Chapter 10

Aquaponics

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Introduction

Currently, world's population is increasing with substantial pace, which ultimately elevates demand for food. The increased demand for food exerts considerable pressure on available resources such as land and water to fulfil the stomach of population. Therefore, it is necessary to develop techniques and methodologies as well as to discover reliable alternative for growing food from available resources in order to extract maximum sustainable production without damaging available resources. There is an urgent need to discover alternative and reliable methods for sustained supply good quality food to overcome hunger and poverty. (Simon Goddek et. al, 2020).

Aquaculture is the fastest-growing sector which is expanding by more than 10% per year to support the agricultural sector in order to fulfil the global needs for valuable animal protein used by humankind (Somerville et. al., 2014; Anon, 2014; Anon, 2020). But not all aquaculture production technologies are eco-friendly and environmentally as well as economically sustainable. Thus, there is an urgent need to integrate aquaculture within the agricultural production systems to reduce adverse environmental impacts. This can be archived through the Aquaponics.

Although aquaponics has developed considerably over recent decades, there are numerous key issues such as awareness, education, concepts of aquaponics, research, integration techniques, culture techniques, merits and demerits, future etc. still need to be fully

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understood. In this chapter efforts are made to understand the basics of aquaponics for future success.

What is Aquaponics?

Aquaponics is an integration of hydroponics with aquaculture system to overcome the problems of water and land scarcity in eco-friendly way. Hydroponics is a soilless plants production in which plant roots grow in a nutrient solution with or without an artificial medium for mechanical support while aquaculture is the underwater farming of aquatic organism species (Somerville et. al., 2014; Lennard & Goddek, 2019). According to Merriam-Webster, aquaponics is a system of growing plants in the water that has been used to cultivate aquatic organisms like fishes. Aquaponics is an economically feasible, sustainable and eco-friendly food production system especially where land and water sources are limited. Production of fish and vegetables is the most visible output of aquaponics units which includes three major groups of organisms. i.e. fish, plants and bacteria (Somerville et. al., 2014). Aquaponics serves as a model of sustainable food production by following certain principles, mostly the waste products of one biological system serves as nutrients for a second biological system. In aquaponics, nutrient waste from fish tanks are used to fertilize hydroponic production i.e. growing vegetables and fruit bearing plants.

Principles of aquaponics:

Aquaponics food production systems is characteristically based on principles of integration of two food production systems, one is hydroponics and other is aquaculture. Following are the few principles of aquaponics system, based on which aquaponics system is designed.

1. Wastes produced by farmed fish is used as a principle nutrient source for the plant growth. Therefore, waste from aquaculture had lesser impact on environment. (Love et al. 2015a, b).
2. Aquaponics system designs encourages the optimum utilization as well as conservation of water, energy and nutrient resources for production of edible biomass without adverse impact on environment.
3. Multiple output from diverse culture systems of the aquaponics setup safeguards food production and economic returns.

The integration of fish and plants results in a polyculture that increases diversity and yields multiple products while water is re-used through this system by means of biological filtration. It is a sustainable and water efficient agri-aquacultural production technology as non-renewable resources are not destroyed but utilized for food production. (Lehman et al., 1993; Turcios and Papenbrock, 2014).

Moreover, small aquaponics can be set on small ground areas, rooftop of building, balcony, backyard of the house, etc. as per the availability of the space and it can be easily operated by single trained person. Aquaponics units will be helpful in producing healthy organic food for human consumption through sustainable and eco-friendly utilization of available resources.

Aquaponics system delivers more benefits as compare to their inadequacies.

Benefits of Aquaponics food production system:

1. It is a sustainable, economically viable and intensive food production system.
2. It is a multiple yielding system that yields fish as well as vegetables in single aquaponics units.
3. It requires minimal water and land.
4. It is a soilless culture system i.e. no need of soil for plant production.
5. Aquaponics system can produce an organic food without use of chemical fertilizers and pesticides.
6. Aquaponics system can produce good quality i.e. nutrient rich food green vegetable, fruits, fishes etc. with better yields in limited area.
7. It has better control on production and hence results in expected yields with reducing chances of losses.
8. It is an eco-friendly system and hence have no or less environmental impacts.
9. It saves energy, money and labour.
10. Anybody can run the aquaponics unit irrespective of gender and age.
11. Helping or unproductive hand of family can manage the system by providing short term training.
12. Aquaponics unit can be set on non-arable land or on balcony or on rooftop etc.
13. Information and materials are available.
14. A lot of scope for food production, training, employment, etc.

Inadequacies in aquaponics food production system:

1. Initial start-up costs of aquaponics system is expensive as compared to the soil vegetable production or hydroponics.
2. Aquaponics farmer need to update the knowledge regarding fish, bacteria and plant.
3. Always balanced integration of fish and plant is not possible.
4. Success of aquaponics depends only on the optimal temperature range of fish and plants i. e. in unfavourable condition it not feasible.
5. Mistakes or accidents can cause catastrophic collapse of system.
6. Aquaponics is energy demanding system and requires mandatory daily monitoring.
7. Aquaponics system reliable on uninterrupted electricity supply and availability of fish and plant seeds.

Applications of Aquaponics:

The design and inputs for aquaponics setup varies according to targeted level of output. The aquaponics unit can be setup in smaller scale to meet the domestic or family requirements while larger scale aquaponics units can be erected to harness commercial productions.

1. **Domestic or small-scale aquaponics:** Aquaponics designed for domestic production for a family household by using small aquaponics unit of near about 1000 lit of fish tank and 3-meter square of growing space for plants and it is demonstrated in Fig.1.

Fig.1. Small or domestic aquaponics unit (https://www.trees.com/gardening-and-landscaping/aquaponic-plans)

2. **Semi-commercial and commercial aquaponics:** Aquaponics system is designed for Semi-commercial or commercial purposes by setting a large-scale unit with high initial start-up cost with high production yields per unit area. Although, some commercial

aquaponics units have been failed due to profits as compare to the initial high investment but several aquaponics units running successfully all over the world and a representative commercial aquaponics unit is illustrated in fig.2.

Fig. 2. Commercial aquaponics unit (Source: https://www.bncgi.com/aquaponics)

Biological components and its balance in Aquaponics:

Aquaponics system integrates the fish farming with soilless vegetable production in one recirculating system where fish, plants, and beneficial bacteria lives symbiotically. In aquaponics systems, nitrifying bacteria from grow bed converts the fish waste in plant nutrients while plants in grow bed removes these nutrients by absorbing it to grow. Thus, these clean water is again sent back to the fish tank.

Nitrifying bacteria such as *Nitrobacter* and *Nitrosomonas* first convert ammonia from fish waste into nitrite compounds (NO_2) and then finally into nitrate compounds (NO_3) and then it is used as nutrient for growing plants. These nitrifying process mainly depends healthy balanced population of these bacteria which is ultimately depends upon the water quality parameters such water temperature, pH, dissolved oxygen and surface area on which the bacteria can grow.

Successful aquaponics unit is balanced unit where feed rate ratio is maintained. Feed rate ratio is amount of daily fish feed for every square metre of growing space and expressed in g/m2/day. Somerville et.al. (2014) suggested the feed rate ratio of 40-50 g/m2/day is maintained for leafy aquaponics systems while feed rate ratio of 50-80 g/m2/day are maintained for fruiting vegetable aquaponics systems.

Aquaponics Systems

Site selection: Suitable sites selection for aquaponics mainly depends on accessibility of sunlight, wind, rain exposure, average temperature, availability of utilities and shading structure. Backyard, balcony, rooftop sites are suitable for domestic or small aquaponics unit while barred land assessable with nearby markets are suitable for commercial unit.

Types of aquaponics: There are three main types of aquaponics systems depends on the plant growing techniques (Maranowski et. al. 2017, Somerville et.al 2014)

1. **Media bed aquaponics:** It is also called as particulate bed where plants grow within a substrate. It is made of strong inert material and have a depth of about 30 cm of media containing a high surface area. It provides adequate mechanical and biological filtration by providing separate zones for different organisms to grow. It is sufficiently wetted through flood-and drain system for good filtration waste and nutrients (Fig. 3a).
2. **Nutrient film technique (NFT) aquaponics:** In nutrient film technique (NFT) units, plants grow with their roots in wide pipes supplied with a small and gradual flow of culture water. For proper growth of plants, flow rate of 1 to 2 litres/minute culture water are maintained. Moreover, mechanical and biofiltration are essential parts of this technique to remove the suspended solids and oxidize the dissolved waste (Fig. 3b).
3. **Deep water culture (DWC) aquaponics:** It also known as the raft method or floating system where plants are suspended above a tank of water using a floating raft. Mechanical and biofiltration are added to these growing techniques, as plants are grown on suspended raft and there no media bed for removal of the suspended solids and oxidize the dissolved waste (Fig. 3c).

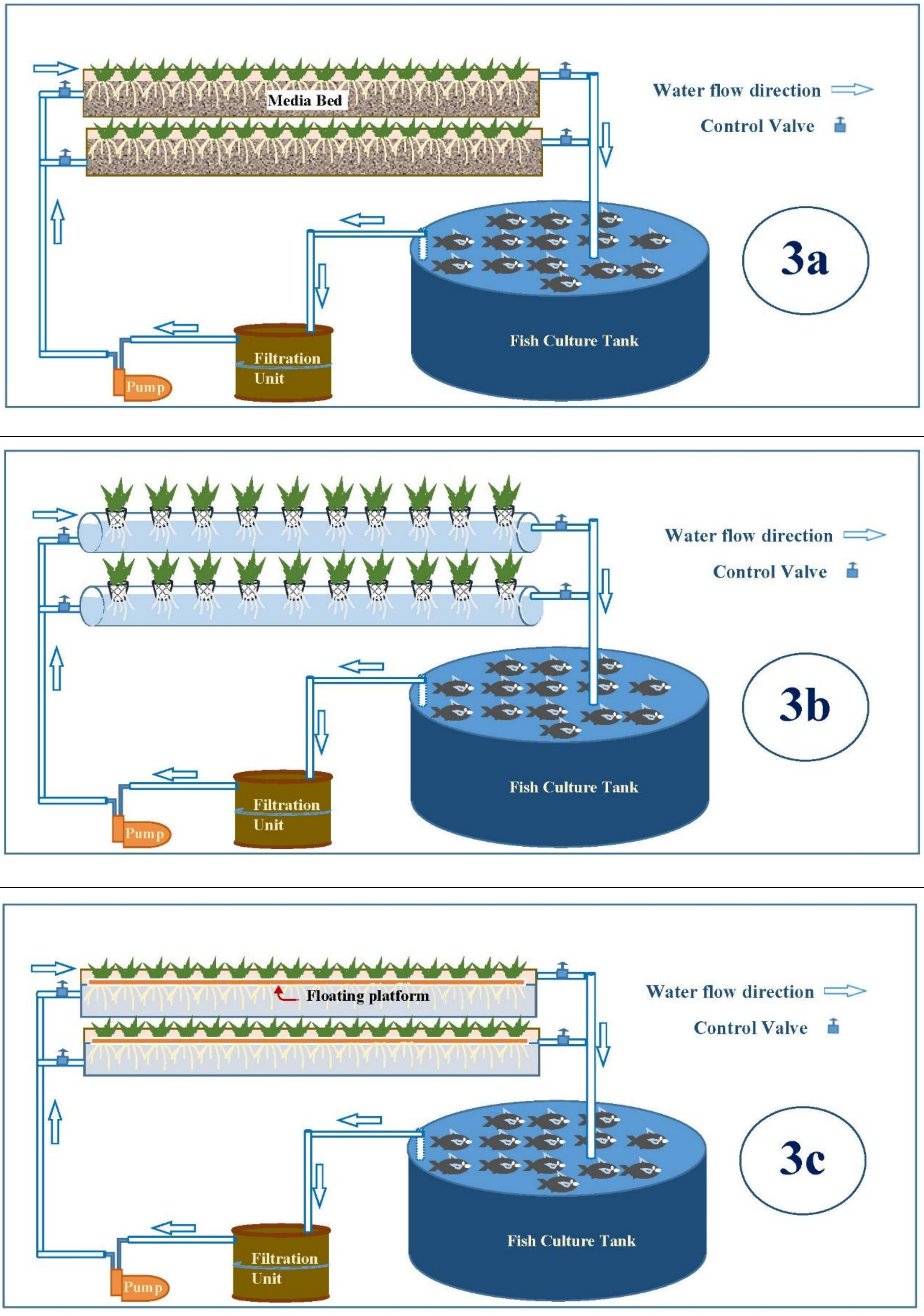

Figure 3: Types of Aquaponics, a: Media-bed Aquaponics, b: Nutrient film (NFT) Aquaponics, c: Deep water culture (DWC) Aquaponics

Crop Selection:

Selection of plant as well fish crops for aquaponics is kay factor for success and it mostly depends on its demand, market prise, seed availability, nutrient content and sturdiness, resistance to diseases and pathogens as well as its suitability for integration in aquaponics.

1. **Plant Crops:** Different researcher and farmer are successfully grown various varieties of vegetables, herbs, flowers and small trees in aquaponics systems. Mostly, lettuce, chives, basil, mint, wheatgrass, spinach etc. are vegetable plants while fruit-bearing plants such as tomatoes, bell peppers, cucumbers, chilly and squash are suitable for farming in aquaponics system.
2. **Fish crop:** Fish species with excellent growth rates, wide tolerance to environmental parameters such relatively low DO levels, poor water quality, water temperature, pH, as well as resistance to many diseases and parasites are ideal for aquaponics. Mostly tilapia, common carp, silver carp, grass carp, barramundi, perch, catfish, trout, salmon, largemouth bass, ornamental fishes as well as crustaceans and shell fishes like giant river prawn, shrimp, urchins, abalone are most suitable for framing in aquaponics.

Culture Management and Harvesting practises in aquaponics:

Management of aquaponics system is achieved through monitoring water quality, plant and fish crop management.

1. **Monitoring of water quality:** For optimal growth and health of fishes good water quality must be maintained in a recirculating fish tank. Success of each aquaponics food production system is associated with a healthy ecosystem with satisfying water quality parameters for growing fish, vegetables and bacteria and water quality need to manipulate to meet these criteria. On regular basis monitoring of water quality parameters is needed in aquaponics system. To achieve this testing of water quality parameters such as dissolved oxygen (DO), pH, temperature, total nitrogen, and water alkalinity is done by using available water quality testing methods or testing kits and then taking particular measures for it. According to Somerville et.al (2014) optimal range of water quality parameters to maintain healthy ecosystem of all three organisms such as fish, plat and bacteria in aquaponics unit are given in Table 1.

Table 1. Optimal range of water quality parameters for aquaponics units

Parameters	**Temp (°C)**	**pH**	**Ammonia (ppm)**	**Nitrite (ppm)**	**Nitrate (ppm)**	**DO (ppm)**
Optimum range for Aquaponics	18-30	6-7	< 1	< 1	5-150	> 5

2. **Management Practices for Plant:** Plant seedlings can be planted into the system after detecting nitrates in the system. In general, initially in the first few week plant growth in aquaponics systems is slightly lower than plant growth in soil or hydroponic system but becomes faster in upcoming week after the nutrient base has been built in the system. In aquaponics we can plan for continuous harvest and transplant of vegetables by staggered planting. While harvesting full plants from system we have to take care about to remove the entire root system from culture bed.
3. **Management Practices for Fish:** Mostly artificial feed containing adequate nutrients such proteins, carbohydrates, fats, vitamins and minerals are recommended for feeding the fishes in aquaponics. Protein content of feed is the most important factor for building of biomass of farmed fish species. Herbivorous and omnivorous fishes requires 32% protein feed while carnivorous fishes requires more than 32% protein feed for better growth.

   Feeding is done two times a day at the rate of 3-5 % of body weight depending stage of culture by dividing ration in two parts. Initially larval or juveniles stages are requires more quantity of feed as well as higher percentage of protein in feed. Mostly in aquaponics the targeted harvest is near about 10-20 kg for a 1000 litre fish tank by panning partial or complete harvest.

Conclusions:

The detailed study of aquaponics leads to conclude that the aquaponics will not only generate revenues but also ensure optimum utilization of resources and water conservation. The aquaponics will ensure the production as multiple production systems are integrated together. Moreover, waste from one system will serve as input in another thereby reducing the waste management issues. Water as well as nutrients are recirculated within system for conservation of water and nutrients, making it one of the most water efficient culture systems. The study also showed that the aquaponics system can be structures in different designs which can be accommodated in range of places ranging from small rooftop or balcony to large farms. The aquaponics system will be important systems fulfilling nourishment and employment to considerable population in near future.

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