Automated Aquaponics System to Support Sustainable Development Goals

Preprint · January 2022

3 authors:

Muhammad Razin Basar
Universiti Kuala Lumpur - Malaysian Institute of Information Technology (UniKL MIIT)

Aznida Abu Bakar Sajak
University of Kuala Lumpur

Muhammad Suzarilshah bin Zakaria
University of Kuala Lumpur

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Muhammad Razin Bin Basar
Computer Engineering
MIIT, Universiti Kuala Lumpur
Kuala Lumpur, Malaysia
razinbasar@gmail.com

MuhammadSuzaril Shah bin Zakaria
Computer Engineering
MIIT, Universiti Kuala Lumpur
Kuala Lumpur, Malaysia
suzarilshah@gmail.com

Shafina Mohamed Salleh
Computer and Network Engineering
Gerik Vocational College
Kuala Lumpur, Malaysia
shafina.salleh@moe.edu.my

Aznida Abu Bakar Sajak
Computer Engineering
MIIT, Universiti Kuala Lumpur
Kuala Lumpur, Malaysia
aznida@unikl.edu.my

Abstract—**The project's ultimate goal is to construct an automated aquaponics system that will aid in the implementation of sustainable development goals around the world. Aquaponics systems have received great interest in recent years because of their ability to minimise resource demand while also improving food products, such as vegetables and fish, particularly during Covid-19, when the industry is experiencing difficulties. Water-based aquaponics is a mix of hydroponics and aquaculture that replicates the natural environment to successfully apply and develop natural cycle understanding within an indoor environment. As a result of this understanding of natural cycles, it was possible to design a system that had capabilities comparable to those of a natural environment but with the added benefit of electrical modifications that increased the system's overall efficiency. It is discussed in this thesis how the solution was developed, which includes the overall design, prototype, and several sensors that were used to monitor the system, which included fish and plants, how technology was used to provide the best water quality for the fish, and what potential advantages there are to the current market.**

Keywords—Internet of Things (IoT), Sustainable Development Goals (SDG), Blynk, Arduino

I. INTRODUCTION

The Sustainable Development Goals (SDG) are the blueprint for achieving a better and more sustainable future for all. They address the global challenges we face, including poverty, inequality, climate change, environmental degradation, peace, and justice [1]. With the help of Industrial 4.0 technology, these goals can be achieved faster. Some work had been done to achieve those goals where the Internet of Things (IoT) was used been published in [2-6]. From all the 17 goals, goal no 11 focus on Sustainable Cities and Communities. There needs to be a future in which cities provide opportunities for all, with access to basic services, energy, housing, transportation and more. The UN food agency, FAO, warned that hunger and fatalities could rise significantly in urban areas without ensuring that poor and vulnerable residents have access to food [1]. This paper suggests that one way to ensure there is no shortage of food in the urban cities is to implement Aquaponics systems using the Internet of Things technology in the housing areas because of their ability to help reduce resource demand while also enhancing food products, such as vegetables and fish.

Moreover, the popularity and practicality of urban farming are increasing, and techniques such as aquaponics are becoming more significant for sustainably ensuring food security. Aquaponics reflects the natural ecosystem in which it is practiced. Aquaponics is the study of the link between water, aquatic life, bacteria, nutrient dynamics, and plants that grow close to one another in waterways across the world. Aquaponics, which takes its cues from nature, harnesses the power of bio-integrating these individual components: transforming the waste by-product from the fish into food for the bacteria, converting it into the perfect fertilizer for the plants, and re-circulating the water back to the fish healthily and safely.

This farming method has numerous advantages over the conventional farming method, including reducing land and water use by 90 per cent compared to the conventional farming method. Increasing social capital and civic participation in low-income neighborhoods are the most significant benefits of urban farming, and these are the most noticeable benefits. In addition, the exchange of knowledge, cultural values, and gardening skills that are learned via gardening serves as a social bridge, assisting in preserving food traditions and customs. Using vertical farms, greenhouses, and hydroponics to grow crops in urban areas has provided urban farmers with novel ways to produce crops. However, these technologies can be significantly more energy-intensive than more traditional agricultural methods. Nonetheless, if correctly implemented, urban farming can contribute to the overarching objective of decreasing human impacts on the climate and strengthening food system resilience, as outlined in SDG Goal No. 11: Reduce Human Impacts on the Climate and Build Food System Resilience. To counteract climate change and its consequences, immediate action must be taken.

This project aims to design and construct a smart aquaponics system that can combine fish farming with plant development in a cost-effective manner. Water quality monitoring and regulation are accomplished by using a variety of sensors and actuators, as well as microcontrollers and microprocessors throughout the device. On the other hand, the initial experiment did not include sensors for the concentrations of soluble solids, ammonia, nitrate, and pH levels. Therefore, more functions and upgrades to the system are proposed in this project, including an automatic sensor for ammonia and pH levels in the tank, which will help to alleviate the problem.

To summaries, aquaponic systems have the potential to address a wide range of sustainability issues in the agricultural field, most notably the ability to generate high yields with minimal additional nutrients while also significantly reducing nitrogen discharge and water depletion from aquaculture operations. This prototype will serve as a starting point for Internet of Things (IoT) applications in aquaponic systems to simplify work and develop a more comprehensive way to aid those working in the agriculture industry.

II. METHODOLOGY

The section on research methodology includes step-by-step instructions for completing the project successfully. The success of the project may be ensured by using an appropriate methodology for the monitoring system. This section will describe how to explain the selected approach, as illustrated in Fig. 1, along with how it will be utilized to develop a prototype. Furthermore, the outcome will be addressed to collect as much information regarding water quality as possible utilizing all available sensors. Using the 5W1H question-and-answer framework, the model identified issues and defined goals, after which it presented those aims and challenges (What, Who, Where, When, Why and How). To make this project more controllable and versatile, certain enhancements and the combining of numerous procedures from this model will be put into place.

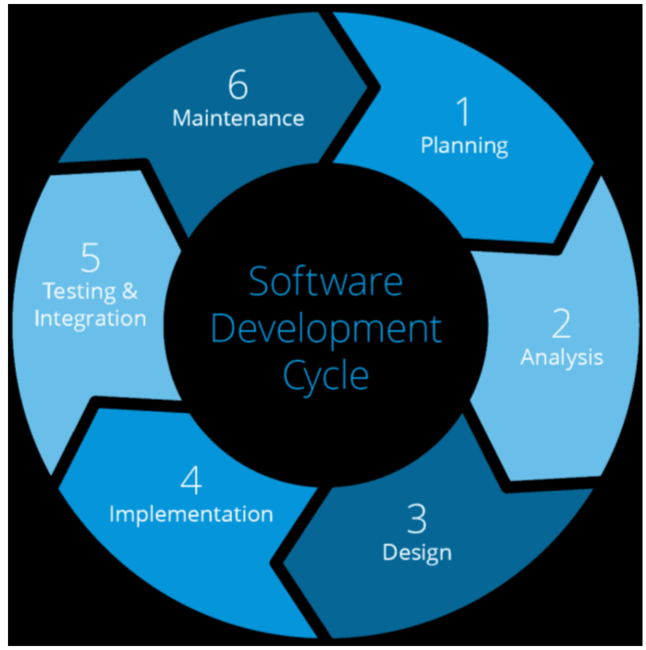

Fig. 1. Iterative Agile model

A. Initiate and Planning

Begin conceptualizing ideas, the need to incorporate some futures to transform the current project into a more manageable framework that can be implemented and improved in terms of showcasing the key plan, which is to contribute to the achievement of sustainable development goals. Identifying all new futures that can be introduced into the aquaponic ecosystem is also a part of this procedure. This process has multiple steps, including developing a research strategy based on any relevant gaps, existing expertise, and research methods. To provide a better method to move this project forward to the following phases, all content from journals, books, and the internet will be collected.

Title	Automated Indoor Aquaponics Cultivation Technique	Autonomous Aquaponics Systems using 6LoWPAN based WSN	IoT based Aquaponics Gardening Approaches
Author	M.F. Saaid, N. S. M. Fadhil, M.S.A. Megat Ali, and M.Z.H. Noor	N Hari Kumar, Sandhya Baskaran, Sanjana Hariraj, and Vaishali Krishnan	Aishwarya, K. S., Harish, M., Prathibhashree, S., and Panimozhi, K.
Year	2013	2016	2018
Purpose	Evaluating the recirculation of Aquaponic systems when assessing the growth efficiency of a comet goldfish symbiotically positioned with spinach.	Discovered that ammonia from fish waste would lower pH to 7.2, while the ecology needs a pH range of 5.8 to 6.0 under normal conditions	Aquaponics utilizing Internet of Things technologies and building an integrated system with the aid of a few sensors interfaced with a microcontroller.
Result	Deduce that ammonia and nitrates impact on fish development	Monitor the amount of nitrate, they suggested using three sensors: temperature, pH, and a nitrate sensor	The automated water supply's second function is that it provides water to the plants. Plants need a certain volume of specific nutrients for growth

Fig. 2. Literature Review Research

B. Design

The sort of project, the design of the documentation, and the project's compatibility with all other standards are important considerations to make.

This design phase has to identify some criteria that could be computed and accommodate Aquaculture ecology, for example, if the project design process is complete. This would pose a danger during the construction of the prototype testing phase. Following that, a list of all hardware and software resources required to trigger the prototype was likewise compiled and distributed.

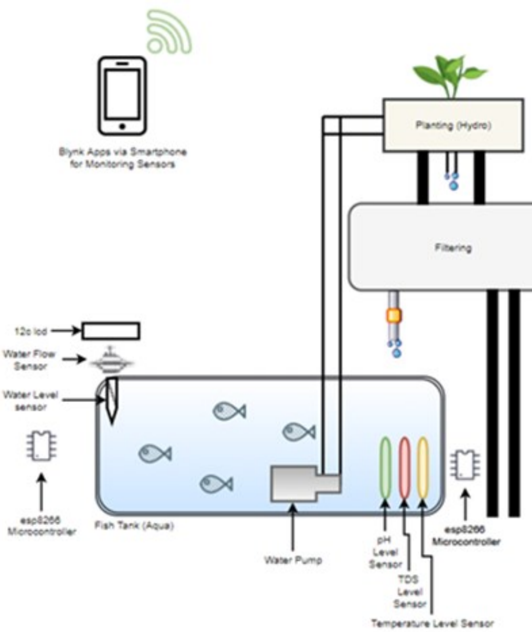

Fig. 3. Prototype Design

C. Implementation

The development and implementation of the idea would be a further step in the project's execution and growth cycle. It would be a significant component of bringing the idea to fruition. Before deciding which sensor to use, it is necessary to identify all of the accessible parameters. The pH level and the ammonia level are the measures that need to be made in the water. The water filter at the top of the system is equipped with a sensor that monitors the tank's health. The water is then filtered through the plant roots. Sensor hardware sensors, such as water, pH, and TDS sensors, were employed before the design and parametric calculations could be completed.

The characteristics and options for managing the agitating aquaponic environment will be available through mobile applications produced by Blynk.

Fig. 4. Prototype Setup

D. Testing

The project was tested to identify any defects in the system. Each of the connected sensors was tested whether it is working properly. Any defects found in the system were fixed and tested again to ensure that the defects were fixed. Testing process also will do and take all data from calculated parameters have been analyzed in this iteration to discover trends in automatic Aquaponics systems when testing is observed into the smart aquaponics system when it comes to smart aquaponics systems. This ensures the objectives are achieved. Blynk was able to take the TDS level, EC level, PH level and also the Temperature level. All the value will be store through the email via CSV.

Fig. 5. Blynk Setup

E. Deployment

In order to improve system quality assurance, the user community is actively involved in receiving regular reviews of system modifications. Users can keep an eye on the app regularly and report defects to the software developers for specific applications, updates, and patches that may even be present in the development environment at the time of reporting. By automating repeated activities, it will increase the efficiency of deploying and redeploying while utilising this inventory.

III. HARDWARE AND SOFTWARE

The hardware and software, as represented in Table I, are required for the successful completion of this project. This stage covers the project's goals, needs, specifications, and the tooling and software used in the project. This phase is critical for gathering project information that will be used to advance to the next phase.

TABLE I. HARDWARE AND SOFTWARE

	Item	**Unit**
Hardware	NodeMCU ESP8266	3
	TDS Level Sensor	1
	Analog pH Sensor	1
	Temperature Sensor	1
	Water Flow Sensor	1
	LCD 12C	1
	Water Pump	1
Software	Arduino IDE	-
	Blynk	-
	Email	-
	Draw.io	-

A. NodeMCU ESP8266

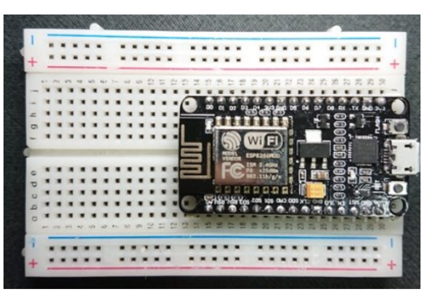

Fig. 6. NodeMCU ESP8266

The ESP8266, commonly known as the NodeMCU (Node Microcontroller Unit), would be an open-source software and hardware development platform. It has a wifi module that has a SOC with an integrated TCP/IP protocol stack, and it also features a wifi module. A network connection for this microcontroller is made possible by this. This microcontroller will be the hub for all of the sensors that have been used. Sensors may communicate with an application using the ESP8266, which allows them to send and receive data. Data can be transmitted and received by all sensor modules since they all function as transceivers.

B. TDS Level Sensor

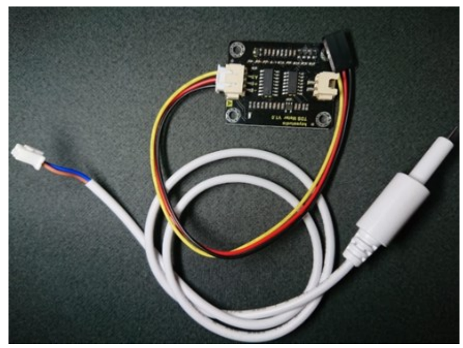

Fig. 7. TDS Sensor

Inorganic and organic materials can be measured and monitored using a Total Dissolved Solids (TDS) sensor.

- VCC = 5V pin
- GND = GND pin
- GPIO = A0

TDS will display two types of data: a TDS value in the range 0-1000ppm, which indicates the value of solids (nitrate and ammonia), and an EC (Electric Conductance), which indicates the strength of nutrient concentrations for plants and animals.

C. Temperature Sensor

Fig. 8. Temperature Sensor

A temperature sensor with waterproof sensor monitoring is included in this version 2 of the device. It is also possible to use it in high temperatures of up to 125 degrees Celsius.

- VCC = 3.3V pin
- GND = GND pin
- GPIO = D5

When using a DS18B20 digital temperature sensor, a 4.7 Ohm resistor must be used in conjunction with it. It is connected to the microcontroller by connecting it to the voltage (VCC) and signal pins. Listed below are the pins that were used to connect with the ESP8266 microcontroller.

D. Analog PH Sensor

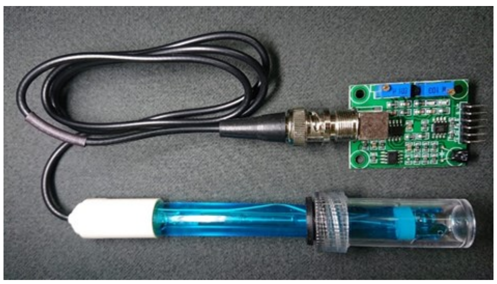

Fig. 9. Analog PH Sensor

Water's acidity or alkalinity is measured using a pH sensor, which ranges from 0 to 14 in terms of its value.

- VCC = 5V pin
- GND = GND pin
- GPIO = A0

The pH value is vital for the health of both plants and fish for them to grow. Some further points: the pH of clean water is 7. Water is considered acidic if its pH value is less than 7, whereas water with more than seven is considered alkaline. Normally, the pH range for surface water systems is from 6.5 to 8.5, while the pH range for the underground water system is from 6 to 8.5.

E. Water Flow Sensor

Fig. 10. Water Flow Sensor

This sensor can display both the quantity and speed as used in connection with the ESP8266 microcontroller.

- VCC = 5V pin
- GND = GND pin
- GPIO = D6

This is a mechanical component that was added to the prototype. The water flow sensor is used to determine the speed of the water flow that enters the tank and the amount of water that has been filled to fill up the tank. According to this sensor, the moving fan will rotate in response to the flow of water, and the voltage used to stimulate the conductor will be measured together with the fan rotation.

F. LCD 12C

Fig. 11. LCD 12C

This LCD screen is a part of an additional mechanical component that synchronizes with the water flow sensor.

- VCC = 3.3V pin
- GND = GND pin
- SCL = D1
- SDA = D2

It is used to display the amount of water in the fish tank and the rate at which the water is being pumped into the tank by the fish. By stating that, the LCD is designed to show the results of the measurements.

G. Water Pump

Fig. 12. Water Pump

The water pump, which ensures continuous water flow from the fish tank into the hydroponics, is already located at the top of the fish tank. This is required to ensure a consistent level of water quality. They use the nutrients from the fish waste as fertilizer for the plants in the plant tray, which serves as a hydroponics system. The water is filtered from the top before returning to the fish tank, and the water flow is designed to provide constant oxygen for the fish. This will allow the fish to thrive while the plants receive nutrients and live in a healthy environment without pesticides. 5V is the required water pump suitable for the size of the tank used for this project.

H. Blynk

Fig. 13. Blynk Application

A database is needed to ensure the data received can be collected and processed, and Blynk, as shown in Fig. 13, is the best choice for this. The user accessed the Blynk application via smartphone to register and create their own dashboard to display all the requirements needed. As well as Arduino IDE as an open-source software to Programme all the microcontroller based on sensor that connected.

```
#include <Blynk.h>
#include <ESP8266WiFi.h>
#include <BlynkSimpleEsp8266.h>

char auth[] = "mqdbP9QFluwUa0KXw9Q8WEL0jLBopneX";
char ssid[] = "AYANG";                        // Your
char pass[] = "";
```

Fig. 14. Code For Blynk

Fig. 14 shows how to connect the microcontroller by including all libraries, connect the esp8266, which includes a built-in wifi module into the code, and link the code together using Blynk applications. To establish a connection between Blynk and the microcontroller, firsty is to configure the authentication token provided by Blynk apps and send it to email address. Afterwards, configure the SSID (service set identifier), the name associated with an 802.11 wireless local area network (WLAN), which can be accessed through a home network or a hotspot.

IV. RESULT AND DISCUSSION

Project Data

Created_at	TDS	EC	TEMP	PH
24/10/2021 19:02	72	0.178	26.94	6.59
24/10/2021 19:03	73	0.18	26.94	6.59
24/10/2021 19:05	73	0.18	26.93	6.59
24/10/2021 19:07	72	0.178	26.93	6.59
24/10/2021 19:08	72	0.178	26.94	6.59
24/10/2021 19:10	72	0.178	26.94	6.59
24/10/2021 19:12	71	0.172	26.94	6.59
24/10/2021 19:13	70	0.171	26.94	6.59
24/10/2021 19:15	72	0.178	26.94	6.59
24/10/2021 19:17	72	0.178	26.94	6.59

Fig. 15. Project Data

Fig. 15. displays the findings obtained from the sensor and recorded in the database of the channel. Each column in Fig. 15 had five rows. When the data was collected, the first column should provide the precise time that it was collected. "TDS" stands for dissolved solids, and it is involved of ammonia and nitrate, which were measured in the data.

Next, there was an "EC," and the information was for the nutritional strength. In the third column. It is followed by the letter "TEMP," which stands for "temperature level." The final column had the value "PH," obtained from the pH sensor's readings.

According to the graphic outputs intended to be exhibited and measured, the project data had been divided into various categories. This instrument provides data on the total dissolved solids (TDS), electrical conductivity (EC), temperature, and pH value. Each one of the results was recorded within 15 minutes of the event taking place in general.

A. Results

Fig. 16. TDS Level vs Time

The reading from the TDS sensor is represented in the figure above by a Blynk graph and a numeric number. The sensor data is visualized as a blue bar graph versus time, whereas the digital method makes TDS value data from smartphones easier for people to understand and interpret.

In this graph, the total soluble solids of the water are represented on the x-axis, while time is represented on the y-axis. The TDS number indicates the consistency of the soluble solids in the fish tank after two weeks of 15-minute sessions with the fish tank. In general, the base level for TDS value is between 50 to 150 parts per million (ppm).

The value of the tap water in the fish tank is 49 parts per million (ppm) on the first day of installation of this prototype. In comparison, the value is approximately 72 parts per million (ppm) after two weeks of operation of the prototype. The substances in the systems, such as fish waste and plant fertilizers, are responsible for the value growth. Based on the value, it can be concluded that the water is still in good condition and is suitable for the growth of both fish and plants.

Fig. 17. EC Level vs Time

An additional type of data produced by a TDS sensor is the measurement of the value of the Electric Conductance (EC) level, which reflects the nutrient strength for both fish and plants. The reading depicts the EC value of the water in the fish tank after two weeks of deploying the prototype, which contains fish and baby Pak choi in the process of growing.

A red shadowgraph is created from the graph to show the sensor data versus the passage of time. Although the digital approach is meant to make EC data from smartphones more useful for users, it is not without its limitations. The EC value in the water is represented on the x-axis, while the passage of time is represented on the y-axis. In this case, the value is consistent in the range of 0.15 to 0.20 mScm2, and to conclude that the plant and fish received sufficient nutrients to grow healthily.

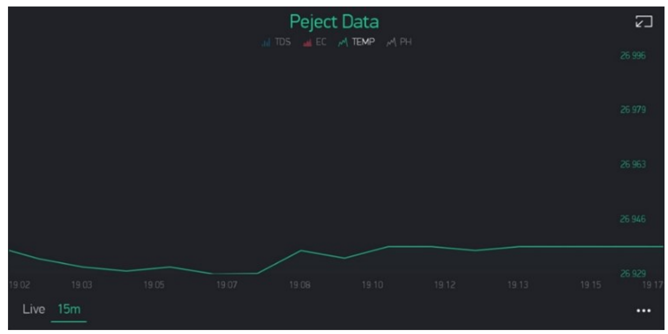

Fig. 18. Temperature vs Time

The figure shows a Blynk graph and numeric output of the temperature sensor reading due to the temperature sensor observation. A green line graph is used to illustrate the sensor data versus the change of time. However, the digital approach is intended to make temperature data from smartphones more helpful for users.

The x-axis represents the temperature of the water, and the y-axis represents the passage of time. The temperature trend has remained consistent during the 15-minute testing period, making it optimal for the growth of both the fish and the plant.

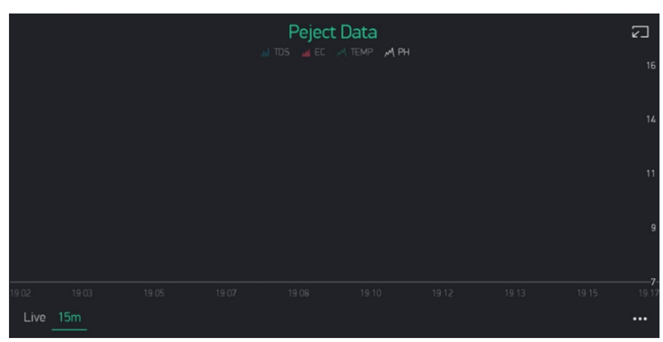

Fig. 19. PH Level vs Time

The reading from the pH sensor is represented in the figure above by a Blynk graph and a numeric number. A white line graph illustrates sensor data as it changes over time, whereas the digital approach makes pH data from smartphones easier for people to understand.

The pH of the water is represented on the x-axis, and the time is indicated on the y-axis of this graph. The pH value reflects the consistency of the solution of 6.59, and it is in the range of 6.0-8.0. Plants require slightly acidic pH levels of 6.0 to 6.5, but fish prefer pH levels ranging from 6.0 to 8.5, according to the National Institute of Standards and Technology.

As a result, this demonstrates that the pH of the water in the tank is balanced with the requirements of active bacteria in this aquaponics system to provide needed nutrients for the plant to grow.

B. Analysis

Threshold for Water Quality

Thresholds		
	General	Result
TDS LEVEL (ppm)	50 - 150	71-73
EC LEVEL (mScm2)	0.15 – 0.2	0.17-0.18
TEMPERATURE (°C)	30	26
PH LEVEL	6.5 – 8.5	6.59

Fig. 20. Threshold for Water Quality

The threshold readings for the Blynk data, collected in tabular form, are depicted in Figure 19. The optimal dissolved solids concentrations are between 50 and 150 parts per million (ppm) [14]. Besides the TDS sensors detecting dissolved solids, including ammonia and nitrates, the sensors also detect the presence of EC values, which indicate the number of nutrients available for fish and plants to grow in a healthy environment.

The recommended value for EC is 0.15 to 0.2 $mScm^2$, depending on the application. According to the table, the TDS sensor readings for dissolved solids levels are between 71 and 73, while the EC readings are between 0.17 and 0.18, which are ideal values. To strengthen the accuracy of the TDS sensor's output, the pH value must be accurate and within the range of the threshold required to preserve water quality. The pH level should be between 6.5 and 8.5 for the fish and plants to remain in the best possible condition, provided that the water contains sufficient nutrients [13]. When it comes to the reading taken, there is consistency for the pH value of 6.59, and it is also consistent with the temperature of 26°C, which is a condition of room temperature. When the readings fall within defined ranges, the farmer or user is not required to take any action. They will only act if the sensor's reading falls outside of the recommended range.

When the prototype is used, the result obtained is within the acceptable threshold range and is suitable for both the fish and plant. In addition, both the fish and the plant received adequate nutrients, demonstrating that the prototype can produce nutritious and clean food based on the outcome of the project and the food produced.

V. CONCLUSION

Aquaponic systems can address a wide range of sustainability issues in the agricultural field. Smart Aquaponics Systems are an SDG-friendly initiative that can alleviate the need for food production. Aquaponics allows for the simultaneous cultivation of plants and fish in a single system, saving time and money on logistics and making it one of the most efficient farming systems compared to other methods.

There are numerous advantages to using an aquaponics method rather than either aquaculture or a hydroponics system on their own. The sharing of expenses for parts and the repurposing of waste materials from one device to another reduces the need for further nutrient supplementation, resulting in a reduction in the overall water consumption of the entire system. As a result, the food distribution system becomes more environmentally friendly.

Besides, this prototype will serve as a starting point for Internet of Things (IoT) applications in aquaponic systems to simplify work and develop a more comprehensive way to aid the agriculture industry. The project demonstrates that technology can be integrated with aquaponics, automating duties such as pumping fish's wastewater into the plant tray, allowing the plant to benefit from the nutrients, and cleaning the water for the fish to drink and also got to monitor all the data to get the best water quality for the fish and plant.

A new detailed Internet of Things technical report defining the guiding principles and mechanics from a regulatory aspect has been deemed necessary to assist Malaysia's rollout and acceptance of IoT technology. In this age of rapid technological growth, the Internet of Things (IoT) provides insights into how individuals might incorporate technology into their daily life. Because the Internet of Things provides important information that can apply in various ways, it is being used worldwide, including in Malaysia. However, while it has many advantages, it also has drawbacks and obstacles when utilizing it in various businesses.

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