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AQUAPONICS – THE FUTURE FARMING

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Abstract

Aquaponics is a bio-integrated system that combines aquaculture (raising fishes) and hydroponics (growing plants in water and without soil). A symbiotic relationship exists between the fishes and the growing plants. The fish waste provides organic food for the growing plants and the plants naturally filter the water in which the fish live. The fish waste has ammonia which is converted into nitrites and nitrates by nitrifying bacteria. These nitrates serve as nutrients to the plants. Once the plants uptake the nutrients and clean them out of the water, the water is returned to the fishes for further fish culture, and the perpetual cycle begins again. Aquaponics is easier and more productive than organic gardening or traditional agriculture and uses less water, less electricity and less labour than any other system in the world. Aquaponics has been explored as a possible solution to the foregoing environmental, energy and food shortage problems.

Keywords: Aquaponics, hydroponics, fishes, plants

1. Introduction

The word aquaponics comes from words aquaculture, which is the cultivation of fish or other water-based animals, whereas plants grown in a sterile medium or completely in water known as hydroponics. Aquaponics is the combined culture of fish and plants in recirculating systems. These recirculating aquaculture systems incorporate the production of plants without soil [1].

Aquaponics is easier and more productive than organic gardening or traditional agriculture, using less water, less electricity and less labour than any other system in the world.Aquaponics has been explored for several decades as a possible solution to the foregoing environmental, energy and food shortage problems [2].

2. Aquaponics

The two major components of aquaponics systems are the fish and the plants. The natural characteristics and requirements of each of these components actually support the growth and health of the other. Fish digest their food and it produces waste which is released into the water the fish are swimming in. This waste is rich in substances that plants need to grow and produce. The water is moved from the tank to growing beds where the plants are placed. The plants take up the nutrients and use them to create energy for growth. The water continues back into the fish tank in a continuous cycle (Figure 1). In general, the fish provide food for the plants and the plants provide a clean environment for the fish.

The following advantages are claimed for aquaponics [3]: Significant reduction in the consumption of water; Growth of plants is much faster; Vegetables are highly organic, bigger and healthier; Reduction of use of artificial fertilizer; Reduction in disposal of fish waste; Reduction in land is required to grow the same crops; Easier to setup; Reduced damage from pests and disease; and No weeding or bending down. Although a number of advantages have been reported, there are a few demerits as follows: Expensive to setup; Need of green house; Water needs to be constantly monitored; Complicated for the amount of fish; Electric energy input is required; Cannot grow root crops.

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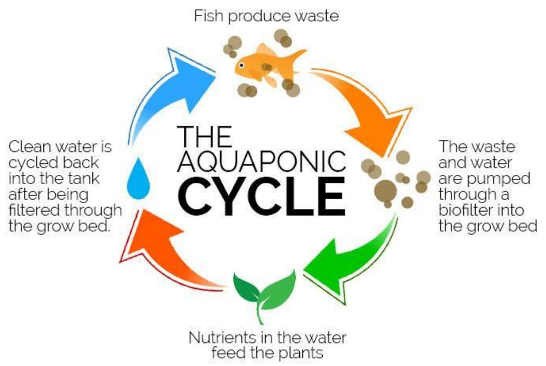

Figure 1. Nitrogen cycle in aquaponics system

3. Components of aquaponics systems

Aquaponic systems come in all shapes and sizes. Regardless of the size, materials used, or level of complexity, all systems share the same basic design that consists of the same components [4]:

Rearing tank: The tank or container where the fish / aquatic animals are raised and fed.

Settling basin: A unit to capture all uneaten food and detached biofilm and where fine particles can settle out.

Biofilter: A place where the bacteria can grow and convert ammonia to nitrates and organic wastes to carbon dioxide, which are used as nutrients for plants.

Hydroponics portion: This is where the plants are grown by taking up the excess nutrients from the effluent water.

Sump: This is the lowest point in the system and is where the water flows, after which it gets pumped into the rearing tank.

4. Aquaponics system

Aquaponics is considered as a potentially important system with two profit centres namely fish and plants. Aquaponics is also known as the integration of hydroponics with aquaculture. It serves as a mode of sustainable food production by certain principles as follows,

- Waste products of one biological system serve as nutrients for another system.
- Water is re-used through filter and is re-circulated.
- Integration of fish and plants increases diversity and yields multiple products.

4.1Home aquaponics

Little number of fishes, small fish tank and nice amount of vegetables constitute the home aquaponics system (Figure 2).

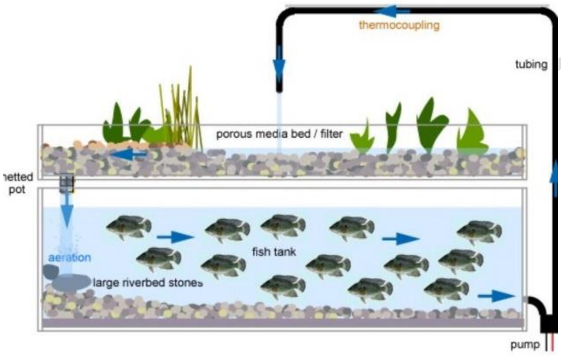

Figure 2.Home aquaponics

4.2Backyard aquaponics

At the backyard of house it is possible to build bigger aquaponics system, like the one made from one IBC (Intermediate Bulk Container). The upper part can be sliced half and put it upside down to make it as grow bed and use the down part as fish tank. Figure 3 shows the backyard system.

Figure 3. Backyard aquaponics

4.3Commercial aquaponics

Commercial aquaponics (Figure 4) are huge aquaponics systems with huge sizes of grow-beds, huge amount of growing fishes and moreaquaponic food production.

Figure 4. Commercial aquaponics

5. Aquaponic methods

There are three main types as mentioned below[5]:

5.1 Media bed technique

Media filled bed units(Figure 5) are the most popular design for small scale aquaponics. These designs are efficient with space, have a relatively low initial cost and are simple. In media bed units, the medium is used to support the roots of the plants and also the same medium functions as a filter, both mechanical and biological. Media bed technique can become expensive at a larger scale. Media can become clogged if fish stocking densities exceed the beds' carrying capacity and this can require separate filtration. Water evaporation is higher in media beds with more surface area exposed to the sun.

Figure 5. Media bed technique

Choice of media

The media needs to have adequate surface area for bacterial growth, neutral pH and be inert, good drainage properties, be easy to work with, sufficient space for air and water to flow within, be easily available and cost effective and light weight. Common media include light expanded clay aggregate, limestone, volcanic gravel, limestone,river bed gravel and pumice.

5.2 Nutrient film technique (NFT)

The nutrient film technique (Figure 6) is a hydroponic method using horizontal pipes each with a shallow stream of nutrient rich aquaponics water flowing through it. Plants are placed within holes in the top of the pipes, and are able to use this thin film of nutrient rich water. This technique has very low evaporation because the water is completely shielded from the sun. This technique is far more complicated and expensive than media beds.

Figure 6. Nutrient film technique

5.3 Deep water culture technique (DWC)

The DWC method (Figure 7) involves suspending plants in polystyrene sheets, with their roots hanging down into the water. This method is most common for large aquaponics systems growing one specific crop and is more suitable for mechanization. This technique has minimum water loss by evaporation. The polystyrene rafts insulate water from heat losses / gains keeping constant temperatures.

Figure 7. Deep water culture technique

6. Water quality parameters in aquaponics systems

6.1 pH of the water

The pH of the water has a major impact on allaspects of aquaponics, especially the plants andbacteria. The water pH must be monitored closely. The pH level indicates the amount of nutrients available for the plants in the system and warns when the system (and the fish) is in danger. An acceptable pH level is between 6.0 and 8.0. The ideal level for an aquaponics system is 7.0.

6.2Dissolved Oxygen

Oxygen is essential for all three organisms involved in aquaponics; plants, fish andnitrifying bacteria all need oxygen to live.The optimum DO levels for each organism to thrive are 5‑8 mg/litre. Water temperature and DO have a uniquerelationship that can affect aquaponic food production. The capacity of water to hold DO decreasesas temperature increases; warm water holds less oxygen than cold water.

6.3Water Temperature

Water temperature affects all aspects of aquaponics systems. Overall, a generalcompromise range is 18‑30 °C. Temperature has an effect on DO as well as on thetoxicity (ionization) of ammonia; high temperatures have less DO and more unionized(toxic) ammonia.Also, high temperatures can restrict the absorption of calcium inplants. The combination of fish and plants should be chosen to match the ambienttemperature for the systems' location, and changing the temperature of the watercan be very energy-intensive and expensive.

6.4Total nitrogen: ammonia, nitrite, nitrate

Nitrogen is the fourth crucial water quality parameter. It is required by all life, andpart of all proteins. Nitrogen originally enters an aquaponic system from the fish feed,usually labelled as crude protein and measured as a percentage. Some of this proteinis used by the fish for growth, and the remainder is released by the fish as waste. Thiswaste is mostly in the form of ammonia (NH_3) and is released through the gills andas urine. Solid waste is also released, some of which is converted into ammonia bymicrobial activity. This ammonia is then nitrified by bacteria,and converted into nitrite (NO_2^-) and nitrate (NO_3^-). Nitrogenous wastes are poisonousto fish at certain concentrations, although ammonia and nitrite are approximately100 times more poisonous than nitrate. Although toxic to fish, nitrogen compounds arenutritious for plants, and indeed are the basic component of plant fertilizers. All threeforms of nitrogen (NH_3, NO_2^- and NO_3^-) can be used by plants, but nitrate is by farthe most accessible.

In a fully functioning aquaponic unit with adequate biofiltration, ammonia and nitrite levels should be close to zero, or at most 0.25–1.0 mg/litre. The bacteria present in the biofilter should be converting almost all the ammonia and nitriteinto nitrate before any accumulation can occur.

6.5 Water Hardness

The final water quality parameter is water hardness. There are two major types ofhardness: general hardness (GH), and carbonate hardness (KH). General Hardness (GH) is the measurement of positive ions, especially calcium andmagnesium.Carbonate Hardness (KH) measures the concentration of carbonates and bicarbonatesthat buffer the pH (create resistance to pH change).

The optimum level of both hardness types for aquaponics is about 60–140 mg/litre.It is not vital to check the levels in the unit, but it is important that the water being usedto replenish the unit has adequateconcentrations of KH to continueneutralizing the nitric acid producedduring the nitrification process andto buffer the pH at its optimum level.

7. Fish suited to aquaponics

There are several species of both warm water and cold water fish that are well adapted to growing in recirculating aquaculture systems. These include tilapia, cat fish, trout, perch, carp, arctic char, goldfish and largemouth and striped bass[4].

8. Plants suited to aquaponics

Many plants can be grown in aquaponics systems, and the choice of plants will depend on the stocking density of the fish being grown because this will influence the concentration of nutrients in the fish effluent. Plants that are well adapted to aquaponics systems include lettuce, basil, spinach, herbs and watercress. Other plants such as tomatoes, cucumbers and peppers have higher nutrient requirements and will only do well in aquaponics systems that have high stocking densities of fish [4].

Plant growth requirements

For maximum growth, plants in aquaponics systems require 16 essential nutrients. The essential elements are arbitrarily divided into macronutrients, those required in relatively large quantities, and micronutrients, those required in considerably smaller amounts. Three of the macronutrients – carbon, oxygen and hydrogen are supplied by water and carbon dioxide gas. The remaining nutrients are absorbed from the culture water. Other macronutriemts include nitrogen, potassium, calcium, magnesium, phosphorus and sulfur. The seven micronutrients include chlorine, iron, manganese, boron, zinc, copper and molybdenum. These nutrients must be balanced for optimum plant growth.

9. Conclusion

Aquaponics systems can be set up anywhere and is a system that could have zero impact on our environment, especially if the pumps are powered through renewable energy sources. Although vast fields of grains, is not suitable to grow in aquaponics, it is possible to grow any vegetable and various types of fruits. Aquaponics systems are suited even in an urban setting and therefore eliminates the need to clear jungles and forests to meet the growing food demand.

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