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Smart Aquaponics System: Challenges and Opportunities

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ABSTRACT

Aquaponics, despite their name, pose a revolutionary change to the organic agriculture field. The world is facing a number of serious issues of which climate variation, population rise, water scarcity, soil degradation, and food security are among the most significant. Aquaponics, as a closed loop system consisting of hydroponics and aquaculture elements, could contribute to addressing these issues. However, there is a lack of assessable research to sustenance the growth of economically feasible Aquaponics systems. The Aquaponics system aided as a model for an aquatic ecosystem established in nature. Because of the synergetic uptake and release of effluent from fish to plants, periodic monitoring of Aquaponics system is vital. To address this problem, an autonomous control system is needed. This takes the benefits of integrating an autonomous control system for continuous autonomous monitoring and control of a dynamic system. In this paper, opportunities that have the potential to fill the gap between execution and research of commercial Aquaponics systems have been recognized. The analysis shows that Aquaponics is proficient of being an imperative driver for the growth of integrated food production systems. The regions suffering from water scarcity will predominantly benefit from this technology being functioned in a commercial environs. This paper comprehensively surveys the antiquity of Aquaponics, interprets their key aspects and significance, and delivers a contrast of various smart Aquaponics systems.

Key words: Aquaponics, Hydroponics, Symbiotic environment, smart Aquaponics system

INTRODUCTION

Increasing concern about sustentation of environment as well as health hazards associated with agrochemicals and assure the consumer's engrossment to safe and hazard free food are the major factors that lead to the growing eagerness in different forms of agriculture in the world [1]. Organic agriculture is one among the broad spectrum of production methods that are concerned to the environment [2]. Aquaponics is a sustainable source of food in organic agriculture. Aquaponics mentions to any system that combines conventional aquaculture with hydroponics in a synergetic environment. Aquaponics farming is an incredibly prolific way to grow organic vegetables, greens, herbs and fruits without using any agro chemicals with the added benefit of fresh fish as a safe, healthy source of protein. It is a revolutionary technique for growing plants, where the aquaculture effluent is diverted through plant beds in a sustainable closed system [3]. The fish and plants are reliant on the balance of dissolved nutrients and quality of the water, as they generate and utilize metabolic products from each other. Because of the symbiotic uptake and release of nutrients from fish to plants, periodic monitoring of aquaponics system water is essential [4]. It requires sincere contribution of our valuable time and sufficient care. One of the shortcomings that encounters in aquaponics system is the exertion in maintaining optimal levels of production and the consumption of time to monitor and manually reset parameters to the prerequisite extents. In order to overcome these demerits, an autonomous control system is required.

The era of Aquaponics starts from the 'stationary islands' established in shallow lakes in Central America (Aztec's chinampas 1150-1350 BC). A survey, led by Love et al. [5], illustrates that aquaponics has been getting growing concern since 2010, which reinforces its increasing impact for society as an innovative response for food security.

SIGNIFICANCE OF AQUAPONICS

Aquaponics comprises the dynamic interaction of fish, plants, bacteria, and their aqueous environment. Aquaponics is a developing technology and the main intention is to reuse the nutrients being pulled out by fishes which are necessary for growing the plans without using the dangerous pesticides and insecticides, including their recycling. A traditional Aquaponics system is depicted in Fig. 1[5]. There are mainly three types of aquaponics systems: the grow bed method, also known as particulate bed, the deep water culture (DWC) method, also known as the raft method or floating system, and the nutrient film technique (NFT) method, which are shown in Fig. 1 [3].

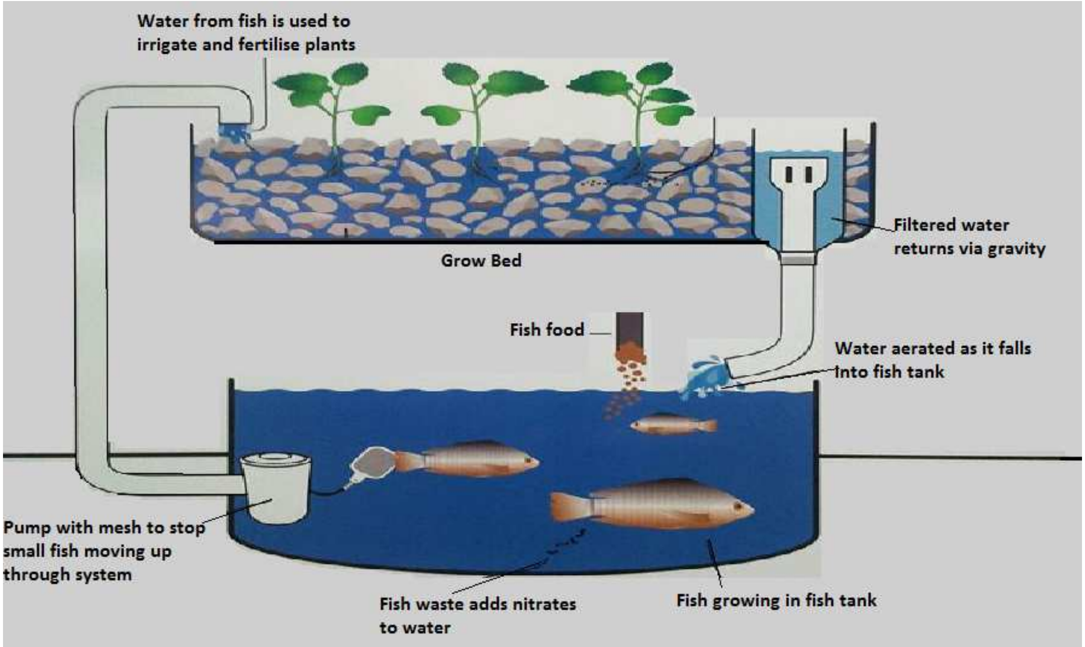

Fig. 1 Traditional Aquaponics System

There are mainly three types of aquaponics systems: the grow bed method, also known as particulate bed, the deep water culture (DWC) method, also known as the raft method or floating system, and the nutrient film technique (NFT) method, which are shown in fig. 2 [3].

Aquaponics have proficient widespread expansion in the world not only for their higher yields, but also for their better use of land and water, modest methods of pollution control, enhanced management of productive factors, their higher quality of products and greater food safety. At present, an efficient predictable mechanism is not available to control and monitor the accuracy for the Aquaponics System [5]. Although aquaponics has assurance, there are also potential challenges that may bound its progress as an extensive food production technology. Built on these past contributions, technologies have arisen over time, the prevailing standards of which are deliberated subsequently.

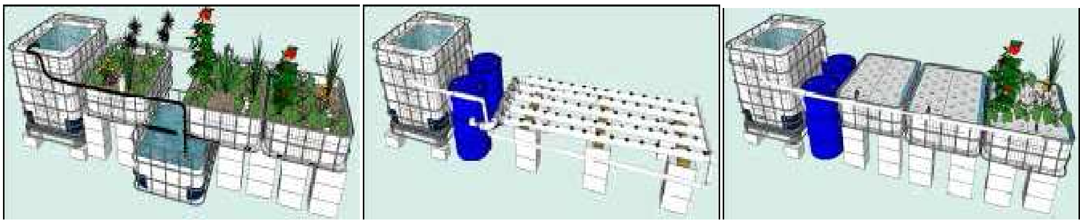

Fig. 2 Various types of Aquaponics Systems

WATER QUALITY IN AQUAPONICS

Water is the vital for an aquaponics system. It is the medium through which plants receive their nutrients and the fish receive their oxygen. It is very significant to understand basic water chemistry and water quality in order to properly manage aquaponics. The plants, fish, and bacteria in Aquaponics systems entail adequate levels of water temperature, pH, and dissolved oxygen for maximum growth and health [3]. Aquaponics is primarily about balancing an ecosystem of three groups of organisms: fish, bacteria and plants. Each organism in an aquaponics unit has a precise tolerance range for each parameter of water quality. The ideal parameters for Aquaponics as a negotiation between all three organisms are specified in Table 1.

Table -1 Tolerance range of Water Quality Parameters in Aquaponics System

Parameter	Temperature(^{0}C)	pH	Ammonia(mg/L)	Nitrite(mg/L)	DO(mg/L)
Aquaponics	18-30	6-7	<1	<1	>5

SMART AQUAPONICS SYSTEM

Optimal, viable and gainful use of our land and water resource is critical. This concern elevated the risks on emerging innovative new technologies that can encounter these demands in a proficient manner. Technology is growing up and today's technology is proficient of automating the entire agricultural systems. To make sense of this new paradigm, survey the various automated aquaponics systems.

A smart low cost wireless digital farming technique practices an automated system which intimates us about the water quality parameters for keeping the farm sustained. From a technological point of view, integration of WSNs with IOT technology can monitor the soil moisture, temperature, light, pH, and water level through a web interface from any remote location. The large-scale mobile Underwater Wireless Sensor Network (UWSN) is unique networking prototype to explore aqueous environments [6].

By using the WSN, conceived a cost effective and reliable micro sensor which can be recycled in a large scale to monitor and control the parameters that govern the plant yields. The system entails of two types of sensors motes (IRIS and TelosB), special soil humidity sensors, electro-valves that are mote driven with the run-through of relays and a Java application that is used for data aggregation [7]. So building scalable mobile UWSNs is a challenge that must be contradicted by interdisciplinary exertions of acoustic communications, signal processing, and mobile acoustic network protocol. An aqueous sensor network is designated consisting of an array of sensor nodes that can be arbitrarily dispersed all through an aqueous environs. In this work the aqueous sensor network is designated, with application to pH measurement using magneto elastic sensors. This system is self-configuring, communication is multi hop and nodes can be used to actuate switches which can be exploited for predetermined monitoring and controlling utilities. Being centered on WSN, the system can bring in substantial changes to the agricultural system.

Motes WSN is a collection of small, low cost, low power, short range nodes which will work collaboratively to sense and process various physical permits and assign the data effectively over a network. In [8], Prasannan *et al* proposed a control system integrated with Aquaponics through Motes, which plotted the distribution of temperature of the ecosystem, soil moisture, pH of the soil, water level and Light intensity over a period of time. For the implementation wireless sensor platform, they used MICAz. Data acquisition is done by using the MDA100CB sensor board, which has a thermistor, light sensor and general prototyping area. From the gathered data developed a Yield Factor which could aid to exploit the resources effectively to enhance the productivity.

Wang *et al* [9] proposed the Smart Monitoring and Control System Based on OpenWrt, which postulates about flow meters, pH, ultrasonic range finders and digital temperature sensors, as well as principles of signal conditioning and closed loop control. This is an intelligently interactive application, where the data that conquered by webcam and some smart sensors are investigated and processed for man-machine interface. Meanwhile, users can also use the mobile terminal to monitor and control the smart aquaponics remotely. The hardware system consists of Arduino and WRTnod, where, WRTnode, based on Wi-Fi AP-Soc, is open source development board hardware.

Guerrero *et al* [10] proposed a system using Wireless Sensor Network Controls to monitor an indoor aquaponics system. This research report covered the use of a wireless sensor network (WSN) to monitor and remotely control various water constraints in an aquaponics system which served as a model for an aquatic biome found in nature. An aquaponics system is not absolutely a close system as fish requisite to be fed almost daily so an automatic food dispenser was created. This system used Arduino as the microcontroller and each control was tested under a simulated field environment and each executed as expected. This paper describes a control system that will be more accessible to troubleshoot with an aquaponics system.

Espinosa-Faller *et al* [11] established the applicability of Zig Bee wireless sensor network technology to recirculating aquaculture systems. In this work, they developed low-cost modules and wireless sensor network based on the Zig Bee standard in order to monitor a recirculating aquaculture system. Temperature, dissolved oxygen, water pressure as well as electric current sensors were comprised in the setup. Modules for reading and transmitting sensor values through a Zig Bee wireless network were settled and verified. The modules were installed in a recirculating aquaculture system to transmit sensor values to the network coordinator. A monitoring program was created in order to display and store sensor values and to compare them with reference limits. An alert is emitted in case reference limits have been reached. E-mail and an SMS message alert can also be sent to the cellular phone of the system administrator, so immediate action can be taken. A web interface allows Internet access to the sensor values. The system monitors some of the related variables in recirculating aquaculture in real time and sends alerts when a reference limit has been reached.

In a simple Arduino controlled Aquaponics System, an Arduino microcontroller is to regulate the frequency of the system cycling, which consents the user to tap into the aquaponics cycle and turn a fixed constraint mechanical system into an elastic, electronically precise dynamic system that can be regulated and customized for a specific aquaponics application. The Arduino Data Acquisition and Control System (ADACS) projects [12] in Automating Aquaponics with Arduino use the mail API to alert owners of failed/congested pumps, when environmental circumstances move outside of user distinct assortments, and when grow lights fail or don't turn on. The Environment DAQ is an open source Arduino shield, which is used here to monitor air temperature, comparative humidity and light in aquaponics grow beds.

Hence a Smart Aquaponics system delivers incessant monitoring of the health of the system and tolerates the user to spot the potential problems like acidic pH levels in the fish tank early on and take the obligatory action. Moreover, with the above systems, an aquaponics system doesn't have to track continuously. The user can regulate the timing of the aquaponics cycle for optimal yield, as well as balanced power consumption. In addition, if necessary the system can be remotely controlled and monitored through the Internet.

CONCLUSION

Given the fact that aquaponics trails nutrient and water reusing principles, it seems to be a promising solution for viable aquaculture and hydroponic practices. However, further research and developments are desirable as established by the challenges described in this paper. These encounters need to be resolute with the intention to establish fully controlled and standardized aquaponics systems that will be easy to handle and economically feasible. So the driving forces for a smart aquaponics system development are the unsatisfactory monitoring and considerable time reduction. Reliability and accuracy are the key design requirements for such systems. The system works continuously to automatically maintain the critical set points and targets ensuring that both aquaculture and hydroponic production sub-systems are run optimally. The competitiveness of the production method depends on technological advances, and climatic and geographic environments that need to be evaluated and cannot be generalized. In many large realistic applications, TelosB and MICAz motes seem to be the best choice. But in classroom modelling Arduino appears to be the most effective choice. This conclusion came from the fact that the typical transmission rate of Arduino is much more than the MICAz motes. Even though the reception rate is higher for MICAz which make them suitable for large realistic simulation models. The cost effectiveness of Arduino makes them suitable for classroom modelling.

The Smart Aquaponics systems can also be further enhanced by adding nitrate and water conductivity sensors to get more insight into the water quality in the aquaponics system. Furthermore, fish food disposal process can be further automated. In addition, data logging and data analysis functionalities can be easily added to the automated Aquaponics systems.

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