

AQUAPONICS PH VALIDATION USING ARTIFICIAL INTELLEGECE

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ABSTRACT

This study explores the use of Artificial Intelligence (AI) to improve pH monitoring in an aquaponic system that combines aquaculture and hydroponics to create a symbiotic environment for fish and plants. Aquaponics offers the benefits of sustainable agriculture, with optimal water quality, particularly pH levels, critical to ecosystem health. The purpose of the study is to develop the prototype of aquaponic pH validation that supports AI integration, and pH verification through sensors. The development of an aquaponic prototype using AI with sensor and Blynk apps used in pH validation. The pH sensor functions effectively and shows the optimal pH level in each water sample taken. The higher the water temperature the higher the pH level. The average pH reading is 7.37 and 7.47 by weekly monitoring which complied the average pH level according to National Water Quality Standard (NWQS) for Malaysia which is 6.5 to 8.5. The integration of Artificial Intelligence (AI) in aquaponics for pH monitoring has demonstrated significant potential in enhancing system stability and sustainability. An AI-supported aquaponics system with real-time pH monitoring, managed through Blynk apps has successfully achieved the objectives.

1. Introduction

Aquaponics is a sustainable farming method that integrates the growing of plants without soil (hydroponics) and the raising of fish (aquaculture) into a mutually beneficial ecosystem. In aquaponics, the essential source of nutrients for plant growth comes from the nutrient-rich water of the fish tank. It creates a symbiotic relationship between fish, plants, and beneficial

microorganisms. This sound system promotes efficient use of resources minimizes waste production and enables sustainable use of water and nutrients aligned with Sustainable Development Goals (SDGs). The 2030 Agenda for Sustainable Development, adopted by all United Nations Member States in 2015, provides a common framework for peace and prosperity for people and the planet, now and in the future. The importance of pH level in water is related to SDG 6: Clean Water and Sanitation.

A study by Wang et. al (2023) suggests that pH has a significant impact on plant performance and yield in both aquaponic and hydroponic systems and that, like hydroponics, a pH of 6 is desirable for aquaponic systems to improve plant crop yield without compromising nitrification activity and fish yield. To measure the effects of pH in an aquaponic system, experiments were conducted using aquaponic setups at three different pH levels (6.0, 6.5, and 7.0), alongside a hydroponic system for comparison. Swiss chard (*Beta vulgaris* L.), kale (*Brassica oleracea* L.), mustard greens (*Brassica juncea* L.), cilantro (*Coriandrum sativum* L.), lettuce (*Lactuca sativa* L.), and arugula (*Eruca vesicaria* L.) were cultivated alongside tilapia (*Oreochromis niloticus*). The study found that variations in pH did not impact feed conversion ratio, fish biomass, or the abundance of ammonia-oxidizing bacteria (AOB). However, a lower pH in aquaponic systems resulted in increased fresh and dry mass, as well as higher nutrient levels in all tested plant species.

Maulini et. al (2022) developed a solution to monitor the state of water with pH, ammonia and temperature sensors based on the Internet of Things (IoT). The Arduino plays a role in tracking changes in temperature, pH, and ammonia as a data processing subsystem reader for the pH probe sensor, DS18B20 temperature sensor, and MQ135 sensor. It is used as monitoring parameters, pH sensors to detect the acidity of water, temperature sensors for temperature measurements, the MQ135 gas sensor for ammonia and ESP8266 as a WLAN interface to send data to Android without using actuators. The pH, temperature, and ammonia data were compared with existing literature as reference measurement data. Temperature sensor calibration was performed using a mercury thermometer as the reference, while pH calibration was conducted using buffer solutions with values of 4 and 7. Ammonia (NH₃) calibration was based on the MQ135 datasheet.

The application of Industry 4.0 (4IR) technology to pH measurement involves the integration of advanced sensors and IoT systems to enhance agricultural also practices in vertical farming as explained by Hinojosa-Meza et. al (2022). The implementation of a cost-effective and portable instrument, that enables accurate pH measurements for global Vertical Farming (VF) applications, has been described. The design of the instrument has a limitation on analogue to digital conversion (ADC), with a minimum detectable value of 0.028 pH units, and a typical absolute accuracy of ± 0.062 pH units. It can be overcome with the implementation of an AI algorithm to detect and compensate for mechanical instabilities of the instrument, and to incorporate other critical sensors, such as total dissolved solids meters, for VF applications that will be included in the future.

One of the challenges regarding 4IR was the limited research and commercialization of IoT technologies. There was a need for more research and development focused on the commercialization of IoT technologies specifically tailored for aquaponics. It included identifying which parameters could be controlled, monitored and predicted to reduce manual

labour, and establishing performance metrics for aquaponics to increase understanding of the process (Reyes Yenes, 2020).

According to Channa et. al (2023), aquaponics is a complex ecosystem that demands multidisciplinary expertise, continuous monitoring of critical parameters, and significant initial investment and maintenance costs. Key factors such as dissolved oxygen (DO), ammonia levels, pH, temperature, and sunlight exposure must be carefully managed. To tackle these challenges, AI and IoT have emerged as essential technologies. Recent studies have increasingly explored their application in automating processes, enhancing efficiency and reliability, improving system management, and reducing operational costs.

Maintaining optimal pH levels in aquaponics is essential for aquatic life. Fish generally grow in a pH range of 6.5 to 8.5 according to the National Water Quality Standard for Malaysia while plants typically perform best in a slightly acidic to neutral range. Deviations from these ranges can stress the organisms, impacting growth and nutrient uptake. Adjustments to pH levels can be made by adding safe buffering agents to maintain stability, especially in systems with fluctuating water sources. Monitoring pH regularly, particularly in new or highly stocked systems, ensures that conditions remain balanced, as pH levels can shift with temperature or water changes. The pH level based on the water classes and uses can be referred to in Table 1 and Table 2 as published by the Department of Environment (DOE).

Table 1: National Water Quality Standards for Malaysia (2020)

PARAMETER	UNIT	CLASS					
		I	IIA	IIB	III	IV	V
Ammoniacal Nitrogen	mg/l	0.1	0.3	0.3	0.9	2.7	> 2.7
Biochemical Oxygen Demand	mg/l	1	3	3	6	12	> 12
Chemical Oxygen Demand	mg/l	10	25	25	50	100	> 100
Dissolved Oxygen	mg/l	7	5 - 7	5 - 7	3 - 5	< 3	< 1
pH	-	6.5 - 8.5	6 - 9	6 - 9	5 - 9	5 - 9	-
Colour	TCU	15	150	150	-	-	-
Electrical Conductivity*	µS/cm	1000	1000	-	-	6000	-
Floatables	-	N	N	N	-	-	-
Odour	-	N	N	N	-	-	-
Salinity	ppt	0.5	1	-	-	2	-
Taste	-	N	N	N	-	-	-
Total Dissolved Solid	mg/l	500	1000	-	-	4000	-
Total Suspended Solid	mg/l	25	50	50	150	300	300
Temperature	°C	-	Normal + 2 °C	-	Normal + 2 °C	-	-
Turbidity	NTU	5	50	50	-	-	-
Faecal Coliform**	count/100 ml	10	100	400	5000 (20000) ^a	5000 (20000) ^a	-
Total Coliform	count/100 ml	100	5000	5000	50000	50000	> 50000

Table 2: Water Classes and Uses

CLASS	USES
Class I	Conservation of natural environment. Water Supply I – Practically no treatment necessary. Fishery I – Very sensitive aquatic species.
Class IIA	Water Supply II – Conventional treatment required. Fishery II – Sensitive aquatic species.
Class IIB	Recreational use with body contact.
Class III	Water Supply III – Extensive treatment required. Fishery III – Common, of economic value and tolerant species; livestock drinking.
Class IV	Irrigation
Class V	None of the above.

2. Materials and Methods

2.1 Aquaponic Prototype Development Phase

In the design phase, the design selected to execute the project is the Nutrient Film Technique (NFT). This design was chosen because of the functionality and efficiency of the lifecycle of the system. The frame was built with multiple joints and fittings such as L elbow and T joint. For the tray of the plant pot, a 4-inch diameter PVC pipe was used to hold up the plant pot for both levels. Three holes were drilled for each pipe to contain the plant's pot. The end cap was used to close the end of the pipe. Figure 1 shows the development of the project during the early stages.



Figure 1: Prototype in NFT design

A pipe of 22 mm was used to connect the tray for both levels and to the main tank. The use of PVC pipe over rubber pipe is to ensure the rigidity of the materials and to avoid any leaks. Figure 2 shows the completion of the aquaponics setup without the module attached.



Figure 2: Prototype of aquaponic pH validation

2.2 Component in AI Sensor

Materials and components used to build the sensor control board are quite easy to access for the public and quite affordable. The list of each component is summarized in Figure 3.

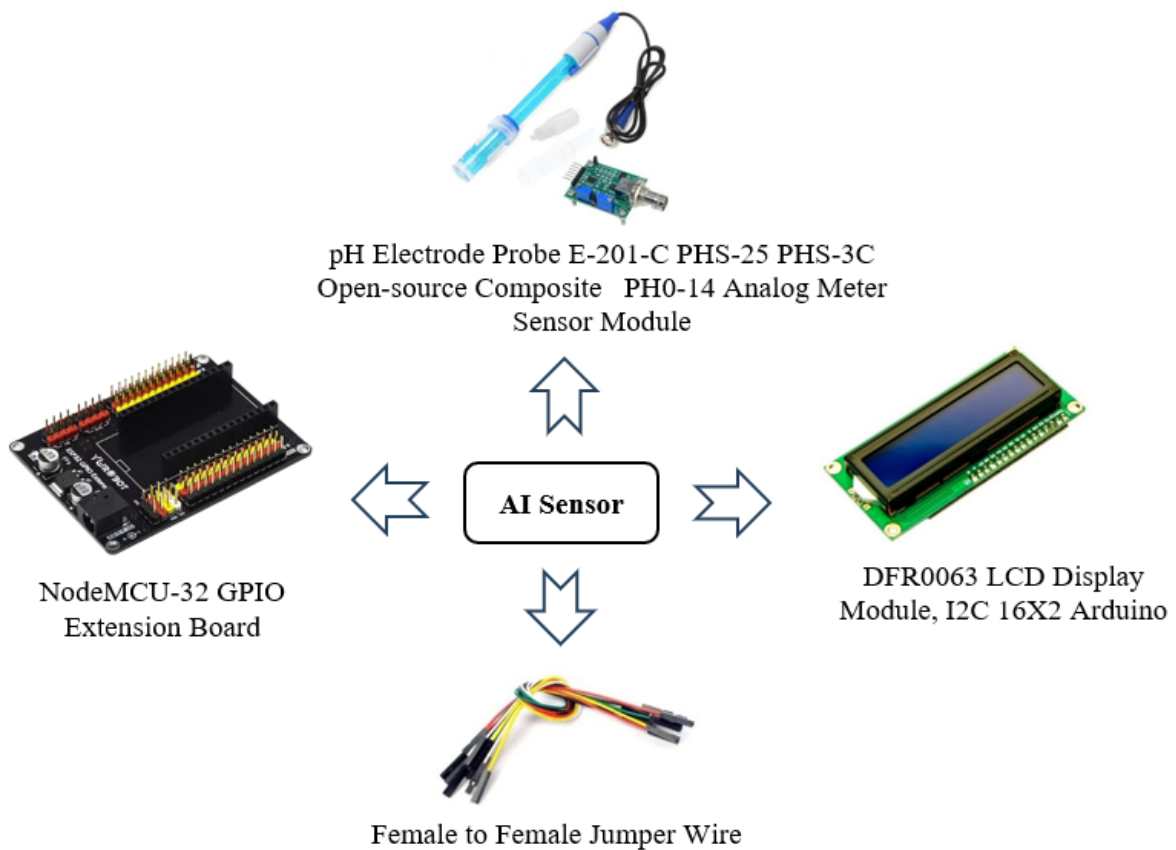


Figure 3: Components in AI Sensor

2.3 AI Sensor Development Phase

Developing the control board is a crucial part of the project. A lot of consideration must be taken to the details for each component and item used in the project. Thus, each step requires a thorough process to ensure the outcome of the control board works properly. The installation process is as follows:

- i. Connect all the components and ports using jumper wire. Use a portable power bank to power up the module which consists of NodeMCU-32 GPIO Extension Board, PH Electrode Probe E-201-C PHS-25 PHS-3C Open-source Composite, PH0-14 Analog Meter Sensor Module and DFR0063 LCD Display Module. Figure 4 shows the main component of the module.

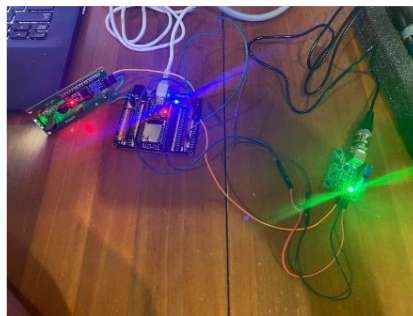


Figure 4: Connection between components

- ii. Once the components are properly linked, the board should be uploaded with coding to ensure functionality according to project specifications. Coding is uploaded from a laptop and transferred to the board using a Universal Serial Bus (USB) cable. All coding for the module was uploaded using the Arduino IDE.
- iii. Run a test to ensure the module and pH sensor running appropriately according to the initial plan. The dish soap water is used to test the sensor, and the result is 4.11 which is acidic. After the probe of the sensor has been dipped into the dish soap water, rinse it with clean water before putting it back into the buffer sample. The reading of the sensor turns back to 7 which shows the calibration of the pH sensor is correct and passed the test phase. Figure 5 shows the process of testing the pH sensor.



Figure 5: pH sensor testing process

- iv. Arrange all the items within the junction box and attach the Female-to-Female Jumper Wire. Tape the wire securely to ensure that it does not detach when moving the junction box. Drill an adequate size hole in front of the junction box to insert the LCD display into place. Drill holes on both sides of the junction box to connect the pH sensor and the power supply. Figure 6 depicts the entire sensor module.



Figure 6: Complete set of the AI sensor module

2.4 Blynk Application Development Phase

The Blynk app was used in the project to help consumers monitor their projects even from far away. It is a powerful and user-friendly Internet of Things (IoT) platform that simplifies the process of building connected applications for controlling and monitoring devices remotely. It enables developers to create IoT solutions without requiring extensive programming or technical expertise. The platform comprises a mobile app, a cloud service, and libraries for integrating with microcontrollers such as Arduino, ESP32, and Raspberry Pi.

Users can design custom dashboards using widgets to display data, control devices, or receive notifications in real-time. The platform supports various communication protocols, including Wi-Fi, Bluetooth, and Ethernet, making it versatile for a wide range of IoT projects. The procedure will be explained step by step as follows:

- i. Download Blynk apps in the App Store or Google Play on your device as in Figure 7.



Figure 7: Blynk apps

- ii. Insert coding based on the interface that was chosen in the initial plan. Insert coding according to requirements in the application and setting up the User Interface (UI) layout. Figure 8 shows the coding that has been uploaded to the board into Arduino IDE.

```

1 #define BLYNK_TEMPLATE_ID "TPID000000000"
2 #define BLYNK_TEMPLATE_NAME "AQUAPONIC SYSTEM"
3 #define BLYNK_AUTH_TOKEN "LHG5j9rgkztimwDkLmZmoyci"
4
5 #define BLYNK_PRINT Serial
6 #include <BlynkEsp8266.h>
7
8 #include <Wire.h>
9 #include <LiquidCrystal_I2C.h>
10
11 LiquidCrystal_I2C lcd(0x27, 16, 2);
12
13
14 #define PI_OFFSET -10.00
15
16 #define SensorPin 34
17 unsigned long int expValue;
18 float b;
19 int buff[10], temp;
20
21
22 char ssid[] = "kulim";
23 char pass[] = "123456789";
24
25 BlynkTimer timer;
26
27
28
29 void setup()
30 {
31   lcd.init();
32   lcd.backlight();
33
34   Blynk.begin(BLYNK_AUTH_TOKEN, ssid, pass);
35
36   timer.setInterval(10000, sensor);
37
38
39

```

Figure 8: Coding in Arduino IDE

- iii. Set up the Blynk apps interface with gauge and chart in the menu with the necessary colour to help differentiate the pH level. Figure 9 shows the layout of the Blynk apps.

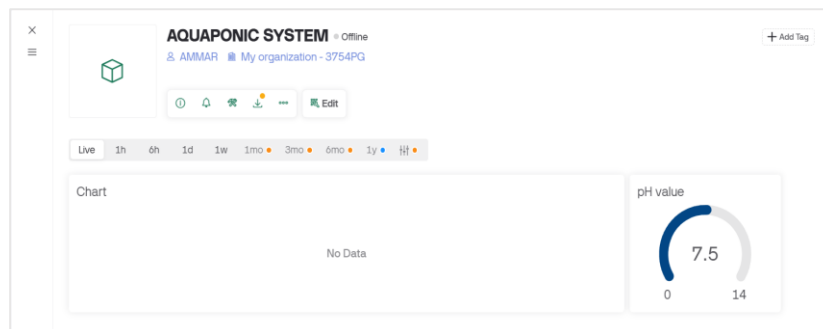


Figure 9: Layout in the Blynk apps

2.5 Prototype Testing Phase

The testing phase plays a critical role in ensuring the quality, performance, and user satisfaction of the integrated aquaponics pH validations using AI. The testing phase verifies that all components operate according to specifications, performance testing assesses system efficiency and reliability, and user testing provides valuable feedback on functionality and satisfaction. These phases require many details to ensure that the data that were extracted are accurate.

3 Discussion

Data was gathered over two weeks using sensors designed to monitor and validate pH levels in the aquaponics system. The sensors with custom coding, provided real-time pH readings and ensured continuous monitoring for optimal water conditions.

Based on Table 3, shows that the monitoring was done at three different times of the day which are morning, mid-day and afternoon. The pH level in each week presents the most similar reading. It indicates that the aquaponic system has consistency in the reading. It across both weeks ranged between 7.2 to 7.6, reflecting a stable pH level with minimal fluctuations.

Table 3: pH level in two weeks monitoring

Week	Date	Time (24hr)	pH level	Average pH level
1	21 Oct 2024	8:00	7.2	7.37
	23 Oct 2024	12:00	7.5	
	25 Oct 2024	16:00	7.4	
2	28 Oct 2024	8:00	7.3	7.47
	30 Oct 2024	12:00	7.6	
	1 Nov 2024	16:00	7.5	

The average pH level for week 1 is 7.37 while in week 2 is 7.47. However, the pH levels rise slightly during the day, but the current dataset does not provide sufficient evidence to confirm any variations. The dataset also presented in line chart as Figure 10 to see the fluctuation. The consistency of pH level illustrates the good water quality without any significant variations over time.

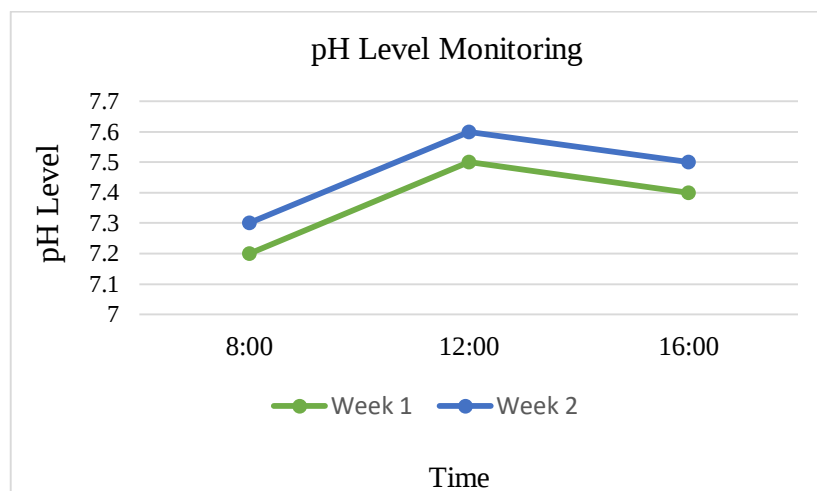


Figure 10: pH level

The ideal pH level is in the range of 6.5-8.5 according to NWQS. If the pH in a water body is too low or too high, it can stop the growth rate and disturb aquatic life. Sudden changes will cause negative effects on aquatic life because it can stress the ecosystems which leads to hatching and survival rates reduction (Fondriest, 2025).

4 Conclusion

This study highlights the effectiveness of using Artificial Intelligence to monitor pH levels in aquaponics systems. Through the integration of Blynk apps, real-time data collection and monitoring allowed for consistent pH control, which is essential for the health of aquatic life. The AI-enabled system brought significant operational advantages by reducing manual monitoring requirements, which increased the system's overall efficiency and reliability. However, several factors were considered in assessing the system's performance. Sensor placement, for example, influenced the accuracy of pH readings, as did environmental fluctuations in temperature and water quality. These variables can impact pH stability and emphasize the need for strategic sensor calibration and placement.

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