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Aquaponics: An Evolving and Sustainable Food Production Technology That Could Support the Nutritional Maintenance of the Growing Human Population

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Abstract

Aquaponics is an integrated technology that combines aquaculture and hydroponic technology to grow fish and plants together. It is a closed-loop, recirculating fresh water system in which plants and fish live symbiotically. There are different forms of aquaponics based on size and structure ranging from small indoor or outdoor units to large commercial units. According to a 2013 United Nation's report, the world human population is growing at a fast pace. The estimated human population for 2015 is about 7.3 billion and will reach about 8.5 billion by 2030. This rapid population growth will put stress on the accessibility to healthy and affordable food. Additional food production through increased agricultural activities will not a viable option. It will cause significant environmental damages, such as loss of habitat, loss of water resources, leaching of nitrogen and other chemicals, eutrophication, etc. Therefore, alternative and sustainable food production methods are to be explored. Studies indicate that aquaponics is a versatile, cost effective and reliable food technology in the simultaneous production of vegetables and fish. It shows the potential to be a viable method for sustainable food production and play a vital role in securing food security for the future world.

Keywords: Aquaculture, hydroponics, sustainable agriculture.

1.0 Introduction

The world human population is on the rise. According to the United Nation's Economic and Social Affairs, the estimated world population will be about 7.3 billion in 2015 and will reach 8.5 billion by 2030 (UN, 2013). Access to nutritious and affordable food is a basic requirement for the healthy sustainability of growing human population. Coleman-Jensen (2014) reported that as of 2013, about 39% of low-income households and 14% of all households were considered to be "food insecure" (Coleman-Jensen, 2014a; Coleman-Jensen, 2014b).

The added human population would demand an additional food supply. However, additional food production through increased agricultural activities will have substantial environmental impacts, such as loss of habitat, nutrient leaching, eutrophication, etc. In the past 20 years, nitrogen use in chemical fertilizers has been exceeded 20 times causing severe eutrophication to water bodies (Dutta, 2014; Dutta 2015). Water is a scarce commodity which is evident by a growing water shortage in some megacities around the world (Haase, 2015). It is a key component for agriculture and up to 75% of the world's fresh water is used for agricultural processes. As water runs through agricultural lands, it collects chemicals from fertilizers and drains into surrounding water bodies or leaches them into the ground water. Only about 10% of the nitrogen contained in the fertilizers is used by agricultural plants (Jones, 2002), the rest enters the environment, which is the key source of eutrophication.

There is a global concern about how future generations will produce more food in a sustainable manner. Agriculture has substantial environmental impacts on natural resources such as conversion of natural habitats into agricultural lands, nutrient leaching into ground water, pollution through pesticides and other chemicals. These are all serious issues.

Aquaponics integrates an aquaculture system (fish production) with a hydroponic system (vegetable production without soil) in a symbiotic environment. In aquaponics, fish are raised in a tank or reservoir. Reservoir water gets polluted with nitrogenous

wastes (mostly ammonia and nitrite) from fish and fish-feed. This water is then pumped to plants grown in a hydroponic medium. Bacteria convert nitrite and ammonia to nitrate. Nitrate is then used by plants as nutrients. Finally, water filtered through hydroponic medium is returned to the reservoir and the cycle repeats. This arrangement represents a sustainable ecosystem where both the plants and the fish can flourish using limited space and less water without producing environmental wastes. Fish is not only a healthy source of protein; it is cheaper to produce as fish production requires less feed as compared to other conventional protein sources. On the average, 1lb of fish production requires 1.7 lbs of feed. Whereas, the average feed requirements will be 2.0, 3.5, and 8.0 for chicken, pork and beef, respectively (Kris, 2012)

As stated earlier, aquaponics is a marriage between aquaculture and hydroponics. The history of aquaponics goes back about 1,500 years in China where an innovative entrepreneur farmer used duck droppings to feed fin fish, fin fish waste to feed catfish, and then catfish wastes for rice cultivation (Jones, 2002). The concept of aquaponics was reintroduced in the mid-1980s when Watten and Busch (1984) of the University of Virgin Islands described aquaponics as a reusable water circulation system for plants and fish. In 1986, Zweig reported a deep-water integrated aquaculture and hydroponic vegetable production system. During the latter part of the 1980s, McMurty developed an integrated aqua and hydroponic culture system called Integrated Aqua Vegiculture System (IAVS) in which water circulated through a hydroponic (sand or pebble bed) medium (McMurtry, 1990; McMurtry, *et al.*, 1990). The deep-water and IAVS are considered to be the two principal aquaponics systems (Marklin *et al.*, 2013).

2.0 Types of Aquaponics

There are five emerging primary aquaponics methods (Datta, 2014).

i. Nutrient Film Technique: In this system water from the fish tank flows through a filter system into a gutter while plants are suspended above the water. The gutter only holds a thin layer of water and plant roots are touching the water film. This system is described to be cheap, scalable and suitable for leafy vegetables.

ii. Vertical System: In this system, vegetables are grown in columns above the fish tank. Filtered water is pumped at the top of the column that flows down through the plant roots. This system is suitable for leafy vegetables as well.

iii. Media Based System: This is also known as the gravel bed system. In this system, seedlings are grown in containers filled with porous rocks that can store air and water. Water from the fish tank is pumped and circulated through the containers. Water provides nutrients for the plants while rocks acts as filters and support the plant root systems. This is the simplest form of aquaponics system to construct.

iv. Deep water culture system: This is mostly used as a commercial method in which plants are floated using a floating board on top of the water and plants roots are submersed in fish tank water. Floating boards are typically made from plastic and Styrofoam with netted holes. Net holes are used to hold the plant pots.

v. Wicking Bed System: In this system, plant roots are fed through a water supply from fish tank once a week during summer and once a month during winter. This is mostly used to grow root vegetables such as carrots, radish, beats, etc.

Figure 1 illustrates an aquaponics system showing the conversion of ammonia produced from fish and feed wastes into nitrate by bacterial action. Nitrate is used as plant nutrients and recycled water returns to fish reservoirs.

3.0 Advantages and Disadvantages of Aquaponics

a) Advantages of Aquaponics

- The main advantage of aquaponics is its self-sustainability. Nutrients from fish wastes feed the plants and the plants recycle the water and keep it clean for a healthy sustenance of the fish population.
- This fish and plant polyculture is 100% organic and additional fertilizers or chemicals are not used.
- Water is an important commodity and will be the scarcest commodity of the future world. By recycling water, this system uses only a fraction of water that could be used for conventional plant production. Water loss through waste removal and evaporation is typically about 1-1.5% of the total volume of water (Hambrey, 2013).

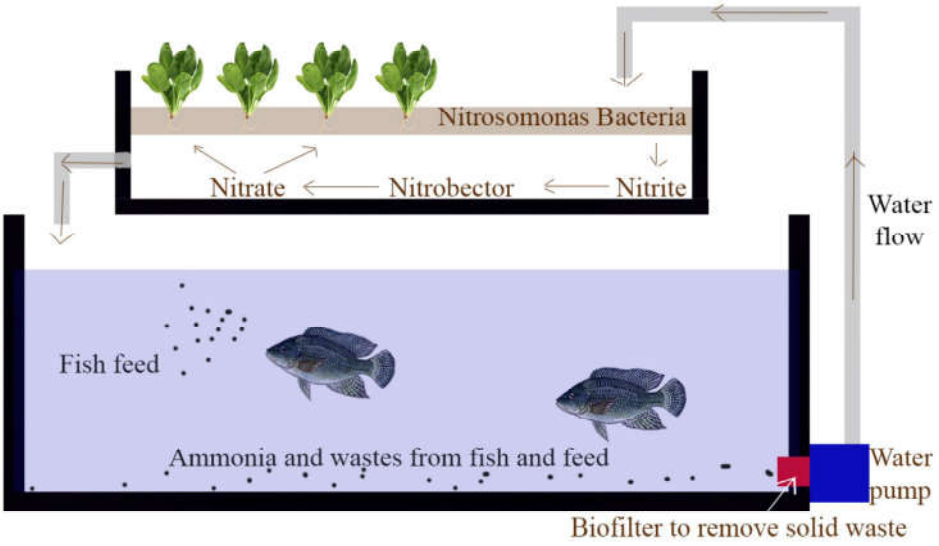

Figure 1: An illustration of an aquaponics system.

- Aquaponics provides higher yields as compared to conventional aquaculture. It provides year the around optimal growth and produces market sized fish in 9 months as compared to 15-18 months in conventional fish farms (Hambrey, 2013).
- The low cost local food production enhances the local economy and supplies fresh food to the community.

b) Disadvantages of Aquaponics

- Although aquaponics is a cost effective system, the initial cost of establishment is higher than setting up conventional hydroponics.
- Aquaponics is mostly suitable for areas with stable climatic conditions. Climate fluctuations, especially extreme weather conditions may affect both the plant and the fish populations. A climate controlled aquaponics system will increase the establishment and operating costs.
- To maintain the oxygen demand of fish and bacteria, aquaponics will require an intensive aeration and pumping operation. Therefore, it will involve some energy costs (Hambrey, 2013).

4.0 Discussion and Conclusions

Aquaponics resembles a natural aquatic ecosystem in which wastes form fish serve as plant nutrients and plants help clean the water for the fish population. This is a particularly suitable approach for arid climates as it limits water loss and requires much less water to grow plants as compared to soil-based systems. In fact, the only water loss from an aquaponics system is by evaporation and transpiration from the plants (Marklin *et al.*, 2013).

Aquaponics is gaining popularity among scientists and the general population. It conserves price-less groundwater, eliminates human exposure to harmful farm chemicals and recycles components it produces. Since it is a low-cost, sustainable and self-paying system, it is economically beneficial to the producers and the consumers. Furthermore, aquaponics systems are versatile as they can be designed from small indoor or outdoor units to large commercial units, using the same technology (Mohamad *et al.*, 2013).

As aquaponics culture is gaining a rapid popularity, it is expected to serve as a viable method for sustainable food production and play a vital role in securing food security (Hart *et al.*, 2013) to meet the added food demands in the upcoming centuries.

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