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Optimizing Arowana Fish Breeding with IoT Aquaculture

Agus[1], Suryadiputra Liawatimena[2], Gilang Wiranda[3], Diki Arisandi[4*]
[1]Computer Science Department, Binus Graduate Program, Bina Nusantara University, 11480 Jakarta, Indonesia
[2]Computer Engineering Department, Faculty of Engineering, Bina Nusantara University, Indonesia 11480 Jakarta, Indonesia
[3]Master of Applied Computing Department, Politeknik Caltex Riau, Pekanbaru, Indonesia
[4]Faculty of Information Science and Technology, Multimedia University, Melaka 75450, Malaysia.
e-mail: [1]agus001@binus.ac.id, [2]suryadi@binus.ac.id, [3]gilang@alumni.pcr.ac.id, [4*]diki@univrab.ac.id

Abstract

Monitoring and controlling water temperature and pH levels are crucial aspects in maintaining a healthy environment for breeding Arowana fish. Arowana fish are sensitive to fluctuations in water temperature and pH levels, which can lead to stress, diseases, and even death. Therefore, it is essential to regularly monitor and maintain the temperature and pH levels within suitable ranges for the fish. This study aims to develop Internet of Things (IoT) technology that is expected to assist Arowana fish farmers in monitoring and controlling more effectively and practically. The methodology employed in this study is a case study approach, with Arowana fish farmers as respondents. In monitoring the water quality for Arowana fish, many farmers still rely on traditional farming models that heavily depend on experience, lacking the ability to assess water quality and environmental changes scientifically. By utilizing LoRa and cellular technologies, this study provides intelligent solutions for water quality monitoring to create controlled and sustainable growth conditions. The ultimate outcome of this research is the development of an IoT-based application designed to enhance the efficiency of Arowana fish farming. This application involves automatic control of water pH and temperature in three different treatments. The methodology employed in the application design involves the development of an IoT-based system integrated with temperature and pH sensors. The functionality of the application includes real-time monitoring and automatic control of the aquarium environment. Testing was conducted through a series of field trials to ensure system performance and reliability. With a pH range of 6.5 - 7.5 and temperature range of 26 - 30°C, this application has proven to provide optimal responses for Arowana fish farming, enhancing growth and reducing feeding time.

Keywords: *IoT, Arowana, Temperature, pH, Sensors.*

1. Introduction

Temperature and water pH monitoring and control are critical factors in the success of Arowana fish farm breeding [1]. Arowana are tropical fish, and their growth and health depend on maintaining a stable water temperature within a narrow range of 26-30°C. Any significant fluctuations in water temperature can lead to stress, reduced appetite, and even death in the fish [2]. Hence, constant monitoring and control of water temperature are necessary to ensure a stable environment for Arowana fish growth and survival. In addition to temperature control, water pH monitoring and control are equally crucial for Arowana fish farm breeding [3]. Arowana fish are sensitive to changes in water pH levels, and any fluctuations can cause stress and illness in the fish. High or low pH levels can affect the fish's immune system, making them more susceptible to diseases and infections. Hence, maintaining a stable water pH level within the range of 6.5-7.5 is essential for Arowana fish farm breeding [4]. Regular monitoring and control of water pH levels can help prevent diseases and reduce the risk of fish mortality, leading to healthier fish and higher profitability for the fish farm [5].

The golden-red Mahato arowana fish is a prehistoric species that is on the verge of extinction if not preserved. In its 2012 annual report, the World Living Natural Resources Conservation (IUCN) lists the Golden-red Mahato arowana fish as one of the endangered fauna. One method for preserving the arowana fish population is to conduct captive breeding under government supervision by issuing special permits [6]. However, arowana captive breeding in Indonesia is experiencing issues with its water temperature and pH monitoring system, even though water temperature and pH are critical parameters to monitor in captivity activities. Water temperature and pH have a significant impact on arowana fish survival [7]. The pond environment's temperature will affect the fish's digestive and immunological systems. The optimal temperature in the breeding pond ranges from 26 - 30 °C, with no substantial fluctuation in temperature between day and night [5]. When provided food, the fish will respond optimally, and its immune system will likewise function well. Temperatures above 30°C make fish slow to move and allow parasites such as fungus and bacteria to proliferate and infect fish quickly, but temperatures below 26°C led fish to lose their appetite and damage their immune system. While the recommended pH range is between 6.5 and 7.5, fish will grow optimally in that range [8].

The traditional temperature monitoring process for fish farm breeding, including arowana, typically involves the use of digital thermometers and pH meters that are placed in the water tanks or ponds where the fish are being raised [9]. These devices provide real-time readings of the water temperature and pH levels, which are crucial factors for the health and growth of the fish. The temperature and pH levels are usually monitored multiple times a day, and adjustments are made to the heating or cooling systems, as well as to the addition of chemicals or other treatments, as needed to maintain optimal conditions for the Arowana fish. Some advanced systems may also include automated sensors and controllers that can adjust the temperature and pH levels automatically, based on pre-set parameters and data analysis [10].

The latest approach to monitor the Temperature and water pH is by utilizing the IoT [11]. IoT, or the Internet of Things, refers to the network of physical devices connected to the internet [12], that can collect and exchange data [13]. Some research on monitoring temperature and pH for fish breeding using IoT has been done before. Periyadi conducted a previous study in which researchers utilized Arduino as a microcontroller and connected it to a temperature sensor and turbidity sensor for control using a pump and relay as ON/OFF and carried out the experiment in a closed container such as an aquarium [14]. Huan Conducted the research by developing aquaculture informatization and monitor aquaculture ponds based on the narrow band internet of things (NB-IoT) technology. This system provides remote collection and data storage of multi-sensor processor information, as well as intelligent control and centralized management of breeding ponds. The system uses STM32L151C8 microcontroller and sensor terminal real-time acquisition, such as temperature, pH value, dissolved oxygen [15]. Another research regarding fish breeding monitoring is conducted by Hang by proposing a blockchain-based fish farm platform to ensure agriculture data integrity. The designed platform aims to provide fish farmers with secure storage for preserving the large amounts of agriculture data (temperature, pH, and oxygen) that cannot be tampered with. Diverse processes of the fish farm are executed

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automatically by using the smart contract to reduce the risk of error or manipulation [16]. Saha performed a system to monitor the water quality of aquaculture utilizing Raspberry Pi, Arduino, various Sensors, Smartphone Camera, and Android application. Android phone is used as the terminal device to monitor the water condition using an android application through Wi-Fi and Internet [17]. Kim develops the thermal energy management system of warm water energy that is utilized in a fish farming system based on Internet of Things (IoT). This research proposed to build a smart fish farming system that has the function of sensing and monitoring by several sensors such as oxygen, temperature, pH, and water level. It also provide a close loop water flow control in the aquarium which are controlled by microcontroller and supported by Message Queue Telemetry Transport (MQTT) protocol on the mobile application or website application [18].

Previous studies have identified several flaws, such as researchers failing to consider that water temperature is greatly influenced by the sun, temperature, weather, and climate, and that only using aquarium media in a closed room will not significantly affect the existing water temperature; additionally, researchers must consider including the pH sensor is an important sensor in monitoring water quality. To address the shortcomings, the researchers developed and designed a more practical and effective water quality monitoring and control system through case studies conducted directly in fishponds. The Arduino Uno microcontroller was utilized in this study to monitor and manage the temperature and pH of the water. The NodeMCU board will be connected to the DS18B20 temperature sensor and the PH4502C pH sensor, and data from the sensors will be transferred directly to the Blynk platform in real-time. The system constructed can measure pH on a scale of 0 to 14 and temperature on a scale of -10°C to 100°C, sensor measurement results may be displayed in the form of data or graphics on a monitor or smartphone, and SMS notifications can be sent using the gateway system, for self-control, it makes it simple to accomplish it automatically or manually by pressing on the prepared Blynk platform.

While the literature review provides overview of previous studies on monitoring temperature and pH for fish breeding using IoT, there are gaps identified in the existing research. Firstly, prior studies often neglect external factors such as sunlight, weather, and climate, which significantly influence water temperature. Additionally, the focus on closed-room aquarium environments may not accurately reflect real-world conditions in fishponds. Furthermore, while some studies have addressed pH monitoring, there is a need for a more integrated approach that combines both temperature and pH monitoring. The proposed solution aims to bridge these gaps by developing a practical and effective water quality monitoring and control system specifically designed for fishponds. By utilizing the Arduino Uno microcontroller and NodeMCU board, the system enables real-time monitoring of both temperature and pH levels. This integrated approach offers a more comprehensive understanding of water quality and provides fish farmers with actionable insights for maintaining optimal conditions for fish growth and health.

2. Research Methods

This research was conducted directly in the arowana fish breeding pond of PT. Aquafam Jaya Lestari, Karya Indah Village, Tapung District, Kampar Regency, Riau Province. This pond has been operating for about 2 years in an area of around 10.000 square meters and consists of 16 ponds with 12x23M for each pond and a total number of broodstock of around 200 fish. This location was chosen purposefully because it is one of the arowana fish breeding locations that has a permit from the Ministry of Marine Affairs and Fisheries.

We design the whole proposed monitoring and control in the form of block diagram as seen in figure 1. The Sensor will interface with the microcontroller NodeMCU ESP32 that acts as an open-source IoT platform. It will send the data to cloud storage which is the Blynk server that has been developed to store the data and information. Arduino IDE is a programming language that supports library for Blynk that connects to hardware over Wi-Fi. Blynk application is a platform with IOS and Android apps to control NodeMCU ESP32 through its inbuilt Wi-Fi shield. It can display digitalized information data from the sensor.

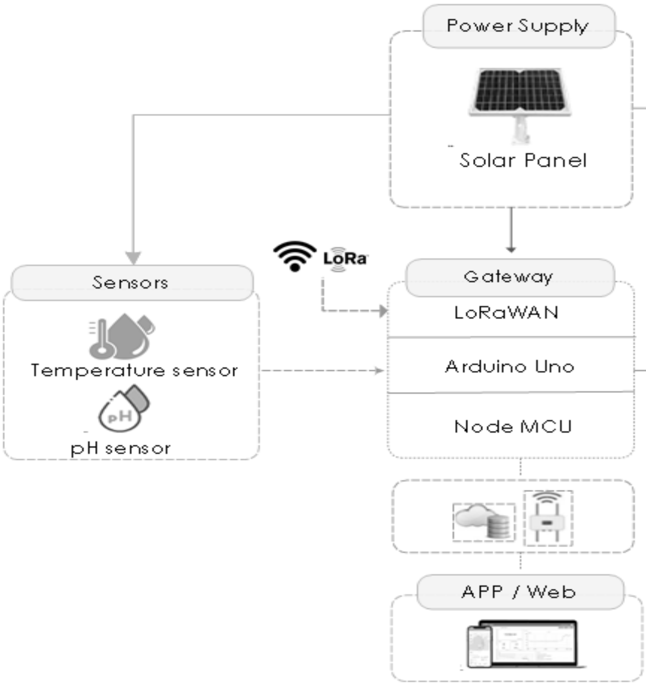

Figure 1. The Whole Block Diagram of Minitoring and Control System

Apart from the block diagram, we also design the connection diagram as seen in figure 2. In an IoT-based temperature and water pH monitoring and control system for an Arowana fish farm breeding, the sensor module collects data on temperature and water pH levels, which is then transmitted to the gateway module that serves as a bridge between the sensors and the Blynk cloud platform. The Blynk cloud receives the data and provides a user-friendly interface for the fish farm manager to monitor the conditions remotely and adjust as necessary. The actuator, such as a water pump or heater, can be controlled through the Blynk app to adjust the temperature or pH levels automatically based on the readings received from the sensors, all through the gateway module.

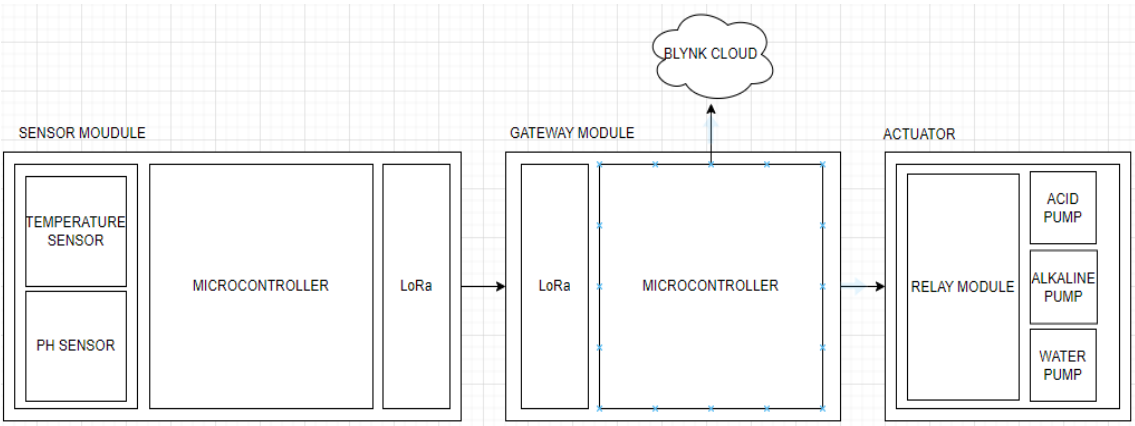

Figure 2. Connection Diagram

Figures 3 and 4 show the flowchart of the Gateway module and sensor module. The flowchart starts by having two sensors (temperature and pH), then the procedure started with the

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connection of a temperature sensor (DS18B20) and a pH sensor (PH4502C) to NodeMCU (ESP32). The data was then saved to a cloud database. NodeMCU will read the database to verify the Temperature and pH sensor values, and the outputs will apply the following conditions: If the pH is more than >7.5 (alkaline), the alkaline pump will activate and drain the liquid prepared to decrease the pH of the water from water drums. If the pH of the water is < 6.5 (acidic), the acid pump will activate and drain the liquid from water drums, which has been prepared to raise the pH of the water. In this circumstance, the aerator will also be activated to generate air bubbles and oxygen in the air to diffuse into the pool water and improve the pH of the water.

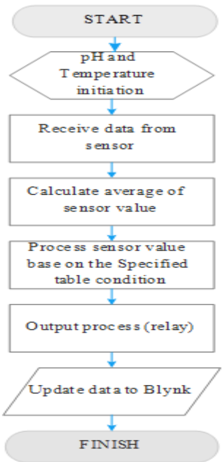

Figure 3. Gateway Module Flowchart

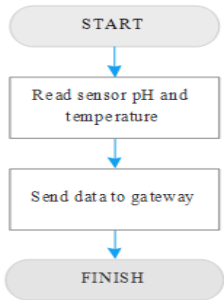

Figure 4. Sensor Module Flowchart

3. Results

3.1. Hardware Development

The connection process is handled by NodeMCU ESP32, which is a development board featuring the popular ESP32 Wi-Fi chip. As it turns out, it can program the ESP32 just like any other microcontroller. Its obvious advantage over the Arduino or PIC is that it can readily connect to the Internet via Wi-Fi. The NodeMCU solves this problem by featuring 10 GPIO pins each capable of using PWM, I2C and 1-wire interface problem by featuring 10 GPIO pins each capable of using PWM, I2C and 1-wire interface.

The information of the arowana fish farm breeding ponds generated by the pH sensor and tempreature sensor. To evaluate the pH status, we use an Analog pH sensor to measure water whether is acidic or alkalinity. The pH scale is a logarithmic scale whose range is from 0 – 14 with a neutral point being 7. The value above 7 indicates an alkaline solution and values below 7 would indicate an acidic solution. It operates on a 5V power supply, and it is easy to interface with NodeMCU. The optimal pH range for fish is 6.5 to 7.5. Low and high pH level harms fish, especially the young fish in immature stages because they are extremely sensitive to pH levels. We leverage a waterproof sensor (DS18B20) to estimate the temperature of its surroundings. Most of the functions in this development are sensing variables in water, thus the DS18B20 being waterproof helps in detecting the temperature of water without being damaged. It can measure extreme temperatures from -55 °C to 125 °C with very good accuracy. The normal range temperature for fish is 26 °C to 30 °C.

3.2. Software Development

First, we use Fritzing as a simulation tool. Fritzing is used to design the circuit beforehand and is used for simulation before transferring it onto hardware. Second, as a microcontroller programming kit, we use Arduino IDE, as a software which is an open-source software used to implement software development. It is used to write and upload programs to Arduino compatible boards, but also, with the help of third-party cores, other vendor development boards. This software allows interference between nodeMCU and the sensors. The language used for this software is C++. The codes were programmed by using Arduino software. Third, for graphical interface, we use Blynk. This software also links the data in the microcontroller to the smartphone. For this project, the Blynk application connected with nodeMCU to the cloud using a Wi-Fi connection.

3.3. pH Sensor Testing

The pH sensor's output is in analog form, which is subsequently translated to a digital voltage of 3.3V. The output voltage is then transformed back into a pH value. This sensor was tested by comparing the results of direct measurements in the breeding pond between the pH 4502C sensor and a pH-Meter. This test was carried out by gathering data from up to ten samples. The sample collected is the pH sensor 4502C value and the pH Meter value used to calculate the comparison of the pH sensor 4502C value with the pH Meter of the water. The data in Table 1 show that the pH sensor (PH4502C) has an accurate result of 98.70%.

Table 1. The Comparison of Test results Between pH Sensor (4502C) and pH Meter

pH Measurement with pH Meter	pH Measurement with pH Sensor	Error %
6.60	6.70	1.52
6.63	6.74	1.66
6.70	6.82	1.79
5.00	5.12	2.40
6.80	6.87	1.03
6.82	6.85	0.44
6.84	6.94	1.46
7.80	7.95	1.92
7.43	7.48	0.67
7.41	7.42	0.13

Based on the table 1, There are several factors that can cause deviations between test results obtained from a pH sensor and a pH meter. Some of the most common factors during this research include different calibration procedures between pH Meter and pH sensor, different temperature samples, and electrode quality from the pH samples.

3.4. Temperature Sensor Testing

The temperature sensor output results are digital, allowing them to be viewed directly without being transformed. This sensor was tested by obtaining samples for 10 days and comparing the results between the DS18B20 sensor and a water thermometer. The sample is the difference in temperature between the DS18B20 sensor and a water thermometer. The comparison of the results provided by the DS18B20 sensor with a water thermometer is determined through sampling data collecting. According to the statistics in Table 2, the temperature sensor (DS18B20) has an accuracy rate of 98.10%.

Table 2. The Comparison of Test results Between Temperature Sensor (DS18B20) And Digital Infrared Thermometer

Temperature Measurement with Digital Infrared Thermometer (ºC)	Temperature Measurement with DS18B20 Sensor (ºC)	Error %
27.90	28.20	1.08
27.40	27.70	1.09

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Temperature Measurement with Digital Infrared Thermometer (°C)	Temperature Measurement with DS18B20 Sensor (°C)	Error %
28.00	28.50	1.79
24.00	24.20	0.83
29.00	30.90	6.55
27.90	28.20	1.08
26.90	27.30	1.49
32.00	33.20	3.75
28.60	28.90	1.05
28.50	28.80	1.05

According to table 2, Several factors may lead to differences in test results obtained from a DS18B20 temperature sensor and a digital infrared thermometer. Among the most common factors are: different calibration procedures between Temperature Sensor and digital infrared thermometer, distance between the thermometer and the object, emissivity of the object, and interference from other objects or substances in the environment.

3.5. Overall System Testing

This phase aims to test the input from the sensor, whether it matches with the output on a computer or android device. The outcomes are the results of monitoring data sent by nodeMCU and then displayed on a computer or Android screen as shown in Figure 5. We also verify the response of the actuator to the information provided from the temperature sensor or pH sensor, with the expectation that the actuator works by responding to the aerator and water pump automatically. All testing conditions shown as table 3 based on the pH and temperature sensor value to actuator status.

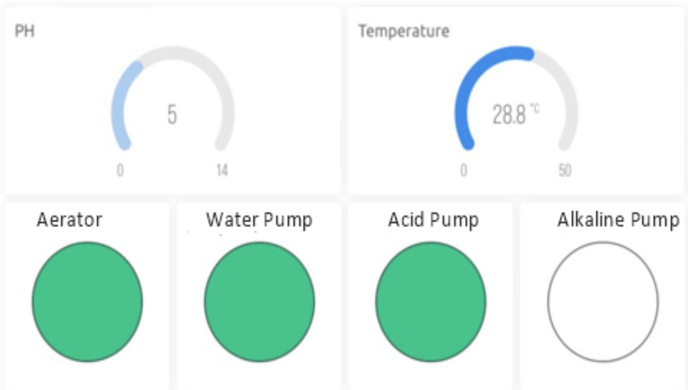

Figure 5. Display of pH and temperature From the Sensors

Table 3. The Test of Actuator Status

pH	Temperature	Actuator Status
<6.5	<25°C or >30°C	Aerator ON, Pump Drum-1 ON, Water-Pump ON
<6.5	26-30 °C	Aerator ON, Pump Drum-1 ON
6.5 – 7.5	26-30 °C	ALL Actuator OFF
>7.5	<25°C or >30°C	PUMP Drum-2 ON, Water-Pump ON
>7.5	26-30 °C	PUMP Drum-2 ON

The data is displayed using the Blynk Platform that has been prepared. The Blynk platform is used to monitor Temperature and pH in real-time during tests. The Temperature and pH values were compared for 10 days to three treatments, namely A (pH below 6.5 and temperature below 26°C), B (pH between 6.5 - 7.5 and temperature between 26 - 30°C), and C (pH above 7.5 and temperature above 30°C). All the condition requires diffrerent feeding responses for arowana breeding ponds as seen in table 4.

Table 4. The Test of Actuator Status

Treatment	pH	Temperature	Feed Amount	Fish Response To Feeding
A	<6.5	<26ºC	0.5 Kg	Less Optimum
B	6.5 – 7.5	26-30 ºC	1.0 Kg	Optimum Feeding
B	>7.5	>30 ºC	0.5 Kg	Less Optimum

The data is displayed using the Blynk Platform that has been prepared. The Blynk platform is used to monitor Temperature and pH in real-time during tests. The Temperature and pH values were compared for 10 days to three treatments, namely A (pH below 6.5 and temperature below 26°C), B (pH between 6.5 - 7.5 and temperature between 26 - 30°C), and C (pH above 7.5 and temperature above 30°C). From the data taken in Table 4 which was carried out for 10 days (Monday – Sunday – Wednesday), the best treatment for arowana fish is treatment A pH 6.5 – 7.5 and temperature 26 – 30°C. This is because, in this treatment, arowana fish swim nimbly and feed as much as 1 kg of feed after each feeding for a duration of 2 times a day in the morning and evening resulting in the optimum weight of the arowana fish being maintained. Treatment B has a pH of 5 - 6 and a temperature of 20 - 25°C, which is why on day 4 (Thursday), the treatment causes the arowana fish to flutter above the surface of the pond due to a lack of oxygen, which can cause a decrease in the fish's breathing rate and heart rate so that if conditions worsen, the fish will faint. In this condition, the fish do not respond well to feeding; half of the 1 kg of feed given is consumed. As a result, the fish's growth is suboptimal. The C treatment with pH 7.5 - 10 and temperature 31 - 35 is not ideal since on day 8 (Monday), high temperatures might lower oxygen levels, causing fish to lose appetite and, in the long run, affecting fish development and reproduction. Only half of the 1kg food is spent, resulting in a less optimal fish response to feeding.

4. Discussion

The findings of this study highlight the significance of accurate pH and temperature measurements for achieving optimal water quality in fishpond environments, crucial for the health and productivity of aquaculture systems. The pH sensor testing results (Table 1) demonstrate a high level of accuracy, with the PH4502C sensor yielding a result of 98.70%. This underscores the reliability of the sensor in accurately measuring pH levels. However, discrepancies between the pH sensor and pH meter readings could be attributed to factors such as different calibration procedures, temperature variations, and electrode quality. These findings underscore the importance of proper calibration and consideration of environmental factors when utilizing pH sensors for water quality monitoring in aquaculture.

Similarly, the temperature sensor testing results (Table 2) reveal a high accuracy rate of 98.10% for the DS18B20 sensor. Despite the accuracy, variations between the temperature sensor and digital infrared thermometer readings may occur due to factors like calibration procedures, distance between the thermometer and the object, and environmental interference. These findings emphasize the need for meticulous calibration and control of environmental variables to ensure accurate temperature measurements for effective fish farm management.

The results of our research demonstrate significant advancements over previous studies in several key areas. Traditional methods of temperature and pH monitoring in fish farms, such as

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those described by Periyadi and Huan, typically relied on closed-room aquarium environments and basic microcontroller setups like Arduino for data collection and control. Our study extends these methodologies by implementing the NodeMCU ESP32, which offers enhanced connectivity via Wi-Fi and superior integration capabilities for real-time data transmission. This upgrade allows for more efficient and accurate monitoring in open fishpond environments, addressing the limitations noted in earlier studies where external factors like sunlight, weather, and climate were often neglected.

Furthermore, previous research by Hang and Saha has incorporated IoT technologies for monitoring water quality, focusing primarily on individual parameters like temperature or pH in isolation. Our integrated approach using the NodeMCU board, coupled with both the DS18B20 temperature sensor and the PH4502C pH sensor, ensures a comprehensive assessment of water quality. The accuracy rates of 98.10% for the temperature sensor and 98.70% for the pH sensor in our study are comparable to or exceed those reported in earlier research, indicating robust performance under real-world conditions. This dual-parameter monitoring system not only ensures optimal conditions for Arowana fish but also demonstrates improved responsiveness and reliability, enhancing the practicality of IoT-based solutions in aquaculture.

Our findings align with Kim's development of a smart fish farming system that leverages IoT for automated monitoring and control. However, our research goes further by testing the system directly in fishpond environments rather than controlled aquarium settings. This approach provides a more accurate reflection of practical aquaculture conditions. Additionally, the implementation of the Blynk platform for real-time data visualization and remote control via smartphones enhances user interaction and operational convenience. The success of our system in maintaining optimal pH and temperature conditions for Arowana fish, as evidenced by the improved feeding and growth rates, underscores the effectiveness of integrated IoT solutions in addressing the complex requirements of fish farming.

In summary, our research builds upon and refines previous methodologies by incorporating advanced microcontroller technology, comprehensive environmental monitoring, and real-time data management. These enhancements not only address the gaps identified in earlier studies but also offer practical benefits for fish farmers, such as increased efficiency, accuracy, and ease of use. This integrated approach marks a significant step forward in the application of IoT in aquaculture, paving the way for more sustainable and effective fish farming practices.

5. Conclusion

Based on the results of testing and analysis of the Internet of Things (IoT)-based monitoring system for Temperature and pH in arowana fish farming, the following conclusions can be drawn: 1). The IoT-based monitoring system for temperature and pH in arowana fish farming has been completed and can be effectively managed to provide the most suitable environment for fish living. 2). Since fish can be monitored in real-time, the failure rate of cultivator output may be decreased; 3). Blynk platform can be used to monitor data on built-in control systems; 4). The results of a comparison test between the temperature sensor and a water thermometer and the pH sensor and a water pH-Meter revealed no significant difference and a high degree of accuracy. For future development, it will be developed for testing in all ponds with the addition of several sensors such as sensors for measuring oxygen levels and water turbidity.

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