Review Article

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AQUAPONIC FARMING

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ABSTRACT

Aquaponic farming is a hybrid food growing technique that has been around for thousands of years and is growing fast globally. It is a sustainable method that combines aquaculture (growing fish) and hydroponics (growing plants) in non-soil media and nutrient-laden water, which presents a unique opportunity for year-round production. The results could lead to a promising future for sustainable agriculture and become the key to global food security. Advancements by researchers and farmers have turned aquaponics into a functional model of sustainable food production. Aquaponics is intended to be a highly sustainable production system that incorporates principles of water conservation, sustainable vegetable production, and organic plant and animal agriculture. The purpose of this article is to discuss the concept of aquaponics, including a brief overview and history of its development. It will also discuss the benefits and components of aquaponic farming systems including suitable fish and plants. To have a successful aquaponic enterprise some important factors of growing fish and plants using aquaponics must be considered.

Keywords: Aquaponics, Food Security, Sustainability, Productivity, Aquaculture, Hydroponics

Introduction

Aquaponics is a method of food production that combines aquaculture - cultivating aquatic animals, such as fish, shrimp, crayfish, or prawns, in tanks and hydroponics - growing plants in water. The fish and plants are cultivated together in a recirculating ecosystem that utilizes natural nitrogen-fixing bacteria to convert aquatic animal waste into plant nutrients used in the hydroponic system. With this combined recirculating system, there is no need to discard or filtrate any water, or add any chemical fertilizers, making it both sustainable and environmentally friendly [1].

Aquaponics is an integrated system that utilizes the best attributes of both aquaculture and hydroponics systems. In a traditional aquaculture system, animal waste byproducts (in the form of ammonia) build up over time and become toxic to the animals being cultivated resulting in, 10 to 20% of the total volume of water being discharged and replaced daily. However, in an aquaponic system, the water produced from the aquaculture portion of the system is fed into the hydroponic portion of the system. The plants are grown with their roots immersed in the effluent (waste) water and the ammonia in the effluent water is converted by bacteria into nitrates and nitrites, that used by the plants as nutrients [1].

The difference between hydroponic and aquaculture farming methods is that *hydroponics* is the process of growing plants in mineral rich waters, whereas *aquaculture* is the process of raising aquatic animals such as snails, fish, or prawns. Aquaponic farming combines the two methods by raising aquatic animals that produce mineral rich waters necessary for plants to grow. This creates a symbiotic environment where the animals feed the plants and the plants provide clean water for the animals [2].

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The growth of the world's population is expected to (nearly) stabilize at approximately 10 billion people in 2062 [3], which poses challenges concerning of water, food, and energy security for humans in the 21st century. Water is the primary resource for life and the entire agro-food supply chain and is the main input when producing agricultural goods in the field. Energy is required to distribute water, produce food, and process and transport agricultural goods. Agriculture requires the largest global use of water, accounting for 70% of total withdrawal, whereas the food production and supply chain consumes ~30% of globally produced energy [4]. Water, food, and energy are inextricably linked by their interaction with each other; therefore, the water−food−energy nexus must be managed in a sustainable way that is concomitant with protecting the environment and maintaining biodiversity. Aquaponic can fulfill the growing global need for animal and plant protein [5][6].

Aquaponics History

Aquaponics refers to the integrated production of aquatic animals and plants by using the same water resources and nutrient inputs. In modern times, aquaponics is practiced within recirculating systems. It was already being practiced centuries, before the first written record of aquaponic methods was published by Fan Lai in China in 500 BC. In the following centuries, the practice was adopted in other parts of eastern and southern Asia. Experts believe it may have arisen independently in a number of regions because there are historical records of this culture from Japan, Peru, Egypt, Greece, and Mexico [7].

Mayan and Aztec cultures developed aquaponic methods before 1000 AD. They created artificial planted rafts called chinampas in lakes and ponds, with plant roots extending below the surface of the water. The ancient Aztec capital, Tenochtitlan, was established in the middle of a large, shallow lake, and by some estimates crops such as corn, beans, squash, peppers, and tomatoes grown on chinampas may have provided half or more of the city's food supplies Although some accounts credit researchers at North Carolina State University for pioneering modern aquaponics in the 1980s, the first example of a modern coupled system was actually developed in Germany and described by Ludwig C.A. Naegel in 1977 [7].

How Aquaponic Farms Work

Aquatic animals are raised in large tanks that over time become clouded with excrement, uneaten fish food, and other animal waste that contain high concentrations of nutrients and minerals. To extract these nutrients from the water (and keep the aquaculture tanks clean), waste is pumped from the fish tank into a flood tank where it is diluted with more water. The flood tank is then emptied into a grow bed where plants use the mineral rich waters and simultaneously help filter the water. Bacteria in the flood tank water is cultured and broken down into ammonia and then turned into nitrites and nitrates. This water is aerated and then returned to the fish tank as clean clear water to support the growth of the animals and restart the process [2].

The Benefits of Aquaponic Systems

Aquaponic farming is a highly sustainable method for growing plants such as herbs and vegetables. It uses 90% less water than traditional farming methods and only one-third of the energy. It is 15% more productive with space, and because there is no need for fertilizers or chemicals, it is inherently organic. Not to mention, the method can be used in almost any sized space and can even be done indoors when used with heating lamps. Because aquaponic farming uses recycled water, it is an economically viable method for farming in areas with arid climates, poor soil quality, or contaminated water. It can even be used year-round in places where the weather is too cold or too hot to grow produce using more traditional methods [2].

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Sallenave's (2014) article titled "Is Aquaponics Right For You?" lists the following benefits of aquaponic systems [1]:

- Waste nutrients produced by the aquatic animals are recovered by the plants. This eliminates the need to discharge water into the environment and minimizes the need to exchange water (other than to top off water that evaporates into the plant biomass). Compared to traditional aquaculture methods, aquaponic systems use much less water, which is especially attractive in arid, water-scarce regions. For example, aquaponic systems use 1% of the water required in traditional pond culture to produce equivalent yields of tilapia.
- Minimizing the need to exchange water, reduces operational costs. This is particularly important in arid climates such as New Mexico, and in heated greenhouses where water or heated water can be a major expense.
- Unlike hydroponic systems, because fish food is applied to the system daily, the plants in aquaponics systems receive a steady stream of nutrients, which eliminates the need to discharge and replace depleted nutrient solutions.
- Unlike hydroponic systems or recirculating aquaculture systems, aquaponic systems require less water-quality monitoring.
- The media used to grow the plants also serves as the surfaces on which nitrogen-fixing bacteria grows. The plants being grown function as filters by removing the nutrients from the effluent water, which eliminates the need to separate biofilters, that can be expensive.
- Plants grown in aquaponic systems receive most of their required nutrients at no cost, thereby improving the system's potential profit.
- By producing two crops (vegetables and fish) with the same system, the operational and infrastructural costs are shared, which increases savings and profit margins.

Some aquaponics enthusiasts are primarily interested in the cultivated plants and the aquatic animals raised simply to provide the low-cost nutrients to their system. Others grow both plants and fish to sell or consume. Some farmers culture edible fish, whereas others raise ornamental fish such as goldfish. The plants and animals produced are locally grown and pesticide-free (aquaponic systems normally operate without using pesticides because of the risk of killing the fish), and the plants require few (if any) additional fertilizers.

Components of Aquaponic Systems

Aquaponic systems come in all shapes and sizes, from simple, low-tech backyard operations to large-scale, more sophisticated commercial operations. Regardless of the size, materials used, or level of complexity, all aquaponics systems share the same basic design that consists of similar components [1].

Sallenave's 2014 article titled "Is Aquaponics Right For You?" lists the following components of aquaponic systems [1]:

- Rearing tank: The tank or container where the aquatic animals are raised and fed.
- Settling basin: A unit to capture all uneaten food and detached biofilm (the film or coating where nitrifying bacteria form on inert material or organic particles). This is also where fine particulates can settle.

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- Biofilter: A place where the bacteria can grow and convert ammonia into nitrates and organic waste into carbon dioxide, which are then used as nutrients for the plants.
- Hydroponics portion of the system: Where the plants are grown using the excess nutrients from the effluent water.
- Sump: This is the lowest point in the system where the water flows and gets pumped back into the rearing tanks.

Raft-based and media-based growing systems: The two primary growing systems used to culture plants in aquaponic systems. Raft-based systems consist of Styrofoam rafts that float in troughs filled with fish effluent that has been filtered to remove solid wastes. Plants are placed in holes in the raft with their roots hanging down in the water. Media-based systems, grow plants in inert planting media, such as gravel, rock wool, sand, or clay pellets, in containers that are flooded with water from the aquaculture portion of the system.

Fish Suited to Aquaponics

Several species of both warm water and cold-water fish are well adapted to growing in recirculating aquaculture systems including tilapia, channel catfish, rainbow trout, perch, common carp, arctic char, goldfish, and largemouth and striped bass. The most common species grown in both home and commercial aquaponic systems is tilapia because it is a warm-water species that grows well in recirculating systems and can tolerate crowding and fluctuating water conditions. However, tilapia is a non-native species to New Mexico; the culture of tilapia or any exotic, non-native species is controlled by the New Mexico Department of Game and Fish. Before importing or beginning to culture any non-native species in New Mexico, an application for “Importation of Exotic Species" must be submitted to and accepted by the Department. There are other options to growing tilapia, such as other fish species, non-edible ornamental species (e.g., goldfish), and freshwater shrimp or prawns [1].

Plants Suited to Aquaponics

Many plants can be grown in aquaponic systems, but the choice of plants will depend on the stocking density of the fish being raised because it can influence the concentration of nutrients in the fish effluent. Plants that have low to medium nutrient requirements that are well adapted to aquaponic systems include lettuce, basil, spinach, chives, herbs, and watercress. Plants that do well in aquaponic systems with high stocking densities of fish and higher nutrient requirements [1].

Aquaponics Considerations

In certain situations, aquaponics is more productive and economically feasible, especially when land and water are limited [8]. While there are many benefits to growing vegetables and fish using aquaponics, it is not without challenges [1]. Successful aquaponics enterprises require special training, skills, and management experience in the area. The following items are key considerations that help prospective growers evaluate their success.

The critical considerations for any producer are:

1. The amount of available space and money for the project. Depending on the size and sophistication of your system, it can require a substantial start-up cost or capital investment. Aquaponic systems also

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require some energy inputs, and because of the highly technical nature of aquaponics, a certain level of skill is necessary to manage the systems adequately. Prospective producers must thoroughly research the different production methods to determine which is best suited to their needs [1].

2. The intended amount vs. the actual amount of food produced (if this is a commercial venture) and ways the product will be marketed. If your goal is to produce aquaponic products to generate income, you will also need to identify and develop niche markets to ensure profitability. As with any new venture, embarking on a commercial aquaponic operation is not without financial risk and should be thoroughly researched before undertaking [1]. The increased production must compensate for the high investment costs needed to integrate the two systems [7].

3. Like any other fish or produce growing systems, aquaponically - grown products are highly perishable. It is important to keep in mind that harvest and post-harvest handling and related marketing considerations are critical components of any aquaponics business plan [9].

To ensure success, it is critical that potential aquaponic farmers perform their due diligence to learning about business planning, market research, and hands-on education before investing in an aquaponics business. Several sources of information are available to learn more on the subject including a number of excellent courses on all aspects of aquaponics taught by world-renowned experts offered throughout the world [1].

Conclusion

Aquaponic systems present a unique opportunity for year-round production of plants and fish. Aquaponics is a form of agriculture that combines raising fish in tanks (recirculating aquaculture) with soilless plant culture (hydroponics). In aquaponics, the nutrient-rich water from raising fish provides a natural fertilizer for the plants, whereas the plants help filter the water to provide clean water for the fish [10]. It can be used to sustainably raise fresh fish and vegetables for a single family or an entire village, or to generate profit in a year-round commercial farming venture, in any environment. Advancements by researchers and farmers have turned aquaponics into a working model for sustainable food production. There is growing interest in aquaponics globally as more people turn to locally grown food produced in environmentally friendly and sustainable ways. Many people being using aquaponics as an enjoyable way to grow their own food in simple backyard operations. Others pursue aquaponics on a commercial scale as a primary or supplementary source of income. For anyone who is curious about aquaponics or who is has considered taking it up as a hobby or business, remember that a successful aquaponics enterprise requires special training, skills, and management.

Conflicts of Interest: The author declares no conflicts of interest.

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