Flexible Farming using IoT-based Hybrid Aquaponic System

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ABSTRACT
Addressing the challenge of securing a suitable water source for fish and plant cultivation, innovative solutions like aquaponics integrate aquaculture and hydroponics. However, maintaining an aquaponic system requires manual labor for regular water quality checks. Proper management of pH, ammonia, nitrite, and nitrate levels is crucial to sustain optimal conditions for both aquatic organisms and plants, as fluctuations can lead to stress and health issues. This study helps farmers to monitor and manage the farm without manually checking the parameters. The device is integrated with various sensors and modules and has a mobile application where a farm owner and employees can monitor or manage the farm system. The proponents are motivated to help increase freshwater fish and crop production. This project will be advantageous for farmers as it can improve the yield of freshwater fish and agricultural products.

Keywords
Smart, Smart, Aquaponic, Farmer, Monitoring, Monitoring, Agriculture, Fish, Crops.

1. INTRODUCTION
Many people experience mental health challenges, which can affect both their The demand for food rises with the growing population of people. It takes a lot of time, labor, and land to cultivate plants using traditional agricultural methods. [1] According to the World Bank Organization (2022), urban or rural populations will require food to support basic needs as the population is projected to reach over 10 billion by 2050. Additionally, traditional agricultural methods crop production is also declining due to climate change. One of these solutions is aquaponic farming. It is also an alternative method of producing freshwater fish and plants without using large spaces and agricultural land.

The proponents adopted the use of real-time monitoring to the parameters of the aquaponic system. [2] The IoT-based Aquaponic System by Dutta, et al. helps and monitors the aquaponic farm easily to avoid the problem that will affect the growth of the fish and crops. It features monitoring the pH, temperature, and humidity using appropriate sensors.

After perceiving those values, the values were displayed through a Liquid Crystal Display as well as on the web application to help farmers on monitoring the system in real-time to prevent problems. moving. The proponents adopted the existing features and add more features to make the system more flexible. Additionally, the proposed project combined two (2) hydroponic methods: Deep Water Culture, and Nutrient Film Techniques. The system offered three operational modes: the first managed aquaculture and two hydroponic techniques (Deep Water Culture and Nutrient Film Technique), allowing farmers to select their preferred method; the second mode focused solely on aquaculture in the absence of hydroponic operations, while the third mode controlled all hydroponic techniques when aquaculture was inactive. The design aimed to enhance adaptability and productivity for farmers by efficiently managing cultivation methods. It sought to increase freshwater fish and crop production, potentially benefiting farmers significantly

2. RELATED LITERATURE
The Philippines has been identified as having one of the highest Aquaponics is a system that combines aquaculture and hydroponics to grow fish and plants together. Fish waste provides nutrients to the plants, and the plants purify the water for the fish. An efficient system that incorporates IoT technology can use sensors and automation to address challenges and offer an all-inclusive kit for growing organic vegetables at home. Aquaponics is an environmentally-friendly plant production system that integrates soilless cultivation and recirculating aquaculture. It makes full reuse of wastes, which are used as fertilizers for plants. This method is more productive than soil-based agriculture, and it consistently saves water, making it ideal for producing food in areas affected by climate change and resource limitations [3].

The biofilter is a critical component of an aquaponics system, as it provides an extended surface area for beneficial bacteria to thrive. Ammonia is converted by the bacteria adhering to the bio medium into nitrates, which are nutrients needed by plants to develop. Although the bacteria may exist everywhere in the aquaponics system, as the system and the fish get older, they eventually won't be able to take the burden [4]. Biofilters will become the source of nutrients for the plants in an aquaponic system, the proponents will use biofilters rather than directing the fish waste into the hydroponic system. The biofilter can separate the fish solid waste. The key to keeping plants healthy in a hydroponic system is maintaining the proper temperature of the nutrient solution and water. The ideal temperature range for the water solution in hydroponics is between 65°F and 80°F

(18 and 26 °C), which promotes healthy root growth and optimal nutrient [5]. For humidity of the plants, the ideal humidity range for optimum plant growth in an aquaponic system was around 50 - 70% [6].

The proponents will adopt the ideal temperature and humidity in hydroponics. This study will apply to the threshold for the plants and when the system only manages the hydroponic while the aquaculture is not active.Properly managing the water's pH level is essential for the success of an aquaponics system. Balancing the pH requirements of bacteria, plants, and fish is crucial, aiming for the ideal range of 6.8 to 7.2. This ensures optimal bacterial function and nutrient availability for plant growth [7]. But according to Nelson and Pade Aquaponics (2023) [8], the choice of fish and plants to be included in an aquaponic system depends on the specific application of aquaponics. A wide variety of crops can be grown using aquaponics. Commercial growers often focus on growing tilapia, lettuce, and leafy greens. The proponent will adopt the study of Nelson and Pade Aquaponics, aligning with similar temperature and pH requirements. They choose tilapia, which thrives in a pH range of 5.5 to 9.0, and leafy lettuce with a pH range of 5.5 to 6.0 for greater success due to closer pH matches. The system will maintain a pH level between 5.5 to 6.0.

Measuring water electrical conductivity can reveal vital insights into plant health and required adjustments. Elevated EC levels may indicate nutrient blockages in plants, where accumulated salts hinder nutrient absorption. Despite continued fertilizer additions, plants may exhibit signs of nutrient deficiency due to this blockage in the growth medium. Failure to monitor EC levels may result in plants experiencing nutrient lockout. The optimal EC range for hydroponics falls between 1.5 and 2.5 dS/m. Higher EC levels hinder nutrient absorption, while lower levels can significantly impact plant health and yield [9]. The proponents plan to implement the optimal EC range of 1.5 to 2.5 dS/m for hydroponics during aquaculture inactivity. This range facilitates nutrient absorption by plants, ensuring their healthy growth.

Productive cities are a crucial aspect of achieving sustainable urban development, and food production is among the most fundamental functions that should be prioritized. Given the constraints of urban environments and the characteristics of buildings, aquaponics presents a safe and healthy green technology that protects the ecological environment and has a high potential to combine urban structures with plant cultivation [10]. The main water purification farming mode was combined with recent scientific research on cultivation modes and the current development of the recirculating aquaculture industry. It offers a thorough examination of water treatment effectiveness that may be utilized as a guide for developing high-end recirculating aquaculture models and advancing the accuracy and functionality of recirculating water treatment technologies in the future [11]. Although water monitoring is at the center of aquaculture activity, its complexity can often push fish farmers to neglect it. A new age of connected, responsible, and effective aquaculture will come about when user-friendly IoT technologies for fish farming are developed. IoT for aquaculture needs to be smart, affordable, easy to deploy, reliable, and highly efficient [12].

Aquaponic systems are becoming increasingly popular over coupled aquaponic systems, a deep-water culture hydroponic component and media bed component are optimal for commercial and research applications, respectively, Tilapia and dark leafy vegetables are the most successful species used and Nitrospira (bacteria often occur in close association with ammonia) may play a more important role in the aquaponic nitrification process than expected [13].

3. METHODOLOGY

The proponents conducted the study at the FishTech Philippines Inc. located at Tapuac Rd. Dagupan, Pangasinan. They actively grow red tilapia, lettuce, water spinach, and sow lettuce in a seedling tray or grow box using sterilized cocopeat and hydroponically - grown lettuce in a cup using the Nutrients Film Technique method (NFT). The proponents conducted observation, interviews, and surveys for the Smart Hybrid Aquaponic System. During the observational phase, farmers engaged in discussions detailing their farm maintenance practices and the challenges encountered.

Topics covered included insights into pH level management, where farmers shared their methods and experiences in maintaining optimal acidity levels. Additionally, discussions revolved around challenges faced by such temperatures. The observation and interview aimed to gather valuable firsthand information, offering a deeper understanding of the practical aspects and concerns of farmers involved in the project.

To quantify the project's effectiveness, the proponents applied a formula, calculating the percentage based on the outcomes. The first formula [1] is the evaluation of the farm owner and employee to assess the effectiveness and efficiency of the project. The following formula [2] was used to determine the overall assessment of the project.

The evaluation results led to the conclusion that the project demonstrated effectiveness and efficiency. This determination was derived from the farm owner and employee providing affirmative responses to all questions in the evaluation

$$\textbf{\textit{Percentage}} = \frac{\textit{Total No. of Questions Answered Yes}}{\textit{Total No. of Question}}\ x\ 100\ (1)$$

$$\textbf{\textit{Percentage}} = \frac{\textit{Farm Owner} + \textit{Employee}}{2}\ (2)$$

4. PRESENTATION OF ANALYSIS OF DATA

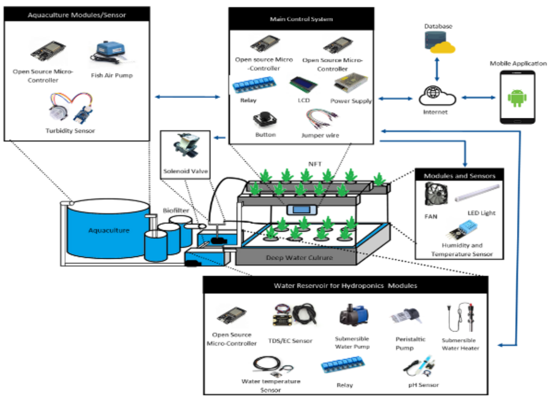

Figure 1. Operational Framework for the Proposed Project

The Smart Hybrid Aquaponic System helped the farmer produce freshwater fish and agricultural crops with less manual monitoring. The proponents used an open-source electronic platform with built-in Wi-Fi, a pH sensor, a water temperature sensor, a button, a turbidity sensor, EC, and others. The project consisted of five (4) open-source electronic platforms, and one of those will acted as the main core to receive and send data to and from open-source microcontrollers. The mobile application will serve as a tool for monitoring and configuring if the internet was available. Using a mobile application and a built-in LCD monitor, users could have monitored the condition of the aquaponic system. Additionally, it enabled system configuration, including thresholds for water temperature, humidity, pH level, and others.In the aquaculture and hydroponic system, the proponents deployed an open-source electronic platform in each system, acting as the brain where all sensors and modules were connected. All data gathered by the sensors was restored in the microcontroller to make appropriate adjustments based on the algorithm embedded in it. All the data gathered were sent to the main core of the system.

The pH sensor determined the acidity and alkalinity. pH levels were important in the aquaponic system to make the system successful. Low pH levels could have been detrimental to the whole system; the nitrification process decreased and created stressful conditions. The pH sensor assisted in monitoring the proper pH level in the system. When the sensors detected the unbalanced pH level, the peristaltic pump worked to provide appropriate needs such as pH down and pH up solutions to maintain the ideal pH in the system.The proponents used a water temperature sensor to monitor the water temperature in the system to prevent it from dropping. When the sensor detected a drop in water temperature, the submersible water heater will turn on to maintain the appropriate water temperature. If the water temperature rised, the aerator will create a waterfall to cool down the water temperature.

During the project’s system design phase, the functional requirements were defined. Functional requirements help identify missing requirements. It enables the proponents to determine the system’s intended service. The proposed project’s functionalities follow:

- Maintain the appropriate needs of the crop and or freshwater fish.
- Configure the Smart Hybrid Aquaponic System based on the appropriate threshold using the mobile application and the built-in controller.
- It can provide real-time monitoring.

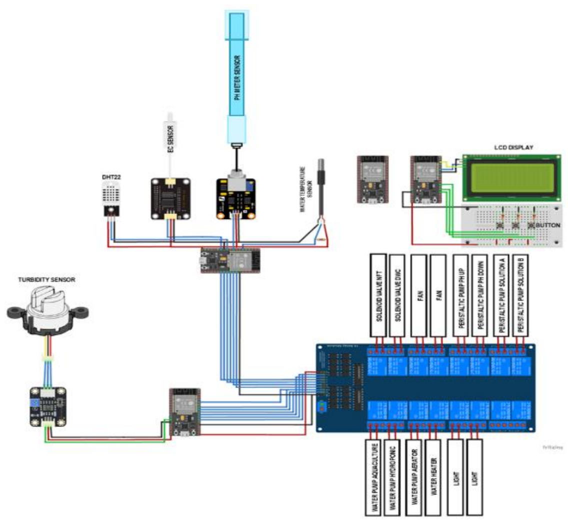

Figure 2. Schematic Diagram of Smart Hybrid Aquaponic

The schematic diagram consists of modules and sensors that connect to the microcontroller such as pH sensor, EC sensor, water temperature sensor, DHT22, and turbidity sensor. The relay modules are connected to the two microcontrollers to optimize the performance of the system.

Modules and sensors are connected to the microcontroller, it has a sensor that can determine the acidity or alkalinity of the water. The normal pH range of the aquaponic is 6.8 to 7.2, if it detects below 6.8 the peristaltic pump will work to provide the pH up solution to maintain the pH level but when it detects the pH level above 7.2, the peristaltic pump will work to provide the pH down solution. The water temperature sensor determines the temperature in the water. Based on the proponents interview the normal water temperature for fish is 28 – 32 °C, if the water temperature sensor detects a temperature below 28 Celsius the submersible water heater will work, but when it detects a temperature above 32 Celsius the aerator will work to help lower the temperature.

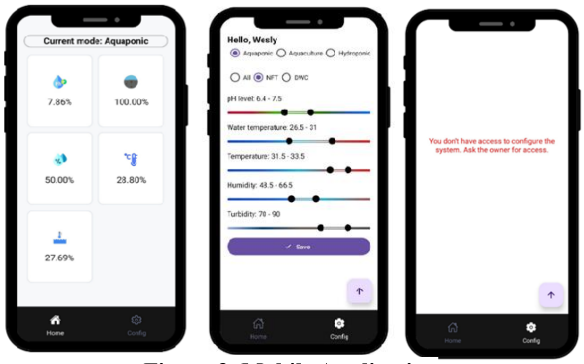

Figure 3. Mobile Application

The home screen for aquaculture mode in mobile applications. contains pH level, water temperature level, and turbidity level. A mobile application design for aquaculture. If users pick the aquaculture mode, users can keep an eye on important info about the water, such as how acidic it is (pH level), how clear it is (turbidity level), and how warm it is (water temperature level). This makes it easy for the users to ensure the water conditions are just right for the fish or other aquatic creatures they care for. Pressing the configuration button reveals the mobile app's settings screen. Access is exclusive to the owner, unless permission is granted to employees.

The screen includes a radio button for selecting modes, a dual-range slider for threshold adjustments, and a save button to apply changes. Each operating mode consists of a different type of threshold. The aquaponic operating mode (Plate 6), contains a radio button to let the user choose to open in the hydroponic part, which contains All (NFT and DWC), NFT, and DWC. Configuration of threshold consists of pH level, water temperature level, temperature level, humidity level, and turbidity level. When the user pressed the arrow-up button again and then clicked the log-in button, it will resulted in the user getting signed out. After the sign-out process, the system automatically redirected the user to the log-in page, facilitating the initiation of another sign-up procedure if desired. The employee did not have access to configure the threshold. Therefore, if the employee clicked the configuration, a warning would pop up.

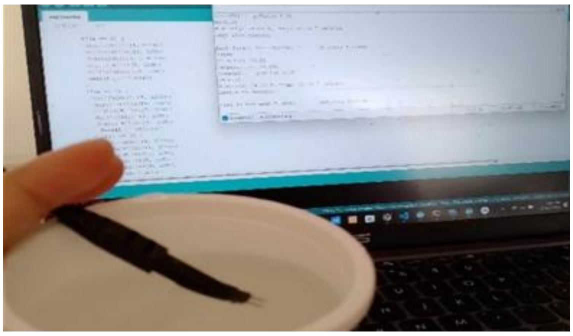

Figure 4. Testing every sensor and module using Arduino IDE

Proponents used a tool called Arduino IDE to code and upload code to the microcontroller. This tool made it easy to create, debug, and upload codes into different types of microcontrollers. Arduino programming, supported by lots of helpful libraries, was crucial to ensuring everything worked smoothly to build the project. The proponents used Arduino IDE to write and check the code before sending it to the ESP32. During the coding process, IDE is used to check every sensor to know if it functions properly. The proponents tested all sensors using the proper library in Arduino IDE to ensure all sensors are accurate in giving exact data to help the system manage the threshold . Modules are also tested in the coding phase to see if it is working properly. The proponents ensured all designated sensors on every microcontroller were working correctly and ready to upload in the designated microcontroller (ESP32).

The proponents used React Native to create the mobile application, a JavaScript framework and open-source tool capable of creating apps for numerous platforms, including iOS, Android, and web applications. For the database, the proponents used a free web-based database like Firebase, enabling the storage and real-time synchronization of data between users. Utilizing the internet as a network, it allowed the mobile application and prototype to connect.

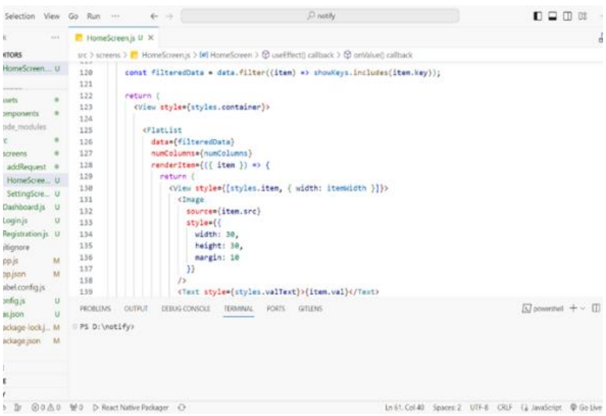

Figure 5. Creating Mobile Application

In Figures 5, proponents built and improved the mobile application using Visual Studio, an IDE for developers. To keep user info safe, proponents used Firestore from Firebase. This ensures that user data is stored securely and can be easily accessed when needed. Real-time database in firebase for handling sensor data specifically its real-time database feature. It helped the user to keep track of sensor info and make sure the mobile app responds quickly.

The proponents tested all sensors using the proper library in Arduino IDE to ensure all sensors are accurate in giving exact data to help the system manage the threshold . Modules are also tested in the coding phase to see if it is working properly. The proponents ensured all designated sensors on every microcontroller were working correctly and ready to upload in the designated microcontroller (ESP32). The proponents used an online database to store the confidential information of the user, such as email and password. The mobile application gets and sent data from the Firestore database. The proponents used another type of database in Firebase (real-time database) to store the project's data, The mobile application sent and received from Firebase and ESP32 sent data (sensor data) to Firebase.

Figure 6. Proponents testing the Smart Hybrid Aquaponic System.

Figure 6 shows the proponents conducted a full system test to identify and address any issues before implementing the project. Once the prototype's reliability was confirmed, owners were informed, and stakeholders tested it to provide feedback. The deployment phase started with a briefing of the project prototype to the stakeholders. All the modules and sensors are integrated and in the designated area. After testing the entire system, the proponents presented the project to the aquaponic owner for demonstration and testing of the proposed project.

Figure 7. Farm Owner testing the project

The proponents present the project to Dr. Westly R. Rosario, the farm owner of 457 FishTech Philippines Inc., located at 457 Tapuac Rd. Dagupan, Pangasinan, along with their employee. Figure 49 shows the proponents discussing every type of sensor that is used in the proposed project. The proponents also presented the features and how the project works such as automatic dispensing of the nutrient and pH solution. The proponents also discussed the temperature and humidity sensor that can determine the temperature of the environment. Additionally, the EC sensor can determine the amount of nutrient solution in the water, and the turbidity sensor used to determine clarity in the water. LCD and buttons were also used where users can monitor and configure the system if the internet is not available. LED light increases the temperature of the environment. The fan serves as the cooling medium when the temperature of the environment increases to the maximum of the threshold. The water temperature sensor used to maintain the water temperature based on the threshold. The peristaltic pump is used as a medium to supply nutrient solution. Solenoid valve serves as water separator in hydroponic. the proponents introduced the project to the employees of the farm. They discussed how the mobile application works and to know how to get access to able configure the threshold of the system. The proponent discussed the different type of operating modes of the proposed project.

5. RESULT, CONCLUSIONS, AND RECOMMENDATIONS

Table 1. Farm Owner, and Employee evaluation result.

Farm Owner	100 %
Employee	100 %
Total	**100%**

With the computation, the project's effective rate is evaluated at 100% by the owner and his employee. The survey results for both the owner and his employee indicate that the project was efficient, reflecting positively on the overall success and productivity of the project.

However, the project acknowledges certain limitations and suggests several avenues for future development. One promising direction is the integration of alternative hydroponic techniques within the aquaponic system to optimize harvest scheduling and provide timely notifications. Additionally, further research is recommended to explore additional factors that could potentially boost crop production. These advancements not only promise to refine the current system but also pave the way for broader applications and improvements in sustainable farming practices in the future.

6. ACKNOWLEDGMENTS

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