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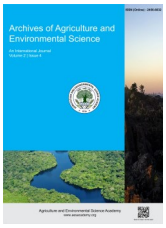

REVIEW ARTICLE

Aquaponics a modern approach for integrated farming and wise utilization of components for sustainability of food security: A review

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ABSTRACT

Aquaponics is the sustainable approaches of present day's world for raising fish species along with vegetables in a symbiotic association for sustainable food production. People are facing food crisis not only because of the adverse environmental condition but also due to unbalance environment population ratio. That is the main reason why the entire world is more concerned about the production of more food for security and sustainability. Present day's modern farming system mainly focus on the productivity increasing technology and in due course individual are utilizing more chemical compounds that result in the degradation of soil. It shows great impact on ecological environment. Most of the cultivable land is also turned out as a site of construction which reduces the cultivable land on earth and ultimately arising the food insecurity. In such a circumstance a new approach of aquaponics might be beneficial where water solely covers the two third of the total mass. Aquaponics is a soilless culture which gained immense popularity as it focuses on organic production of vegetables within a single recirculating aquaponics system. Along with the sustainability it also emphasis economic efficacy and enhancement of productivity. It can be grown used on non-arable lands such as deserts, degraded soil or salty, sandy islands. So, it can integrate livelihood strategies to secure food and small incomes for landless and poor households.

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INTRODUCTION

Along with aeroponics and hydroponics aquaponics is also one of the soilless culture that emphasis production of vegetables and fruits within symbiotic relationship among both components. Other forms of soilless culture include aeroaquaponics, maraponics, algaeponics, haloponics, biofloc technology for aquaponics and vertical aquaponics which are more all less different modern technology that are introduced to alleviate the global food deficit problem. Aquaponics mainly work on the mechanism which is integrated with hydroponics where the fish produced Nitrogen is utilized by plant to complete the metabolic functioning for proper growth and development. In general, the term aquaponics is the crucial linkage between the aquaculture and horticultural crops in which the water inside the apparatus set is recirculating to mobilize the efficient use of nutrients present in the water. This inventive concept is ecofriendly technology introduced for modern agricultural system to increase the productivity. In the modern agricultural system, adoption of technologies, use of machine, infrastructure and expertise is required, therefore, proper access to information and understanding become essential for the success of any incentive technology (Shah *et al.*, 2021a). Exploitation of natural resources for personal benefit of the individual not only reduced the cultivable land but also induce the scarcity of water ultimately leading towards food scarcity in developing countries and arise black

market where price hiking is the primary phenomena. It is the biggest threat of present agriculturist and the major challenge faced by agriculturist is production of agricultural products through sustainable farming approach. In the scarce condition water and nutrient recycling is the best option to solve the emerging problem. Bio-intensive farming system aquaponics is the soil less agriculture system where the production is carried out in combination with aquaculture and hydroponics (Love, 2015).

AQUAPONICS: AMALGAMATION OF HYDROPONICS AND AQUACULTURE

Since aquaponics is the combination of two modern farming concept aquaculture which deals with production of fish and aquatic organism either in the enclosed vessel or container or tank and hydroponics dealing with soilless production of vegetables and plants, they both in combination not only increase the productivity but also enhance optimum utilization of resources. Individually hydroponics required a huge amount of money as it require nutrients for plants and in due process continuous flushing is essential which arise waste disposal problems. Thus, irrigation systems are integrated within these media, thereby introducing a nutrient solution to the plants' root zones. Similarly, fishes growing via the process of aquaculture excrete which consist of number of nutrition which needs to be removed daily to keep the arrangement clean and clear. Aquaculture production methods have been developed in various regions of the planet and have thus been adjusted to the distinct environmental and climatic conditions in different regions. There are two main types of aquacultures—marine and freshwater and the four major categories of aquaculture include open water systems (e.g., Cages, long lines), pond culture, flow-through raceways, and recirculating aquaculture systems (RAS). Each concept has negative impact and if combined together both species are mutually benefitted. That's how the concept of aquaponics emerges.

Working mechanism of aquaponics

The water utilized for aquaculture consist of nutrient rich water which should be disposed. Along with the disposing the content, water should be regulated and circulated time to time so as to facilitates the aeration for fish. And in combination of vegetables and fish, vegetables utilize the nutrient present in the water which is cost effective and efficient. Economic benefit can be increased from fish as well as vegetables. Fish predominantly produces nitrogen rich effluents and if the waste are accumulated in larger quantity, it is dangerous and even lethal for fish life. If this nitrogen can be efficiently used as a source of fertilizer for plants, it acts as a supplementary nutrition for growth and development of the plant. Along with the uptake of the nutrition ultimately the dirty water gets purified and makes further useful for the fish. In the process vegetable can be easily grown and as a supplementary food source fishes are also reared. This mechanism of work is widely used in China, Thailand, and many other developed countries as well. For the effectiveness and to maintain oxygen demand the system also consist of other subsystem like fish tank, sump, circulatory basins, settling basin, air pump (Rakocy *et al.*, 2004).

In comparison to hydroponics and aquaculture initial start-up costs of the apparatus is considerably high which require skilled, technical manpower and deep expertise in natural world for the activities like plumbering or wiring. The setup of the arrangement is energy intensive and require huge amount for the energy. Daily management, organization is the crucial step and minor mistake in the system might collapse the entire setup resulting in the negative productivity. For the functioning of the system there should be the perfect match between the number of quality indicators like pH, temperature, substrate, dissolved amount of oxygen, turbidity and relative humidity.

Major plants grown under aquaponics

Recently aquaponics can be widely used to grow diverse variety of crops which may include agronomic crop and horticultural crops. However, aquaponics primarily focus on the production of horticultural crops typically fruits and vegetables. Fruits with runners and suckers and sometimes crawling or climbers are basically grown under this system. The major fruits include strawberry cantaloupe watermelon, tomatoes, dwarf citrus tree while vegetables like Lettuce, onion, beans, beets, squash, radish, zucchini, asparagus, broccoli, peppers, cucumbers, Swiss chard, peas, carrots, spinach, etc. similarly, Ornamental herbs like basil, orchid, tulip, thyme, cilantro, pansy, sage, aloe vera, lemongrass, violas, wheatgrass, grafted rose, oregano, parsley, etc. are also widely grown in aquaponics. Cereals like sweet corn is also widely grown in this system.

Major fish species used in aquaponics

One of the primary challenges of aquaponics is selection of fish species. The species selected for the system should thrive well in the climatic condition and the selected water quality criteria as well. The selected fish should be easy to maintain and should be more resistant to disease and parasites. The species like tilapia, catfish, largemouth bass, carp, goldfish and can be utilized for the best opposite partner for plants. The fish species tilapia, a disease resistant fish species is tolerant to wide range of pH of about 3-11 and its growth rate is best achieved when the water has pH is of about 7-9. Since the ideal requirement of pH is 6.8 to 7.0 for aquaponics Tilapia is the best grown fish species.

Nutritional requirements of plants

Primarily, for the growth and development of plants it requires structural, functional as well as macro and micronutrients. The primary nutrients essential for plant is Nitrogen, Phosphorus, and potassium. For the customary growth and progress of plants, they need macro nutrients such as C, H, O, N, P, K, Ca, Mg, S and micronutrients such as Fe, Cl, Mn, B, Zn, Cu and Mo. For the higher yielding of plants hydroponics solution should contain the elements in the recommended proportion (Resh, 2012). These are the basic building structural components of amino acids, proteins, and nucleic acids (Pratt, 2014). The nutri-

ents are mainly utilized in the ionic form and metabolism of amino acids in plants (Shah *et al.*, 2021b). The elements like Carbon, Hydrogen and Oxygen can be directly obtained from the open air while the other component should be monitored periodically to sustain the adequate amount for the growth and development. However, fish waste does not consist of iron content that is why should be added artificially for proper growth of the plant (Rakocy *et al.*, 2004).

Nutrition release by fish

Generally, fish feed on the nitrogen rich compounds. Byproducts of fish highly contain Nitrogen in the form of ammonia. In aquaponics system this ammonia is extensively used as a source of fertilizer for plants growth and development and contribute of about 90% ammonia nitrogen (Timmons, 2002). During the process of continuous circulation of water aquaculture chamber proceeds toward hydroponic chamber from where effluents get transformed and the nutrient flows towards the hydroponic components through bio-nitrification. The plant utilizes the nutrient in the form of nitrate (NO_3^-) or ammonium (NH_4^+) (Zou *et al.*, 2016). The ammonia released by the fish initially get converted into nitrite (NO_2^-) and finally to nitrate (NO_3^-) by the action of bacteria (Tyson *et al.*, 2008). The nitrate conversion of ammonia by bacteria makes it less toxic for the fish and primary source of nitrogen for plant which is the basic working principle of aquaponics system (Endut *et al.*, 2014). Thus, biological filtration unit is the essential arrangement required for the process of nitrification in Aquaponics. In order to maintain the balance between the nutrient produced by fish and nutrient uptake by the plant it is most crucial to maintain the fish: plant ratio in the apparatus arranged. As per the statement of Rakocy, the ratio should be maintained on the basis of feeding rate ratio which explain the amount of feed per square meter per day for an individual species of plants. Liable on this an analysis Rakocy recommended the value between 60 and 100 g/daym^{-2} (Rakocy *et al.*, 2004) for green leafy vegetables at the hydroponics compartment.

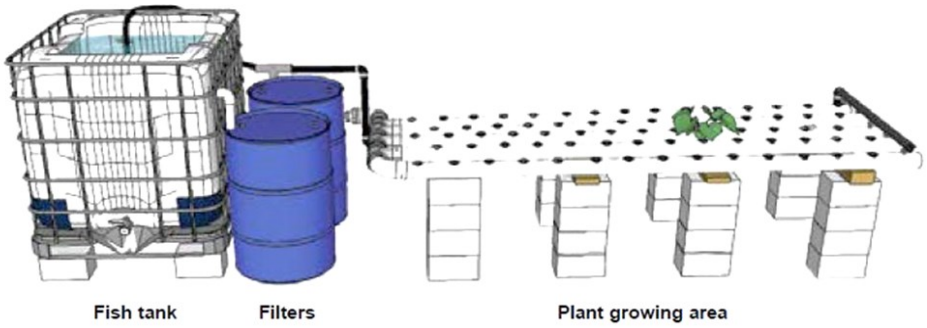

Figure 1. *Nutrient film technique unit (Source: FAO 2014).*

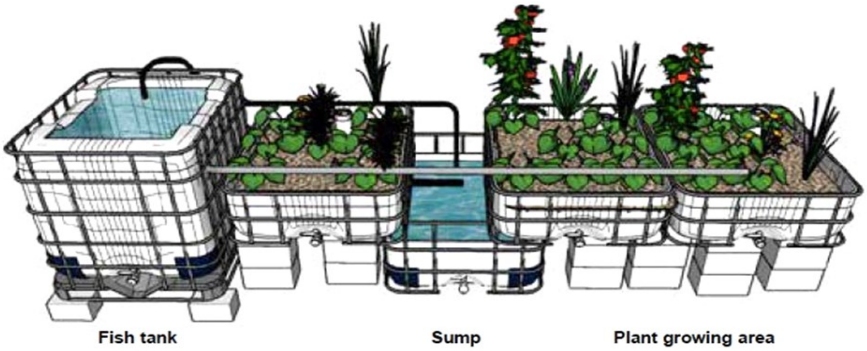

Figure 2. *Floating raft unit (Source: FAO 2014).*

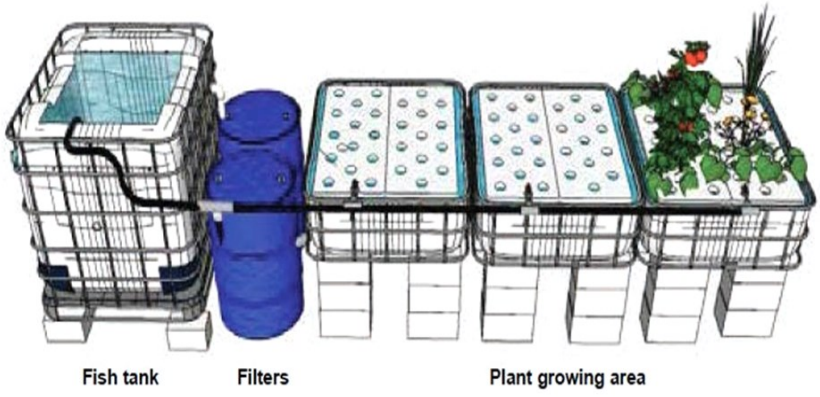

Figure 3. *Media filled unit (Source: FAO 2014).*

Aquaponics design

As per the Engle, Aquaponics systems can be established on the basis of types of bed grow by following different ways. Basically, the categorization might be named as nutrient film technique (NFT), floating –raft (deep water culture) and media-filled (flood and drain) (Figures 1-3) (Engle, 2015).

Nutrient film technique

Plants with small size and low root growth is supported by this technique (Figure 1). The system provides high amount of oxygen which ultimately ensure the high productivity of the vegetable. Since strong root system block the recirculating system of the system only small plants are preferred. To order to avert the clogging solid material should be efficiently removed. It is supported by biofilter and sedimentation tank to remove the solid particles (Engle, 2015).

Floating raft technique

The roots of the plant are allowed to grow freely so as to absorb the nutrient from the water (Figure 2). In this process the water channeled does not get clogged (Liang, 2013). Nitrification apparatus should be attached in this system (Engle, 2015).

Media filled technique

Since the system itself consist of media that allow nitrification it doesn't require bio filters (Figure 3). Media (Zou *et al.*, 2016). In order to supply the sufficient amount of oxygen a siphon is used to create direct contact between plant roots and air (Bernstein, 2011). Regardless of its benefit clogging and oxygen deficit is the major problem in this aquaponics system.

BENEFITS OF AQUAPONICS IN GLOBAL WORLD

Population of the world is increasing in the alarming rate. The environment is increasing in the algebraic ratio while human population is increasing in geometric ratio it is very difficult to maintain the balanced ratio between human and environment. Since the cultivable land is reducing day by day in the name of industrialization and urbanization it is the great concern of the environmentalist and agronomist so as to ensure the food security sustainably (Sharma and Kreye, 2021). Since the cultivable land is reducing day by day in the name of industrialization and urbanization it is the great concern of the environmentalist and agronomist so as to ensure the food security sustainably. Water is the crucial and indispensable requirement of the living organism and to produce the agricultural goods. Energy, food and water are intimately linked with each other. And if water can be used in an efficient way it can protect the biodiversity in sustainable way. Aquaculture is the fastest growing agriculture disciplinary in comparison with other branches of agriculture which fulfill the global nutritional requirement of the world population (FAO, 2014). Since the pesticides used in the system as in hydroponics shows high toxic level than that of the aquaponics same pesticide is not recommend same as that of the hydroponics (Nichols, 2012). Integrated aquaculture with hydroponics, haloponics, aeroaquaponics, maraponics, algaeponics, is the present days needs as all fishes are ecologically balanced, environmentally sustainable, and economically just. And of these are not sufficient to meet the bio economical needs as well. In the early 1970s. In order to solve the problem Recirculating aquaculture systems (RAS) was designed in early 1970s for the optimum utilization and continuous recycling of water so as to artificially rear fish in land-based tanks (Bohl, 1977; Krüner, 1983). However, the greatest challenged visualized is excreta from protein metabolism which is toxic to fish itself and shows lethal characters which can be solve by developing bio-filters (Collins, 1975). However, accumulation of nitrate has adverse effects on fish, and thus, recently in 2010 modern RAS is designed which focus on production of fish including an anaerobic denitrification unit (Martins, 2010), thus make the entire aquaponics system more intricate. To eradicate the negative impact arising by sole aquaculture which by affect the environment adversely, causing eutrophication, and high production cost it is integrated to other soilless cultivation practices (Sneed, 1975). The modern single recirculating aquaponics system (SRAPS) reduced the cost in comparison to conventional system which only focus of the fish production and also function not only indoor but also set up is arranged outdoor (Love, 2014).

Ecological cum environmental avail of aquaponics

Today, vast areas of the surface of earth are occupied by crop production and aquaculture arising some of the major agricultural production difficulties. The hitches might result from the water scarcity which results in dearth and deterioration of arable land. This type of complication is particularly visualized in the developing and underdeveloped countries where the resources is not efficiently mobilized. This has led the environment to adverse impact through soil erosion, soil pollution, water pollution, and in various ways (Heather, 2013) In a closed aquaponics; a system that combines crop production and aquaculture, can reduce the negative environmental impact significantly. The impact of aquaponics in the environment is 50% lower than the separate production systems (Asael Greenfeld, 2021). Generally dissolved phosphorus and nitrogen are released to the water resources through recycle land-based aquaculture system that leads unwanted evolution of micro and macro algae in the water sources. To control water quality in land-based aquaculture, both exchange of water at high rate or water treatment with nutrients and chemicals and its succeeding recirculation can be done which requires a higher cost.

Aquaponics system is ecologically friendly as it utilizes nonrenewable resources that is highly efficient. It can be designated by near to zero-waste liberation (Sommercille, 2014). It nearly waste-free to run, thus there are no detectable hazards on the soil regardless the point that it occupies certain space initially during the time of installation. In the ecological cycle fish feed and faeces are re-used as a source of nutrient for the growth and development of crops (Love, 2015). Even the trash amount of sludge generated from the mechanism can be converted into the beneficial products via composting. Plants recuperate waste nutrients dissolved which are removed through the plant uptake

resulting in the water exchange rate reduction, minimizing discharge to the environment and extending water consumption. Reducing water exchange minimizes the maintaining cost of aquaponics system in parched climates and greenhouses with excessive heat as heated water is a considerable amount of expense in aquaponics system (Rizal, 2018). As aquaponics is done under closed system in controlled conditions, techniques can be utilized conveniently so that they can be adapted to the present world alarming problem that is climate change which may result in temperature differences. Since the growth of weeds are highly reduced by the use of herbicides use of weedicides are not recommended in aquaponics system. However, trace number of weeds are removed by undigging which is quite easy and quick process. As crops are grown under controlled environment in this system, there requires no use of pesticides. Aquaponics, on the other hand, does not employ either, mostly because both would contaminate the fish, plants and the environment. There is no doubt that climate change is a burning issue (Acharya *et al.*, 2021, Sharma and Kreye, 2021). The system does not use soil as a major constituent but still support the organic production and also the entire system is close to that of the environment so Aquaponics is entitled as organic food production without being named as soil grown organic.

There is no doubt that climate change is a burning issue. Many people are unaware of how much distance, energy, and money it takes to bring food from a farm to their plate. The enormous amount of fuel is required to transport food from one place to another especially it is quite longer to transport food to the market places. Aquaponics provides part of the solution for such problems in which aquaponics growing units can be sited on the fringes of suburbia or even in densely populated location like the center of town. This substantially reduces the need to transport food over long distances, which ultimately result in significant carbon emissions reduction. Aquaponics can potentially be an imperative feature of cities basically known to be "blue and green" facilities. It can be assimilated into the local water cycle where individual use grey and rainwater instead of using fresh water. Similarly, it is also used to assimilate local energy flows such as the "watery" concept, (Edwards, 2015) along with local biomass cycles at local level. (Re-use of nutrients).

Conclusion

Aquaponics is modern day soilless agricultural system like hydroponics, aeroponics for sustainability which ensure food security. It mingles with the production with of plant along with the supplementary production of fish. Both plants and fishes are symbiotically benefited. Since the entire world is suffering from food deficit which result in food insecurity. Food insecurity is the present days emerging problem and aquaponics can be the most appropriate solution to solve such problem. Aquaponics system is ecologically friendly as it utilizes nonrenewable resources that is highly efficient. Fish predominantly produces nitrogen rich effluents and if the waste are accumulated in larger quantity, it is dangerous and even lethal for fish life. If this nitrogen can be efficiently used as a source of fertilizer for plants, it acts as a supplementary nutrition for growth and development of the plant. So, aquaponics wisely mobilizes the nutrients which is economically adjust and ecologically sustainable not for the balanced ecosystem only but for the human beings as well. However, number of research is to be conducted to explore its benefits as only limited number of researches has been conducted regarding the topics.

Conflict of interest

The author affirmed no conflict of interest.

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