



Testing the Feasibility of Aquaponics in Farming Poor Communities of Potohar [†]

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Abstract

The demand for food has increased due to the world's expanding population, which has also put pressure on vital resources like water, land, and nutrients. Therefore, in order to guarantee food security, it is imperative to establish alternative, sustainable, and dependable strategies. In recent decades, researchers have developed novel food production methods that collectively enhance the efficiency and sustainability of food systems. Among these, aquaponics stands out as an advanced and eco-friendly agricultural technology that integrates aquaculture and hydroponics. In this system, fish waste from the aquaculture unit is utilized as a nutrient medium in the hydroponic subsystem to grow edible plants. This review aims to assess the potential of aquaponics to produce high-quality fruits, vegetables, and fish while minimizing environmental impacts without relying on chemical fertilizers. The study focuses on system design, nutrient cycling, and productivity parameters to assess its feasibility under Potohar conditions. The expected outcome is to demonstrate that aquaponics can enhance food quality, conserve resources, and uplift the socio-economic status of farming communities by alleviating poverty.

Keywords: aquaponics; fish farming; food production; hydroponics



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1. Introduction

An aquaponic system is the combination of two systems: the first is recirculating aquaculture, and the second is the soilless hydroponics system for fish and crop production. It has become a bio-integrated model for sustainable food production [1,2] and has therefore attracted attention. The adoption of the aquaponics system is increasing. The underlying reason for this result is the interconnection between the aquaculture process and the hydroponic process, which suggests that the system is a promising and feasible food production technique [3]. Alexandratos et al. [4] stated that the aquaponic system can also secure protein safety for the growing urban population that will need animal protein in the future.

Water scarcity, poor soil fertility, and low crop productivity are among the major agricultural challenges faced by Pakistan's Potohar region, which is known for its undulating

topography, semi-arid climate, and irregular rainfall patterns. These factors have limited the livelihood opportunities for smallholder farmers. Introducing aquaponics in this region presents an opportunity to utilize available groundwater and controlled-environment structures to achieve sustainable food production, enhance nutrition, and strengthen rural economies [5].

On the Potohar plateau, conventional agriculture is hindered by low rainfall, nutrient-poor soils, and high evaporation losses, leading to reduced productivity and income instability among small-scale farmers. These challenges make aquaponics a feasible solution, offering a closed-loop system that conserves water, recycles nutrients, and allows year-round production of vegetables and fish even under limited resource conditions [6,7].

However, the prospects for formal agriculture as well as exhaustive animal protein production are challenged by energy price fluctuations, growth variability problems, and sales issues in meeting this demand. Klinger et al. [8] found that resource shortages, such as reducing the area of arable land, restricting freshwater supply, soil disintegration, and soil nutrient consumption, also include an additional layer to these challenges. These challenges strain researchers to take remedial measures to remunerate for the existing shortage of fish production through aquaponics systems [9]. Aquaponics systems are likely to be a superior choice to resolve such issues, but the accessibility of this system has not yet been completely understood from the perspective of cost-effectiveness or technical ability [2]. In this case, this review will be useful for understanding the technical abilities and economic benefits of aquaponics systems and will exhibit that aquaponics systems will be appropriate for use in a commercial environment. There is no relevant research at present in Pakistan that addresses the overall technical and economic feasibility of aquaponics. Therefore, the purpose of this review is to determine whether aquaponics systems are generally feasible for poor farming communities in Potohar.

2. Principles of Aquaponics

The fundamental ideas of aquaponics are as follows:

- (a) Waste materials can be utilized to transfer nutrients from one biological system to another.
- (b) A combination of plant and fish farming can produce manifold products at once.
- (c) In biological filtration and recirculation methods, water can be recycled.
- (d) Local food production systems offer nutritious foods and promote local economies.

In an aquaponics system, nutrient-rich wastewater from the aquarium is used to fertilize hydroponic production beds [10]. This is beneficial for fish health, plant roots, and rhizobacteria, which can eliminate nutrients from the water. These nutrients, produced by fish waste, algae and decaying fish feed, are pollutants; otherwise, they will become poisonous in the fish tanks and are expected to deteriorate water quality parameters, which are harmful to the fish population (Figure 1). On the contrary, the hydroponic bed acts as a biological filter by removing ammonia, nitrate, nitrite, and phosphorus so that fresh and clean water can be used for fish populations. Nitrifying bacteria (associated with plant roots) living in gravel play a key function in the nutrient cycle. Without these microorganisms, the entire system would cease to function [11,12].

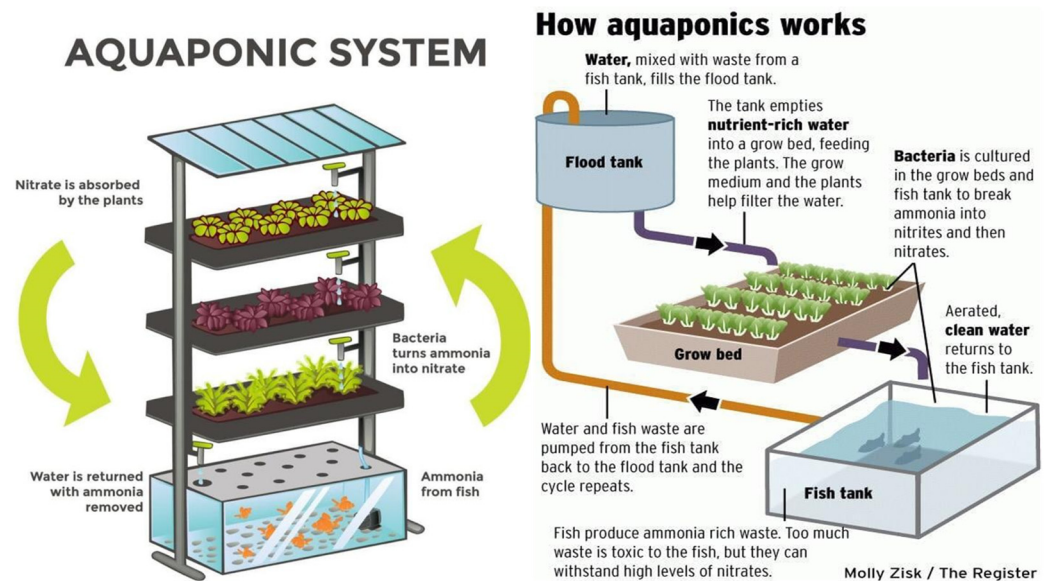


Figure 1. Flow diagrammatic demonstration of the aquaponics system [12,13].

3. Proposed Goals/Objectives

1. Development and adoption of new technologies (aquaponics) for enhancing crop productivity.
2. Up-lifting the living standards of the farming community by alleviating poverty.
3. To improve the lives and livelihoods of farmers by creating a triple impact on livelihoods, sustainable agriculture and nutrition.
4. Establishing and running aquaponics in a greenhouse for research and raising vegetables under appropriate climatic conditions of Potohar.
5. Quality seed production.

4. Final Deliverables/Outcome of the Research

1. Enhance productivity of high-quality off-season vegetables and fruits, along with development and innovation in aquaponics techniques in agriculture.
2. Improved yield (10–30 times higher) compared with the conventional agricultural system before the end of the project.
3. Plants take less time to grow, and plant growth is faster than that of plants grown in the field because there is no mechanical barrier to the roots and all nutrients are readily available.
4. At the completion of the project, an increase in export volume, this will contribute to GDP.
5. Gradual increase in the living standards of farmers and their families.
6. Increase in local sales of the product/crop.
7. Timely availability of the product/crop in the market during the off-season.
8. At the completion of the project, a number of trainees will be skilled in aquaponics technology.
9. Comparison of the annual yield at the end of project through aquaponics, hydroponics and traditional agriculture.
10. Harvesting records of crops under hydroponic and aquaponic technologies.

5. Available Physical Resources and Facilities

Pir Mehr Ali Shah Arid Agriculture University Rawalpindi is operating a state-of-the-art hydroponic facility at Kaliyam Mughal Rawat, 30 km from Rawalpindi on G.T Road

leading to Lahore. The IHA Hydroponics Farm has infrastructure like offices, research labs, stores, residences for workers/labors, and dormitories for officers/researchers. The facility comprises five greenhouses over an area of 5.25 acres. The facility is being operated by the university through a team of workers helped by university experts. Previously, crops planted included tomato, bell pepper, cherry tomato, cucumber, herbs in pack, salad pack, egg plants, and bitter gourd. However, the major chunk of cropping comprises tomato, cherry tomato, cucumber, and capsicum in three colors (yellow, pink, and red).

6. Aquaponic System Design

The aquaponics system can be constructed in numerous designs according to hydrological and functional arrangement. The setup of an aquaponics system is very complicated because it deals with three different components: fish, plants, and microorganisms at the same time. The aquaponics system is based on the principle of the relationship between hydroponic components and the circulation of cultivated elements. This can be illustrated as a mixed culture of fish, bacteria and plants. Therefore, the aquaponics system must consist of vital components such as an aquarium, aerator, pipes, lighting, pumps, biofilters, hydroponic components (media beds), NFT, DWC, RAFT, deep-water tanks, and a sump tank. Other components include half barrels, medium PVC pipes, buckets, and plastic containers, which can also be utilized [14]. The sedimentation equipment includes separator covers, pipes and a sedimentation pump. Every part of the aquaponics system acts with a particular function. Fish release organic wastes into the aquarium as ammonia, and biological filters have two particular processes in which metabolites in fish manure are converted from ammonia into nitrite and subsequently into nitrate during the process of nitrification. Hydroponic elements in the aquaponics system offer plants with the necessary nutrients. Furthermore, the aquaponics system must ensure procedures such as air circulation, water movement, and biological processes for producing the last-stage nitrates. Somerville et al. [15] described aquaponics as a culture of fish, bacteria, and plants in symbiosis and as a sustainable agricultural system that uses water and nutrients in a related circulation cycle (Figure 2).

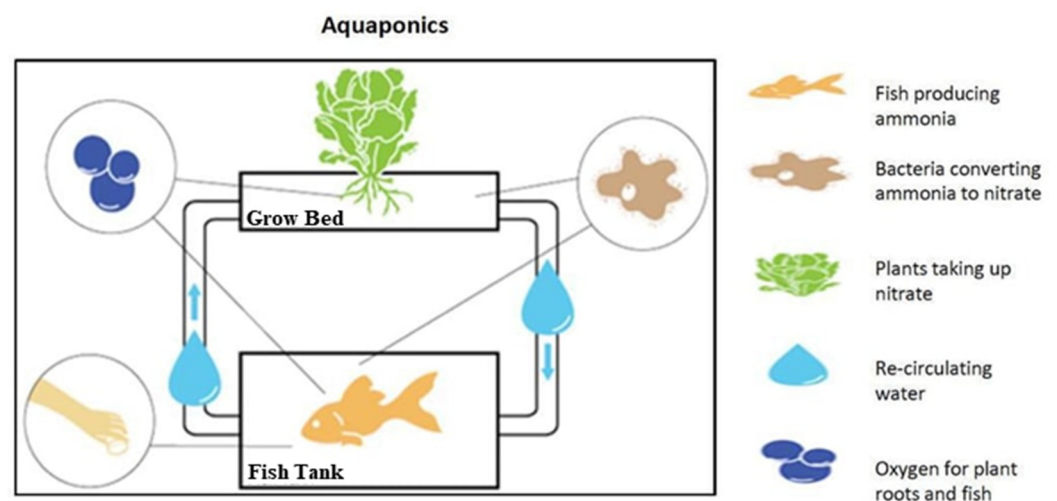


Figure 2. Flow diagram of a recirculating aquaponic system [16].

7. Plant Selection

The selection of plant species appropriate for hydroponic culture (in aquaponics) is associated with fish stocking density and the nutrient availability in aquaculture wastewater. Generally, vegetables like herbs, lettuce, and specialty greens (spinach, chives, basil, and watercress) have short-to-moderate nutritional demands and are well suited for complete

aquaponics. Plants that produce vegetables like tomatoes, cucumbers, and bell peppers have greater nutritional requirements and perform well in well-equipped aquaponics systems. Compared to field-grown tomato varieties, greenhouse tomato types are better suited for low-light and high-humidity conditions in greenhouses [17].

8. Fish Selection

The major step in a recirculating aquaculture system is the selection of fish that are well adapted to warm or cold water, like trout, tilapia, Arctic char, perch, and bass. In commercial aquaponics systems, tilapia is the most common and appropriate species. This is mainly due to its adaptability and ability to withstand unpredictable water quality conditions like pH, temperature, oxygen levels, and dissolved solids [18].

9. Parameters of Aquaponic System

9.1. pH

In any aquaponic system, the stability of pH is a significant and vital phenomenon because living organisms work in the circulatory system and control the metabolism of fish and microbial activities and influence nitrogen use in plants [19]. Somerville et al. [15] stated that the tolerance range of most plants is 5.5–7.5. In the entire aquaponics system, the ideal pH is retained by the addition of CaOH (calcium hydroxide) and KOH (potassium hydroxide) to the bottom of the feed tank, where they dissolve and gradually enter the system. Kim et al. [20] reported that the optimal pH value for biological methods in nitrification processes is in the range of 7.5–8.5. For the nitrification process, the proper pH is 8.5 [19]. The pH is typically maintained between 6 and 7.0 in aquaponics systems because this range allows bacteria to function at their best and allows plant roots to fully absorb all the nutrients they require [19].

9.2. Dissolved Oxygen (DO)

It is one of the key factors in fish farming. This is important for useful nitrifying bacteria, which convert fish effluent into nutrients that can be digested by plants [14]. The dissolved oxygen (DO) contents illustrated the number of oxygen molecules in the water in an aquaponics system. It is an important element for the survival and reproduction of plants, fish, and nitrifying bacteria in the aquaponics system and is calculated in milligrams per liter. Water temperature must be monitored regularly because it is closely linked to dissolved oxygen, and symptoms of root rot can occur if the oxygen level is inadequate at high water temperatures [17]. Most plants require higher DO contents (>3 mg/L), and for biofilters, higher than 1.7 mg/L is recommended to maintain nitrification activity [18]. In addition, it is suggested to keep the oxygen level at 5 mg/L or higher in aquaponics systems to reduce stress on fish and plants.

9.3. Tank Water Temperature

A significant aspect of aquaculture is water temperature, which has an impact on the system's internal organisms. Fish growth, feeding rate, and size are all impacted by water temperature in addition to the creatures it contains [21]. In addition, the water tank temperature impacts the physiological activities of fish in the aquaponics system as well as the efficiency of the biofilter [22]. Moreover, high temperature directly affects the systemic processes of reducing oxygen levels, increasing non-ionized (poisonous) ammonia, and limiting calcium absorption [17]. Oyugi et al. [23] observed that the ideal range of water temperature is necessary for each fish species because it directly affects maximum growth. In an aquaponics system, tilapia fish need warm temperatures (25–27 °C) [24] for maximum growth [25]. Failure to maintain the ideal temperature in the aquarium will greatly reduce

fish growth and cause diseases that lead to other hazards, such as decreased reproductive and digestibility in fish [26]. The ideal temperature for growing vegetables is 20–25 °C, and for biofilters (nitrifying bacteria) it is 25–30 °C. If the temperature falls below 10 °C, tilapia fish die.

10. Conclusions

Aquaculture is one of the fastest growing sectors of agriculture. It offers the ultimate livelihood choice for millions of Pakistani people. Aquaculture must be intensively developed to meet growing demand, reduce poverty and malnutrition more effectively, and become ecologically more sustainable. New technologies will create sustainable aquaculture, which is a new global standard. To enhance the socio-economic status of farmers, it is necessary to adopt new agricultural interventions to expand aquaculture production in a sustainable manner, such as integrated agriculture farming, aquaponic systems, and re-circulatory aquaculture system (RAS).

Highly developed aquaculture systems and other technological improvements have a positive impact on the success, production, investment and marketing potential of aquaculture. Improvements in these aquaculture systems should offer a means to produce healthy, fast-growing plants and fish in an eco-friendly way. Therefore, this improvement will depend on farmers' aspiration, motivation, capacity building, and the development of infrastructure that enables farmers to work with scientists and international donor societies to support new agricultural technologies related to farming.

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