Aquaculture, Hydroponics Agriculture and Aquaponics: Presentation of the State of the Art and of their Possible Integration

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DOI: http://doi.org/10.46431/MEJAST.2022.5106

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Article Received: 27 December 2021
Article Accepted: 12 March 2022
Article Published: 30 March 2022

ABSTRACT

The paper presents a wide literature review on Aquaculture, Hydroponics Agriculture and Aquaponics and their contribution to face issues related to food security, urban population growth, farmland shortages, “food miles”, and associated greenhouse gas (GHG) emissions. Then a plant for their integration in a unique plant is presented referring the detailed description to a future scientific paper.

Keywords: Aquaculture, Hydroponics Agriculture, Aquaponics.

Literature Review

The paper Optimization and Control of Hydroponics Agriculture Using IOT (S.Charumathi, R.M.Kaviya, J.Kumariyarasi, R.Manisha and P.Dhivya) reports that agriculture is plagued by several problems like small and fragmented land holdings, manures, pesticides, chemicals used for agriculture etc. consumers also increasingly demand for the healthy diet that is rich in quality and free of agricultural chemicals and pesticides. This project fills in the above said difficulties and demands using hydroponics and it can go organic. Since it is done in the controlled environment, it can be done anywhere like room terrace, balcony etc. also large number of plants can be planted in a less place. This type of agriculture could be high yielding if monitored and controlled efficiently. In this project they implemented a system that controls the necessary conditions required for the plant to grow hydroponically and cultivators may control the agriculture remotely using IoT [1]. In Automated Aquaponics Maintenance System (Muhamad Farhan Mohd Pu’ad, Khairul Azami Sidek, Maizirwan Mel) an automated aquaponics maintenance system was developed as a prototype to reduce human involvement in the activity. The system covers water level and light-emitting diode (LED) power switch maintenance. Furthermore, the automation system can be controlled via Telegram for user convenient. Moreover, it also measures the pH level of the water as an additional feature. Numerous tests were conducted on aquaponics to observe the reliability of the system at the Malaysian Institute of Sustainable Agriculture (MISA), a non-profit organization focusing on urban farming. Positive results were obtained from the tests which suggested that the system is self-dependent. Therefore, the system is suitable to be used in aquaponics [2].

According to the paper Automated indoor Aquaponic cultivation techniques (M.F.Saaid, N. S.M.Fadhil, M.S.A.Megat Ali, M.Z.H.Noor) aquaponic has become an interesting model for private sector, aquaculture and environmental scientist because of many advantages that can be obtained. The word `Aquaponic` refer to the integration of `hydroponic` (growing plant/vegetable production without soil) with aquaculture (fish farming). The growth performance of comet goldfish (aquatic) against a hydroponic plant of Ipomoea aquatic (water spinach), Spinacia oleracea (spinach) type of leafy vegetable and water plant were evaluated in recirculation of this Aquaponic system towards temperature, light and fish waste effectiveness. The fish were feed with commercial
pelleted feeds containing 30% crude protein which can provide almost all nutrients required for the plant growth. Auto feeder placed in this system used to maintain the growth and survival rates. Filter systems used to remove the amount of waste materials and breakdown products from the water. In this project, a set point is the desired value that needed by the user. The set point will be the desired water level, the monitored temperature in fish tank, the monitored temperature at plant area and the desired amount of food. While Arduino (Mega) function as a brain that used to receive the information from the sensor and come out with an instruction in term of response (action) as the feedback. Then the action will be based on the actuator that was reacted towards the act received. Therefore, this closed system was completed the project development system [3]. The world is facing several serious problems of which population rise, climate change, soil degradation, water scarcity and food security are among the most important as described in the Challenges of Sustainable and Commercial Aquaponics (Simon Goddek, Boris Delaide, Utra Mankasingh, Kristin Vala Ragnarsdottir, Haissam Jijakli and Ragnheidur Thorarinsdottir); aquaponics, as a closed loop system consisting of hydroponics and aquaculture elements, could contribute to addressing these problems. However, there is a lack of quantitative research to support the development of economically feasible aquaponics systems. Although many studies have addressed some scientific aspects, there has been limited focus on commercial implementation. In this review paper, opportunities that have the potential to fill the gap between research and implementation of commercial aquaponic systems have been identified. The analysis shows that aquaponics is capable of being an important driver for the development of integrated food production systems. Arid regions suffering from water stress will particularly benefit from this technology being operated in a commercial environment [4]. The study Biomass Production and Nutrient Dynamics in an Aquaponics System (Jason David Licamele) explains and proves that aquaponic systems can produce lettuce of equal growth and quality compared to hydroponic lettuce production and to determine the stocking density of fish required for plant growth. Aquaponics is the integration of recirculating aquaculture and hydroponic plant production. This paper explains four main objectives. The first it determined the biomass of fish required for plant growth to develop a fish to plant density ratio. The second one explains and compared the lettuce grown with aquaponic water and a hydroponic solution under the same environmental conditions. The third one explains and compared the quality of lettuce grown with aquaponics water plus nutrient supplementation with a hydroponic solution. The fourth one determined the nitrogen dynamics in the aquaponic system and compared the nutrient composition of lettuce grown with aquaponics water with nutrient supplementation and hydroponic solution [5].

**Integrated system and process of systemic cultivation of flora-horticultural products, algae, and food fish fauna**

There exist various aquaponic cultivation systems and are well known, also integrated with fish fauna farms. But it does not appear that contiguous crops of algae and plants have been set up, in a single systemic solution and with structures in pipes in vertical racks. This is an integrated system of multiple cultivation finalized to fish fauna farms. In general, in algal crops the CO₂ requirements are not implemented with natural and contiguous processes, with symbiosis such as those proposed by the invention. However, there are no similar systemic processes for treatment/purification, combining Phyto depuration and algal growth upstream of the water for fish farms, downstream of the latter in a single virtuous, symbiotic, and circular economy process. But this does lack in monitoring and governing remotely or locally and the system that is mentioned is not automated [6].
Key Concepts

Aquaponics is a technique made of two separate farming techniques, namely hydroponics and aquaculture. Aquaponics uses about 90% less water than traditional farming, provides more crop yield per unit area, and does not require the use of poisonous herbicides and pesticides. Hence the produce from aquaponics is organic.

Since the technique can be applied with different types of systems, it is possible to monitor and control it. Making automation a possible solution, which can provide with organic products grown with optimum conditions.

For the monitoring of the system, pH, Electrical Conductivity, and temperature are the main variables that need to be checked. Based on these it can be decided which crops can be grown.


Hydroponics is more efficient compared to traditional land based agricultural methods. In the case of lettuce, hydroponics offered 11 ± 1.7 times higher yields per area and saved up to 95% of water (20 ± 3.8 L/kg/y of hydroponics vs. 250 ± 25 L/kg/y of traditional land based)– mainly lost through evaporation, if not absorbed. The downside is that it required a tremendous amount of energy (90,000 ± 11,000 kJ/kg/y) compared to the 1100 ± 75 kJ/kg/y of traditional land based. The energy consumption is mainly to keep the water circulating, and in the case of indoor hydroponics, to keep the growth LED lights on. This problem is countered by us by integrating solar energy in Cropotronics [7].

Design of a Smart Monitoring and Control System for Aquaponics Based on Open WRT

The paper deals with collecting data from the aquaponics system and transferring wirelessly through the server. The user can access this data through an application and from there decide which system to turn on or off. This signal is then transferred back to the server which then sends the signal to the actuators [8].

The Production of Catfish and Vegetables in an Aquaponic System

A total of fifteen aquaponic sets were installed in an aquaculture setting at Kuala Sungai Baru, Perlis, Malaysia. Over the period of 60 days, two batches of three different vegetables were grown. Catfish were not changed during the cycles. The research recommended the use of catfish for aquaponics mainly due to their tendency to survive in low oxygen environments [9].

Design of Aquaponics Water Monitoring System Using Arduino Microcontroller

Arduino was used to design a complete aquaponics system. pH, temperature, and water sensors were used, and the data collected. If the pH was found out of range, it was automatically brought to the desired value. If any value was found to be out of range of the desired value, a message was sent automatically through GSM.

How to Hydroponics

The book [9] explained different steps of designing a hydroponics system. It includes different models you can use. Different growing materials that can be used to grow seedlings, the type of growing environment plants require. It even includes data on multiple crops and the pH, temperature etc. they require for optimized growth [10].
Table 1. Notable Companies [11]

<table>
<thead>
<tr>
<th>Name</th>
<th>Technique</th>
<th>Country/Region</th>
<th>Product Type</th>
<th>Price</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>GrowUp Urban Farms</td>
<td>Hydroponics</td>
<td>UK</td>
<td>Crops</td>
<td>-</td>
<td>Local produce</td>
</tr>
<tr>
<td>Tailor Made Fish Farms</td>
<td>Aquaculture, Hydroponics</td>
<td>Australia</td>
<td>Crops and Fish</td>
<td>-</td>
<td>Local produce</td>
</tr>
<tr>
<td>Kakovitch Industries</td>
<td>Aquaponics</td>
<td>USA</td>
<td>Designs and builds Custom Systems</td>
<td>-</td>
<td>Mostly for commercial farms</td>
</tr>
<tr>
<td>Aqua Sprouts</td>
<td>Aquaponics</td>
<td>USA</td>
<td>Aqua Sprouts Garden.</td>
<td>$179.95 Bundle (+LEDs etc): $260</td>
<td>Small, decorative system. Can fit on a table.</td>
</tr>
<tr>
<td>The Blue Green Box</td>
<td>Aquaponics</td>
<td>Only USA</td>
<td>System for plants and pumps.</td>
<td>$ 75, $ 120, $ 300</td>
<td>Aquarium and fish Not included.</td>
</tr>
<tr>
<td>Osmo Systems</td>
<td>Water monitoring sensor.</td>
<td>USA</td>
<td>Sensor system. (Includes 5 sensors)</td>
<td>$ 550+</td>
<td>DO sensors included for additional price.</td>
</tr>
</tbody>
</table>

Current Industries

The following companies are working with hydroponics/aquaponics. However, they fail to provide the complete functionality of this project. The mentioned companies all have differences and or are lacking in something compared to our project. GrowUp Urban Farms, Tailor Made Fish Farms and Kakovitch Industries are all commercial scale farms. They do not provide systems for the end user.
AquaSprouts, back to the Roots and the Blue Green Box, though are indoor aquaponics systems, they are more for indoor decoration than sustainable food growth. They provide no monitoring of the system. And so cannot be considered for home farming. Osmo Systems, although their product contains pH, electrical conductivity, and temperature, as well as an option for Dissolved Oxygen sensor; it does not have any variant with which humidity and light sensors can be integrated.

**Future of Soilless Farming Trends**

Soilless farming techniques are majorly used in developed countries, yet its share has continued to increase in the past few years. By the year 2020, hydroponics is predicted to account for about 6% of the Compound Annual Growth Rate (i.e., the total food production) of the entire world. While its Global market share is expected to increase to about 13 billion USD.

![World Compound Annual Growth Rate](image1)

**Fig.1. World Compound Annual Growth Rate**

![Global Market Share](image2)

**Fig.2. Global Market Share**

Shrinking of agricultural land is already an increasing problem of the world, as shown in fig.3. This shortage is either due to de-fertilization of soil, because of heavy agricultural use in the past, or urbanization. This shortage means the word will need to find a suitable alternative for crop productions. The economical alternative in urbanized areas for agriculture, are hydroponics and aquaponics, whose share in CAGR, if increased, can easily account for the food shortage.
Aquaponics requires continuous care and management, which is difficult for the people, because of lack of exposure with the technique. Hence the problem at hand is to make the monitoring automated, in an effort assist the novice farmers in growing produce efficiently, and with minimum loss of crops and fish. Another problem is to make the running cost of system to be minimum to attract the masses. Hence the system designed is light-weight –made of PVCs–, scalable –multiple systems can work together or their size increased - and compensates its energy requirements using Solar Energy.

**Synpaper**

The literature and studies presented by local and foreign authors were considered substantial to the current study because the researchers understand better the most fundamental concepts studied in the research. There are few studies which explains the importance of awareness against malnutrition or undernourishment and that a local food system shall be developed to solve this problem. While some other had given initial information about how aquaponics started including its necessities to operate effectively. Moreover, few of them shared how aquaponics benefits in solving different problems in some countries in terms of environment, agriculture, and the economy. On the other hand, some organization shows the fundamental principles involved in aquaponics and its practical application nowadays. The potential of aquaponics to be a true alternative in farming system is further stated through the research. Finally, the researchers find valuable insights from the related literature and studies mentioned which served as the basis of the present study since they also attempt to determine the benefits of Garden Photo Bio reactor fish system and much more when it will be innovated into a vertical structure to be space-friendly and widely used in urban areas.

**Aquaculture and Aquaponics**

Wild fish stocks are at an all-time low, with many species on the brink of an irreversible decline. Overfishing is on every list of coming or current environmental disasters but with an ever-expanding human population, the pressure on fish to play a significant role in food and nutrition security can be expected to grow.
The “Sea Around Us” database shows that wild fish catches peaked in 1996 and has been falling by 1.22 million tonnes (~1%) per year since. Further reductions are expected due to degraded ecosystems, continued coastal development, destructive fishing practices and climate change. Serious human health impacts are predicted to develop from fishery declines, because 1.39 billion people worldwide currently get more than 20% of their essential micronutrients from fish. Poor people, especially in the tropics, will be more at risk.

Aquaculture appears to be a viable alternative to wild fishing, with the potential to reduce the pressure on some capture fisheries, and in 2014, for the first time, world aquaculture produced more fish for human consumption than fishing did. However, there are many environmental concerns with conventional aquaculture too, particularly in the intensive form favoured by large companies [12].

An emerging paradigm (in aquaculture as well as in other fields of natural resource management) is for planning and management to have a focus on whole ecosystems, rather than solely on anthropogenic requirements. In the literature, this has been referred to as an ‘ecosystem approach’ to aquaculture. In practical terms, ecologically sensitive aquaculture projects ensure food production but reduce or eliminate the detrimental environmental impacts that have been observed in conventional aquaculture. A workshop of experts convened by the FAO in Spain in 2007 agreed that: “An ecosystem approach for aquaculture (EAA) is a strategy for the integration of the activity within the wider ecosystem in such a way that it promotes sustainable development, equity, and resilience of interlinked social and ecological systems” [13].

In addition, the publication resulting from the workshop states that: “Such strategy should be guided by three main principles that should ensure the contribution of aquaculture to sustainable development: (i) aquaculture should be developed in the context of ecosystem functions and services with no degradation of these beyond their resilience capacity; (ii) aquaculture should improve human wellbeing and equity for all relevant stakeholders; and (iii) aquaculture should be developed in the context of (and integrated to) other relevant sectors” [14].

In other words, the three linked spheres of sustainable development - environmental, social, and economic, are upheld and reinforced by this type of aquaculture. Based on this definition, the ultimate example of EAA could be aquaponics, and yet aquaponics has taken a long time to become established and is still underutilised considering its great potential for improving aquaculture in line with the three principles listed above [15].

Aquaponics is defined as the polyculture of fish and plants. The word derives from a combination of aquaculture and hydroponics, which is the practice of growing plants without soil. Typically, aquaponics is part of a recirculated aquaculture system (RAS) where fish waste is used as fertilizer for the plants, to the benefit of both the product streams. Usually, water is the growing medium for the plants, with fish living in that water, but there are many possible varieties of systems. Other designs use soil, gravel or biological material for the plant growth media, and the used fish water may be pumped over the plants, filtered first, and/or chemically adjusted before being used for irrigation.

The aquaponics is a cycle that is naturally present in all waterways, where plants grow using the waste from fish as nutrients, and fish benefit from the cleaner, oxygenated water. In a natural ecosystem, the fish could be eating plants, including microscopic algae, and they might be eating insects, which would in turn be eating down the food
chain-subsisting on phytoplankton or zooplankton. Other elements of this natural food web replicated in an aquaponics facility could include crustaceans such as shrimp or crabs, or even higher animals such as ducks or geese, which, in the case of the Incas of Peru, were utilised to move nutrients from the water, where they ate aquatic plants and small fish, to the land, where they roosted and fertilised the soil.

The concept of aquaponics systems as self-contained ecosystems lends itself to the field of agroecology, and so it is through this lens that that the arguments in the discussion will be made.

Conclusions

Even in an agricultural country where farming land is in abundance, the shortage of water is a big issue, and it needs to be catered for this integrated cultivation and integrated cultivation is the way to solve this issue. One of the main aims of the presented project is to design and develop integrated cultivation system and to bring this system to urban areas, where people have a busy life, hence the need of automation of this technique is extremely important. This project provides smart suggestions and smart monitoring system to the users and makes it easier for them to grow their organic food in their homes and enjoy cheap and healthy food. In a following scientific paper, the proposed plant will be presented in detail.

Declarations

Source of Funding

This research did not receive any grant from funding agencies in the public, commercial, or not-for-profit sectors.

Consent for publication

Author declares that he/she consented for the publication of this research work.

Competing Interests Statement

The author declares no competing financial, professional and personal interests.

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