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Solar Based Smart Aquaponic System

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ABSTRACT

This paper looks at how aquaculture and hydroponics could cooperate to produce an innovative food generating system addressing urban problems of overpopulation and limited land. The proposed aquaponics system combines soilless plant growing with fish farming in a recirculating aquaculture environment, aiming to provide organic, contaminant-free food with less labour requirements than conventional agricultural methods. By recycling water and employing fish excrement as a plant nutrition source, the approach increases freshwater efficiency and lowers nutrient release into surrounding ecosystems. The growing process demands a purposeful management approach to maximise output since it uses a synergistic connection between fish and plants. Specifically, tilapia will be fed a commercial diet that meets their nutritional needs and provides essential components for plant growth. Though the aquaponics system demands steady energy sources to operate and initial expenditure for setup until marketable yields are attained, it offers significant advantages in food output and sustainability. This paper underlines the potential of aquaponics as a scalable substitute for generating sustainable urban food.

Keywords Aquaponics , Solar Energy, Sustainable Agriculture, Smart Farming , Hydroponics, Renewable Energy , Aquaculture , Food Production , IoT (Internet of Things), Water Efficiency , Fish Farming, Plant Cultivation, Environmental Sustainability, Solar-Powered System, Urban Agriculture, Resource Efficiency, Waste Recycling, Agricultural Automation, Urban Food Production, Energy Efficiency , Smart Farming Technology, Maximum Power Point Tracking (MPPT), Aquaponics System Monitoring, Agricultural Innovation

Introduction

Aquaponics is a creative and sustainable food production system that seamlessly combines aquaculture (fish farming) and hydroponics (soilless plant growing) in a closed-loop environment. Urban population increase, nutrient runoff, and water shortage are among the significant problems this approach addresses. In aquaponics, fish waste serves as vital plant nutrients; the plants then filter and purify the water, sending it back to the fish in a good state. By means of efficient resource recycling, this increases food security and lowers environmental effect.

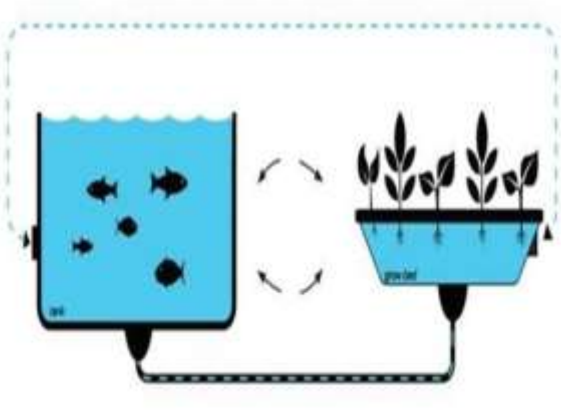

Fig1. Basic of Aquaponic Cycle

The growing need for renewable energy sources, particularly in countries like Malaysia, where fossil fuel consumption is high, begs the incorporation of solar electricity into aquaponic systems. Solar energy can consequently significantly reduce operational costs and dependence on conventional power sources, so promoting ecologically friendly farming practices. Still unresolved are problems like the need for efficient energy conversion using inverters and the cost of solar panels.

Apart from these obstacles, particularly in crowded areas with food scarcity, advances in solar technology and the possibility of using renewable energy provide intriguing possibilities for sustainable food production. This project aims to increase the overall sustainability and efficiency of aquaponics by using a solar-based smart aquaponics system to capture solar energy to operate essential components such water pumps and aeration systems.

As the world population increases, particularly in cities, the importance of sustainable farming practices becomes more pronounced. Already successfully applied in places like China, the United States, and Europe, the aquaponics approach has the potential to revolutionise food production in countries like India, where urbanisation and agricultural land loss are key concerns. By reducing water use and decreasing reliance on chemical fertilisers, aquaponics offers a hopeful solution to the many challenges of contemporary agriculture.

Literature Review

Recent research on the integration of hydroponic systems, solar energy, and Internet of Things (IoT) technology into sustainable agriculture practices is examined in this literature review.

Emphasising their land, water, and energy requirements, one research provides a comprehensive contrast between hydroponic and conventional farming methods. It indicates that hydroponics sometimes consumes less land and water, implying its potential as a more resource-efficient replacement for traditional farming. Although acknowledging variety dependent on technology and size, this paper underlines the environmental benefits of hydroponic systems [1].

A new method using a power estimator among many Maximum Power Point Tracking (MPPT) algorithms for grid-connected solar systems is highlighted in another study. The study indicates that by optimising the incorporation of renewable energy into power grids, this creative approach could significantly increase energy efficiency and overall system performance [2].

Research on aquaponics show the effective development of catfish and plants inside integrated systems. By proving that fish waste is a nutritional source for plants [3], the study indicates aquaponics to be a sustainable food production choice that reduces waste and resource consumption while simultaneously generating fish and crops.

A article also provides an Arduino microcontroller-based monitoring tool for aquaponics water conditions. This cheap, real-time solution provides significant information on water quality parameters, hence improving the management of aquaponic systems and demonstrating the role of technology in supporting sustainable agriculture practices [4].

Another study investigates how IoT devices might manage environmental variables including water quality and nutrient levels by interacting with a solar-powered aquaponics system. This approach not only improves efficiency and automation but also helps sustainable agriculture by lowering reliance on external energy sources.

Furthermore, a research effort demonstrates how to maximise aquaponics systems employing IoT sensors and controls by means of solar energy. The research demonstrates how integrating IoT technologies with renewable energy could support resource efficiency and automation in sustainable agriculture [6].

Research on agricultural sustainability in dry locations emphasises a solar-powered automated aquaponics system intended for Oman. The study underlines how solar energy can regulate vital elements including fertiliser levels and water quality, hence enhancing the performance of aquaponics systems in resource-limited environments [7].

Especially in desert environments with agricultural challenges, the probable increase of local food production and resource management by means of this automated system is enormous [8].

Another study addressing the pressing problem of integrating solar power and IoT into aquaponics systems seeks to increase efficiency and sustainability, particularly in regions with restricted access to conventional energy sources. Significantly contributing to the topic of smart agriculture, the authors propose a solar-powered smart system integrating aquaculture and hydroponics [9].

Finally, the paper "Smart Village: Solar Based Smart Agriculture with IoT Enabled for Climatic Change and Fertilisation of Soil" provides an innovative approach to soil management in agriculture within climatic limits. Although more study on detailed implementation strategies and cost analysis is required, this forward-looking strategy combines solar energy and IoT technology, with optimistic effects for encouraging efficient and sustainable farm practices [10].

The study generally indicates a growing trend towards including smart technologies and renewable energy in sustainable agriculture, particularly by means of aquaponics and hydroponics systems. These policies address the issues of food security and climate change as well as increase resource efficiency.

Design Methodology

Made up of many components, the solar-based smart aquaponics system creates an automated and efficient environment for sustainable fish and plant production. The ATmega328 microcontroller, which acts as the central processing unit, gets and processes data from several sensors and controls output devices to maintain optimal growing conditions. Key sensors are a temperature and humidity sensor tracking ambient conditions, an LDR (Light Dependent Resistor) measuring light intensity, a moisture sensor evaluating moisture levels in the growing medium, and a DS18B20 temperature sensor particularly monitoring the water temperature in the aquarium.

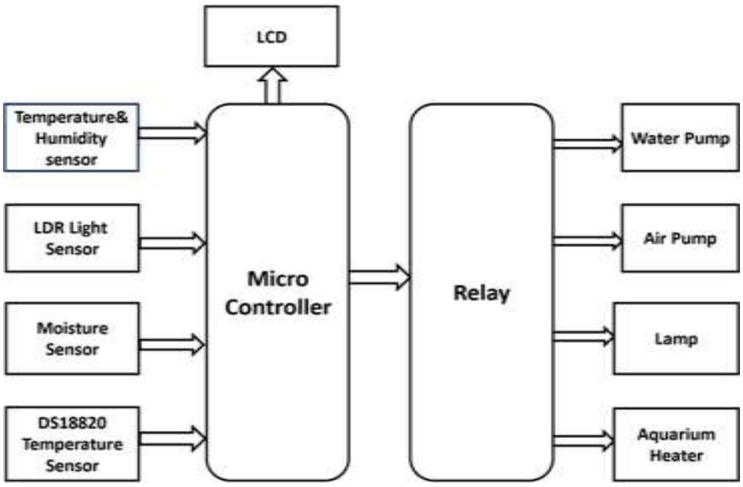

Fig 2. Block Diagram

By displaying real-time data, an LCD provides users essential knowledge of the system state. The microcontroller processes this data and a relay driver controls many output devices. Among these devices are adjustable lamps replicating sunshine with certain spectra to promote photosynthesis, a water pump flowing water throughout the system, and an air pump delivering oxygen to the aquatic life. The microcontroller activates an aquarium heater in colder areas to maintain suitable temperatures for fish health.

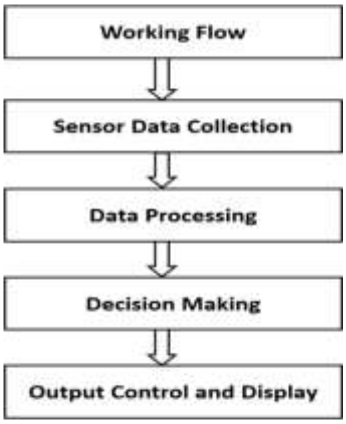

Fig 3. Working Flow

The method involves continuing sensor data collecting after system configuration with all components connected. Processing the incoming data against defined criteria allows the microcontroller to activate or deactivate output devices as needed. For instance, the heater is turned on if water temperatures drop; the water and air pumps operate to ensure proper circulation and oxygenation. Users may monitor system performance since the LCD displays essential environmental data. Running on solar energy, the system might have battery storage to maintain operations during low sunshine hours, therefore supporting sustainability and reducing running costs. This design and strategy provide a self-sustaining aquaponics system that maximises food output by using renewable energy and advanced monitoring technologies, hence enhancing the overall efficiency of the aquaponic environment

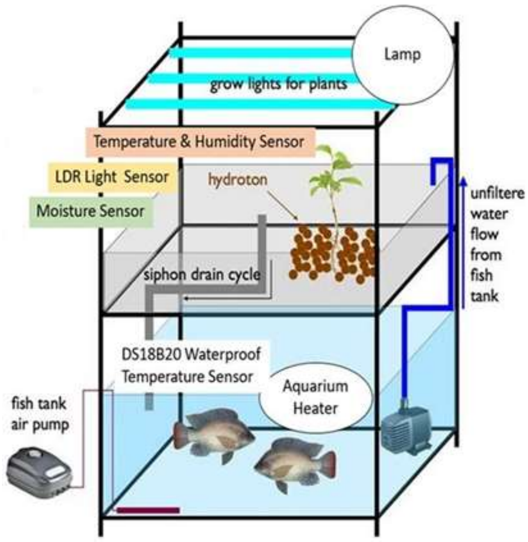

Fig 4. Actual System Design

Result and Analysis

The Fig. 5 shows the output voltage produced by solar panel between 8.00 a.m to 7.00 p.m on 21 Sept 2024. At 8.00 am, early morning generates 12.43V; it gradually increases to 18.49V at 12 noon. It then gradually descends to 7.00 p.m. The link between voltage and current lets us clearly observe that ampere output for solar panel follow the steadily increasing and falling as the voltage line. Captured at Kolhapur, Maharashtra on 21 Sept 2024, this solar panel data reveals a bright, dry, hot day

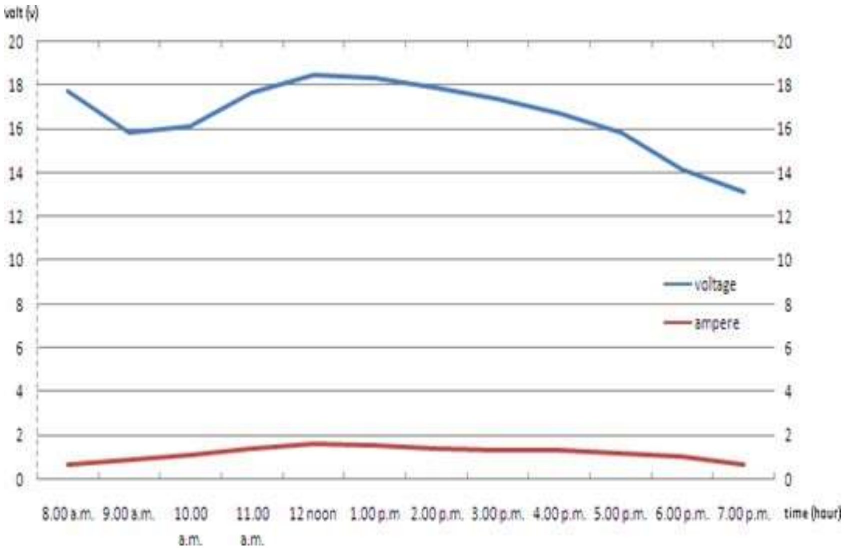

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Fig 5. Solar Panel Output vs Time

Time	**Voltage (V)**	**Ampere(A)**
8:00 AM	18	1
9:00 AM	16	1.5
10:00 AM	17	1.7
11:00 AM	18	1.8
12:00 PM	18.5	1.9
1:00 PM	18.5	1.8
2:00 PM	18	1.7

3:00 PM	17	1.6
4:00 PM	16	1.5
5:00 PM	14	1.3
6:00 PM	12	1
7:00 PM	10	0.8

Conclusion

This project demonstrates that aquaponics is a viable alternative to traditional farming techniques, particularly in terms of water and land usage and operational costs. In an agricultural country like Pakistan, where abundant land exists but water scarcity poses significant challenges, aquaponics offers an effective solution to address this critical issue.

The primary goal of this project was to adapt aquaponics for urban areas, catering to individuals with busy lifestyles. Automation of this technique is essential, and our project introduces a smart monitoring system that provides users with intelligent suggestions, facilitating the growth of organic food in their homes. This not only allows for the enjoyment of affordable and healthy food but also promotes sustainable practices.

Our practical implementation revealed that aquaponics requires a well-established aquaculture system and mature plants of suitable sizes to thrive. This preparation ensures that plants can endure sunlight exposure, while fish can adapt to the fluctuations in temperature and pH levels caused by environmental changes.

In conclusion, aquaponics stands out as a promising countermeasure against the global threats of hunger and famine, particularly in African countries. We advocate for its adoption at an industrial scale to maximize its benefits at both national and international levels.

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