Solar Based Smart Aquaponic System

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Abstract—This project explores the integration of aquaculture and hydroponics to establish an innovative food production system that addresses urban challenges of limited land and overpopulation. The proposed aquaponics system combines fish farming and soilless plant cultivation in a recirculating aquaculture environment, aiming to produce organic, contaminant-free food with reduced labor requirements compared to traditional farming methods. By reusing water and utilizing fish waste as a nutrient source for plants, the system enhances freshwater efficiency while minimizing nutrient discharge into surrounding ecosystems. The cultivation process leverages a synergistic relationship between fish and plants, necessitating a careful management approach to optimize production. Specifically, tilapia will be fed a commercial diet that meets their nutritional needs and provides essential nutrients for plant growth. While the aquaponics system offers significant advantages in food output and sustainability, it requires reliable energy sources to maintain operations and initial investment for setup until marketable yields are achieved. This research highlights the potential of aquaponics as a scalable solution for sustainable urban food production.

Index Terms—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

I. INTRODUCTION

Aquaponics is an innovative and sustainable food production system that synergistically combines aquaculture (fish farming) and hydroponics (soilless plant cultivation) in a closed-loop environment. This approach addresses critical challenges such as water scarcity, nutrient discharge, and the increasing demand for food in urban areas. In an aquaponic system, the waste produced by fish serves as vital nutrients for plants, which in turn filter and purify the water, returning it to the fish in a safe form. This efficient recycling of resources minimizes environmental impact and enhances food security.
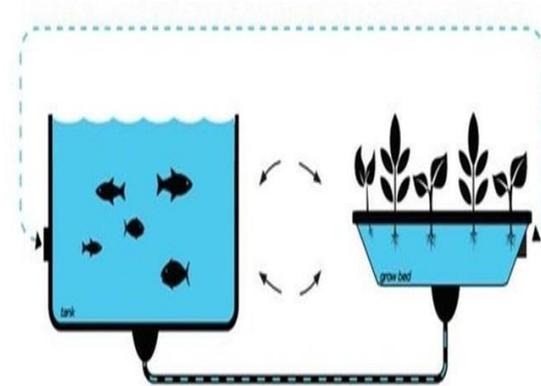

Fig1. Basic of Aquaponic Cycle

The growing need for renewable energy sources, particularly in regions like Malaysia, where reliance on fossil fuels is high, necessitates the integration of solar power into aquaponic systems. Solar energy can significantly reduce operational costs and dependence on conventional power sources, thus promoting eco-friendly agricultural practices. However, challenges such as the cost of solar panels and the need for efficient energy conversion via inverters remain.

Despite these obstacles, advancements in solar technology and the feasibility of using renewable energy present exciting opportunities for sustainable food production, particularly in densely populated areas facing food shortages. By employing a solar-based smart aquaponics system, this project aims to harness solar energy to power essential components like water pumps and aeration systems, thereby enhancing the overall sustainability and efficiency of aquaponics.

As the global population continues to rise,

particularly in urban centers, the importance of sustainable agricultural practices becomes increasingly critical. The aquaponics technique, already successfully implemented in regions like China, the USA, and Europe, has the potential to revolutionize food production in countries such as India, where urbanization and agricultural land loss are pressing concerns. By reducing reliance on chemical fertilizers and minimizing water usage, aquaponics offers a promising solution to the multifaceted challenges of modern agriculture.

II. LITERATURE REVIEW

In this literature review examines recent research that explores the integration of hydroponic systems, solar energy, and Internet of Things (IoT) technology within sustainable agricultural practices.

One study provides a detailed comparison between hydroponic and conventional agricultural methods, focusing on their land, water, and energy requirements. It finds that hydroponics typically utilizes less land and water, indicating its potential as a more resource-efficient alternative to traditional farming. This research underscores the environmental benefits of hydroponic systems while acknowledging variability based on technology and scale [1].

Another paper discusses various Maximum Power Point Tracking (MPPT) algorithms for grid-connected photovoltaic systems, highlighting a novel algorithm that employs a power estimator. The study demonstrates that this new approach can significantly enhance energy efficiency and overall system performance, contributing to the optimization of renewable energy integration into power grids [2].

Research focusing on aquaponics shows the effective production of catfish and vegetables within integrated systems. The study reveals that fish waste serves as a nutrient source for plants, showcasing aquaponics as a sustainable food production solution that reduces waste and resource consumption while simultaneously yielding fish and crops [3].

Additionally, a paper presents a monitoring system for aquaponics water conditions using Arduino microcontrollers. This affordable, real-time solution provides critical data on water quality parameters, improving the management of aquaponic systems and

illustrating the role of technology in enhancing sustainable agricultural practices [4].

The integration of IoT technology with a solar-powered aquaponics system is explored in another study, demonstrating how IoT devices can monitor and control environmental parameters such as water quality and nutrient levels. This approach not only improves efficiency and automation but also contributes to sustainable agriculture by minimizing reliance on external energy sources [5].

Further, a research project illustrates the implementation of IoT sensors and controllers for optimizing aquaponics environments while utilizing solar power. The analysis highlights the benefits of combining renewable energy with IoT technologies to advance resource efficiency and automation in sustainable agriculture [6].

Research focusing on agricultural sustainability in arid regions emphasizes a solar-powered automated aquaponics system tailored for Oman. The study highlights the use of solar energy to manage key parameters such as water quality and nutrient levels, thereby enhancing the efficiency of aquaponics practices in resource-limited environments [7].

The potential for improving local food production and resource management through this automated system is significant, particularly in desert climates facing agricultural challenges [8].

Another study addresses the timely topic of integrating solar power and IoT into aquaponics systems, aiming to enhance efficiency and sustainability, especially in regions with limited access to traditional energy sources. The authors propose a solar-powered smart system that combines aquaculture and hydroponics, significantly contributing to the field of smart agriculture [9].

Finally, the paper "Smart Village: Solar Based Smart Agriculture with IoT Enabled for Climatic Change and Fertilization of Soil" presents an innovative approach to addressing climatic challenges and soil management in agriculture. This forward-thinking solution integrates solar energy and IoT technology,

with promising implications for advancing sustainable and efficient agricultural practices, although further exploration into cost analysis and detailed implementation strategies is warranted [10].

Overall, the literature demonstrates a growing trend toward integrating renewable energy and smart technologies in sustainable agriculture, particularly through aquaponics and hydroponics systems. These approaches not only enhance resource efficiency but also contribute to addressing the challenges posed by climate change and food security.

III. DESIGN METHODOLOGY

The solar-based smart aquaponics system integrates various components to create an efficient and automated environment for sustainable fish and plant production. At its core is the ATmega328 microcontroller, which acts as the central processing unit, receiving and analyzing data from multiple sensors while controlling output devices to maintain optimal growing conditions. Key sensors include a temperature and humidity sensor that monitors ambient conditions, an LDR (Light Dependent Resistor) that measures light intensity, a moisture sensor that gauges moisture levels in the growing medium, and a DS18B20 temperature sensor that specifically monitors the water temperature in the aquarium.
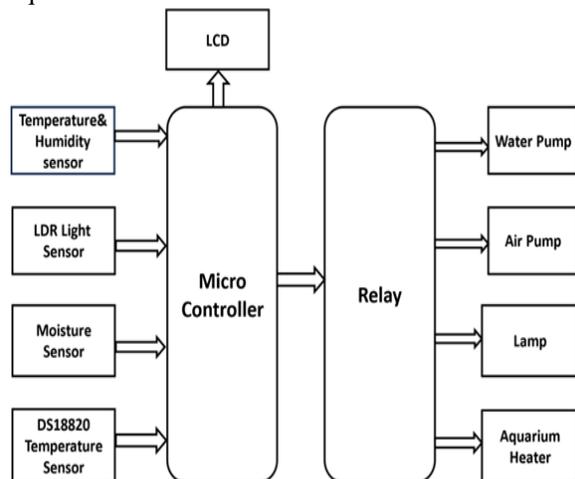

Fig 2. Block Diagram

Real-time data is displayed on an LCD, providing users with crucial information about the system's conditions. The microcontroller processes this data

and controls various output devices via a relay driver. These devices include a water pump that circulates water throughout the system, an air pump that supplies oxygen to the aquatic life, and adjustable lamps that mimic sunlight with specific spectra to promote photosynthesis. In colder environments, the microcontroller activates an aquarium heater to maintain suitable temperatures for fish health.
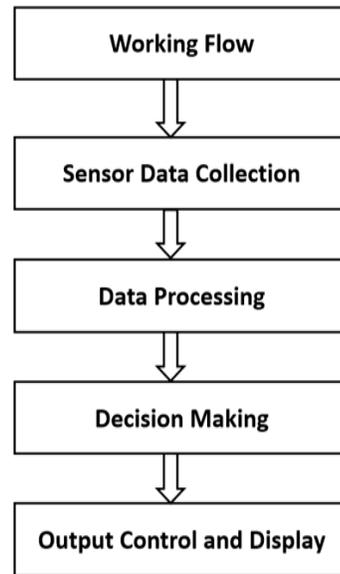

Fig 3. Working Flow

The methodology involves setting up the system with all components interconnected, followed by continuous data collection from the sensors. The microcontroller processes the incoming data against predefined thresholds, activating or deactivating output devices as necessary. For instance, the heater is turned on if water temperatures drop, while the water and air pumps operate to ensure proper circulation and oxygenation. Users can monitor system performance through the LCD, which displays critical environmental data. Powered by solar energy, the system promotes sustainability and reduces operational costs, potentially incorporating battery storage to maintain operations during low sunlight periods. This design and methodology create a self-sustaining aquaponics system that leverages renewable energy and advanced monitoring technologies to optimize food production, enhancing the overall effectiveness of the aquaponic environment.
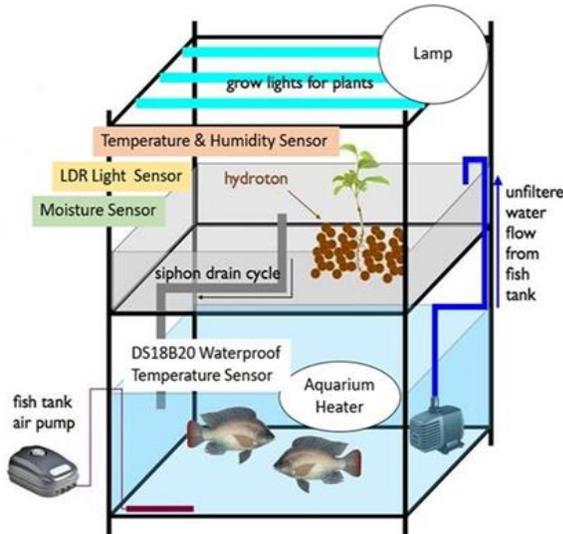
Fig 4. Actual System Design

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

IV. 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. As the early morning at 8.00 am the output is 12.43V and gradually increase until reaches its peak output at 12 noon which is 18.49V. Then the voltage drop gradually to

7.00 p.m. The link between voltage and current, we can clearly see that ampere output for solar panel follow the gradually increasing and decreasing as the voltage line. This solar panel data is captured at Kolhapur , Maharashtra on 21 Sept 2024, the weather on that day is sunny, dry and hot.
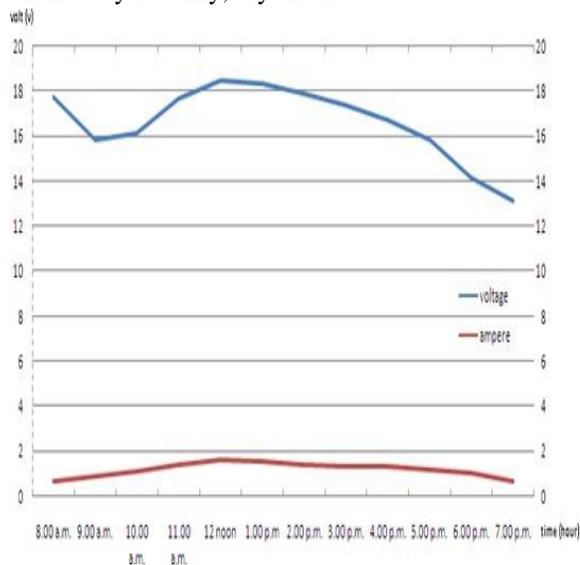

Fig 5. Solar Panel Output vs Time

V. 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.

REFERENCES

[1] Barbosa, G. L. (June 2015). Comparison of Land, Water, and Energy Requirements of Lettuce Grown Using Hydroponic vs. Conventional Agricultural Methods. International Journal of Environmental Research and Public Health. doi: 10.3390/ijerph120606879

[2] Hlaili, M. (2016). Comparison of Different MPPT Algorithms with a Proposed One Using a Power Estimator for Grid Connected PV Systems. International Journal of Photoenergy, 2016, Article ID 1728398. doi: 10.1155/2016/1728398

[3] Mamat, N. Z. (October 2016). The Production of Catfish and Vegetables in an Aquaponic System. Journal of Aquaculture Research & Development. doi: 10.4172/2150-3508.1000181

[4] Murad, S. A. Z. (September 2017). Design of Aquaponics Water Monitoring System Using Arduino Microcontroller. AIP Conference Proceedings. doi: 10.1063/1.5002442

[5] Wang, D. (2015). Design of A Smart Monitoring and Control System for Aquaponics Based on OpenWrt. Proceedings of ICIMM 2015.

[6] Murdan, A. P., & Joyram, A. (2021). An IoT Based Solar Powered Aquaponics System. In 2021 13th International Conference on Electronics, Computers and Artificial Intelligence (ECAI) (pp. 1-6). doi: 10.1109/ECAI52376.2021.9515023

[7] Nagayo, A. M., Mendoza, C., Vega, E., Al Izki, R. K. S., & Jamisola, R. S. (2017). An Automated Solar-Powered Aquaponics System Towards Agricultural Sustainability in the Sultanate of Oman. In 2017 IEEE International Conference on Smart Grid and Smart Cities (ICSGSC) (pp. 42-49). doi: 10.1109/ICSGSC.2017.8038547

[8] Galido, E., Tolentino, L. K., Fortaleza, B., Corvera, R. J., De Guzman, A., Española, V. J., Gambota, C., Gungon, A., Lapuz, K. T., Arago, N., Velasco, J., & Jorda, R. J., Jr. (2024). Development of a Solar-Powered Smart Aquaponics System through Internet of Things (IoT). College of Engineering, Technological University of the Philippines, Manila, Philippines.

[9] A.P. Murdan and A. Joyram, "An IoT based solar powered aquaponics system," 2021 13th International Conference on Electronics, Computers and Artificial Intelligence (ECAI), Pitesti, Romania, 2021, pp. 1-6, doi: 10.1109/ECAI52376.2021.9515023.

[10] Smart Solar-Powered Smart Agricultural Monitoring System Using Internet of Things Devices. In AI and IoT in Renewable Energy (pp. 101-109). Springer. DOI:10.1007/978- 981-16-1011-0_10.

[11] R. Maheswari, H. Azath, P. Sharmila and S. Sheeba Rani Gnanamalar, "Smart Village: Solar Based Smart Agriculture with IoT Enabled for Climatic Change and Fertilization of Soil," 2019 IEEE 5th International Conference on Mechatronics System and Robots (ICMSR), Singapore, 2019, pp. 102-105, doi: 10.1109/ICMSR.2019.8835454.