides of the trellis and cage was left open to allow for sunshine penetration and simple fish and vegetable harvesting. With a bamboo frame and a net canopy, three sides of the trellis and cage was extended 12 inches (like the sunshade of a building). To grow crops, a mixture of dried pond sludge, cow dung, and other manure was used. Several holes was drilled to allow the roots access to the pond water. Flotation was provided by 15–20 plastic bottles, each with a 10 to 15 L floating capacity. After the completion of the construction of cages, plants such as leafy vegetables, less bushy shrubs, climbing veggies, and medicinal plants were grown in low-cost containers such as discarded plastic bottles, plastic baskets, bamboo baskets, plastic plates etc. Potato, spinach, bitter gourd, and tomato are among the vegetables chosen for their nutritional value. During the experiment, water quality measures was assessed. Physicochemical characteristics of pond water were tested every ten days. A Celsius thermometer was used to measure water temperature, and a Secchi disc with a diameter of 20 cm was used to assess transparency (cm). A digital electronic oxygen metre and an electronic pH metre was used to test dissolved oxygen and pH directly. A Hach Kit was used to measure total ammonia in water samples (Model DR 2010, USA). The Hach kit and the appropriate reagent pillow NitroVer-5 was used to quantify nitrate in water samples. During feeding and sampling, the health and illness of the fish was observed. Fish was sampled every 20 days and measured with a ruler and an automated balance to assess length and weight. Farmers will keep track of fish and vegetable production and consumption. Using Microsoft Excel software, the obtained data was analysed using one-way Analysis of Variance (ANOVA). The significance level was established at 0.05 percent.

Integrating culture system has emerged as an innovative technology that is critical for increasing food output and ensuring a steady supply of food. Due to the optimal utilisation of the pond, pond Aquaponic can help more to solving part of these problems and was more popular than traditional purely pond fish growing systems. A floating Aquaponic system is an environmentally friendly fish and vegetable production method that can be utilised to produce fish and vegetables all year. The current study's identification of suitable species, density, and management technique will help to catch the attention of marginal farmers. The strong economics, minimal risk, low initial capital investment, and a 100% return on investment are the main reasons for the popularity of low cost Aquaponic worldwide. Furthermore, harvesting a modest number of fish or vegetables for home consumption or sale is simple, and feeding and maintenance work requires just minimal daily attention. To expand the use of this floating system and make it financially viable, more study is required. If the security of the Aquaponic system can be maintained, this technique can be used in other smaller water bodies such as creeks and rivers, in addition to ponds.

In an aquaponic system, each component plays a vital role in maintaining a balanced ecosystem where plants and fish thrive symbiotically. Let's delve deeper into the scientific aspects of each component:

Grow bed

The grow bed serves as the medium for plant growth in the aquaponic system. By floating plants on the grow bed, they can efficiently absorb water, nutrients, and oxygen necessary for their growth. The use of silicon to seal the drum cap ensures a watertight environment, preventing leaks that could disrupt the system. It's imperative to choose a silicon sealant that is safe for aquatic life to maintain the health of the fish.

Auto siphon

An auto siphon is a crucial component for regulating water flow within the system without requiring manual intervention. Constructed from PVC plumbing parts, the auto siphon facilitates the controlled drainage of water from the grow bed back into the fish tank. The design incorporates elements such as rubber grommets, elbows, PVC pipes, end caps, tees, and PVC balls to create a mechanism that initiates siphoning when the water level reaches a predetermined height. Properly drilled holes in the PVC pipe ensure optimal performance, with an 8 mm hole size being ideal for efficient operation.

Clay pellets

Clay pellets provide an excellent growing medium for plants in the aquaponic system. They offer ample aeration to the root zone, promoting healthy root growth and nutrient absorption. Additionally, the stability provided by clay pellets supports the plants as they develop, ensuring they remain upright and secure within the grow bed.

Fish

Fish are the cornerstone of the aquaponic system, contributing to both nutrient cycling and food production. Freshwater fish, such as roopchand, are stocked in the fish tank and fed twice daily. Their waste products are converted by beneficial bacteria into nutrients that nourish the plants, completing the nutrient cycle. This symbiotic relationship between fish and plants results in efficient food production with minimal water consumption compared to conventional farming methods.

PVC filter

The PVC filter serves to remove excess fish waste from the water, preventing the buildup of harmful substances that could compromise the health of the fish and plants. By constructing a small filter using a 4" PVC pipe, particulate matter and debris are efficiently captured, ensuring water quality remains optimal for both aquatic and plant life.

Thermocol sheets

Thermocol sheets play a supportive role in the aquaponic system by providing a stable platform for the plants. By elevating the plants above the water level, thermocol sheets help prevent waterlogging and root rot, ensuring the plants receive adequate oxygenation and support for healthy growth.

Each component of the aquaponic system contributes to its overall functionality and sustainability, creating a harmonious environment where fish and plants thrive together. Through careful design and consideration of scientific principles, aquaponic systems offer a promising approach to sustainable food production with minimal environmental impact.

RESULTS AND DISCUSSION

The system you described seems to be an aquaponic system, which combines aquaculture (the farming of aquatic organisms like fish) and hydroponics (growing plants in water).

Table 1 Some observations from the experiment

S. No.	pH	Temperature	TDS	Date
1	8	32.5°C	391	12-04-2022
2	8	31.5°C	394	14-04-2022
3	8	31.6°C	419	17-04-2022
4	9	33.2°C	466	20-04-2022
5	9	34°C	463	23-04-2022
6	8	34.2°C	470	26-04-2022
7	8	34.5°C	465	29-04-2022

For the system

The Total Dissolved Solids (TDS) of water increasing initially and then stabilizing at different temperatures while the pH level remains relatively constant suggests a dynamic equilibrium within the system. TDS typically represents the concentration of inorganic salts, minerals, and organic matter dissolved in water. The stabilization of TDS could indicate a balance achieved between inputs (such as fish waste and feed) and outputs (such as water changes and plant uptake). The fact that fish waste impacts TDS but not pH suggests that the waste contributes primarily to the mineral content of the water rather than altering its acidity or alkalinity. This is consistent with the breakdown of organic matter in fish waste leading to the release of minerals and nutrients, which can be utilized by plants for growth. Regular water changes are necessary to maintain water quality and prevent the accumulation of toxins or excess nutrients. This ensures optimal conditions for both the fish and the plants in the system.

For the fish

The observed increase in fish size from approximately 2 inches to 4-5 inches over a month indicates successful growth and development. Feeding the fish three times a day ensures they receive adequate nutrition for growth, while the use of air bubbles helps oxygenate the water, which is crucial for fish respiration. The exposure to low-intensity sunlight likely helps regulate the fish's circadian rhythms and provides a natural source of vitamin D, which is essential for calcium absorption and bone development in fish. The increase in fish size could also be attributed to the favorable conditions in the aquaponic system, such as optimal water quality, nutrient availability, and the absence of stressors commonly found in traditional aquaculture settings.

For the plants

The rapid growth of plants, approximately 1.5 times faster than usual, can be attributed to the nutrient-rich environment created by the aquaponic system. Fish waste, which contains ammonia, serves as a natural fertilizer for the plants. Ammonia is converted into nitrites and nitrates by beneficial bacteria in the system, which are then absorbed by the plants as essential nutrients for growth. The choice of plants such as tomatoes, cilantro, and mint is strategic, as they are known to thrive in nutrient-rich environments and are popular choices for aquaponic systems. The observed growth of tomato plants within 4-5 days after planting is indicative of the rapid nutrient uptake facilitated by the aquaponic system. The symbiotic relationship between the fish, bacteria, and plants creates a self-sustaining ecosystem where waste products are efficiently recycled to support plant growth, thereby maximizing productivity.

Fig 1 Representation of aquaponic systems

Application of aquaponics

Aquaponics, a sustainable agricultural practice that integrates aquaculture (fish farming) with hydroponics (soilless plant cultivation), offers a promising solution for efficient and environmentally friendly food production. By harnessing natural symbiotic relationships between fish and plants, aquaponics systems create a closed-loop ecosystem where fish waste provides essential nutrients for plant growth, while plants help filter and purify the water for the fish. The application of aquaponics extends across various agricultural settings due to its versatility and efficiency. Its low cost makes it particularly appealing for small-scale farmers or those with limited financial resources. This method allows for the simultaneous production of organic vegetables and fish, addressing both food security and economic concerns.

In densely populated urban areas where traditional farming may be impractical, aquaponics offers a viable alternative. By utilizing limited space efficiently, such as rooftops or small plots, aquaponic systems enable urban dwellers to grow fresh produce locally, reducing reliance on long-distance food transportation and minimizing carbon emissions. Monitoring and maintaining water quality are essential aspects of successful aquaponics. Physicochemical parameters such as temperature, pH, dissolved oxygen, nitrite, and ammonia levels must be carefully regulated to ensure optimal conditions for fish and plant health. Continuous monitoring during the experimental period allows for adjustments to be made to maintain stable water quality. During colder seasons, such as winter, water temperature may decrease, affecting the overall performance of the aquaponics system. Adequate insulation and heating mechanisms may be necessary to mitigate these effects and sustain optimal conditions for fish and plant growth. Aquaponics represents a sustainable and cost-effective approach to food production with numerous applications in agriculture. By harnessing natural processes and maximizing resource efficiency, aquaponic systems offer a promising solution for addressing food security challenges and promoting environmental sustainability.

CONCLUSION

The integration of culture systems has emerged as a pivotal technological advancement in India, particularly in addressing the imperative of augmenting food production to sustain a consistent food supply. Aquaponics implemented within ponds has surfaced as a promising solution to enhance productivity, surpassing the conventional pond-only fish farming method by maximizing pond utility. This innovative approach has garnered widespread acclaim due to its dual-purpose utilization of water bodies for fish and vegetable cultivation, proving to be environmentally sustainable, particularly in regions susceptible to floods and saline coastal soils. The implementation of a floating aquaponics system has demonstrated its efficacy in facilitating year-round production of fish and vegetables, presenting a viable opportunity for marginal farmers. Noteworthy contributions include the identification of suitable species, optimal stocking densities, and effective management techniques, thereby enhancing the economic prospects for farmers. A key driver of the popularity of this cost-effective aquaponics system lies in its favorable economic dynamics, characterized by low risks and initial capital outlay, coupled with a rapid return on investment, typically achieved within a span of 80 days. Furthermore, its operational simplicity, requiring minimal daily oversight for feeding and maintenance, underscores its practicality for farmers. However, while the adoption of this technology holds immense promise, further research is warranted to broaden its applicability and facilitate commercial scalability. The adaptability of this floating system extends beyond ponds to encompass diverse water bodies such as beels, rivers, haors, and baors, provided that the integrity and safety of the aquaponics system are upheld. In summary, the integration of aquaponics within pond ecosystems represents a pioneering approach to sustainable food production in India, offering a pathway to alleviate food insecurity while bolstering the economic resilience of marginalized farming communities. Continued innovation and research are essential to unlock the full potential of this transformative technology and extend its benefits to a broader spectrum of agricultural landscapes.

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