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IMPLEMENTATION OF INTERNET OF THINGS (IOT) FOR TEMPERATURE AND HUMIDITY CONTROL IN WATER SPINACH (IPOMOEA AQUATICA) CULTIVATION

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Abstract

Kangkung (water spinach) cultivation requires a stable environmental condition to ensure optimal growth, especially in terms of temperature and humidity. In Tangerang Regency, the annual average temperature ranges from 24°C to 32°C with humidity between 73% and 93%, which aligns well with kangkung's ideal growing temperature of 25°C–30°C. This research designs an automated system based on the Internet of Things (IoT) integrated with an aquaponics concept to control temperature, humidity, and water quality in kangkung cultivation. The system employs a waterproof DS18B20 temperature sensor to measure water temperature, a DHT11 sensor for ambient temperature and humidity, and additional pH, TDS/EC, and turbidity sensors to monitor water quality. Water level is detected using an HCSR-04 ultrasonic sensor. All data is transmitted in real-time through an ESP8266-01 module and can be monitored via LabVIEW on a laptop or through a smartphone. The system also includes an automatic water pump, solenoid valve, and a servo-based auto feeder for the fish. Experimental results indicate the system maintains environmental stability with an average temperature reading error of ±0.5°C and humidity error of ±0.776%. This smart monitoring and control system significantly improves efficiency, accuracy, and the overall quality of kangkung cultivation, especially in tropical climates. The integration of IoT in this aquaponic system offers a sustainable and environmentally friendly solution for modern urban agriculture.

Keywords: ***IoT, Water Spinach, Aquaponics, DS18B20, Arduino, ESP8266***

INTRODUCTION

Modern agriculture faces significant challenges in maintaining stable environmental conditions, especially in the cultivation of horticultural crops such as water spinach (Ipomoea aquatica). Water spinach is widely cultivated in Indonesia due to its economic and nutritional value. However, its growth is highly dependent on stable temperature and humidity. In Tangerang Regency, the average annual temperature ranges from 24°C to 32°C with humidity between 73% and 93%. While this range generally aligns with the ideal growing conditions for water spinach (25°C–30°C), fluctuations in tropical climate conditions still pose a risk to plant quality and productivity if not managed systematically (Putra & Sari, 2021).

The urgency of this initiative lies in the need for smart farming systems that can address the challenges of sustainable and efficient urban agriculture. Conventional farming often suffers from limitations in manpower, time, and monitoring tools, making it difficult to control environmental variables in real-time. Thus, a technology-based solution is essential to measure, control, and report cultivation conditions automatically and accurately. This activity aims to design and implement an Internet of Things (IoT)-based temperature and humidity control system for water spinach cultivation using an aquaponic approach. The system also integrates water quality sensors (pH, TDS/EC, and turbidity) and an automatic fish feeding mechanism to support the aquaponic ecosystem. With automated control, the environmental quality for plant growth can be maintained optimally without the need for continuous manual intervention. The problem-solving plan utilizes IoT technology, including a DS18B20 sensor for water temperature, a DHT11 sensor for ambient temperature and humidity, and an HCSR-04 sensor for water level detection. The system is controlled by an Arduino microcontroller and ESP8266-01 module, enabling wireless data transmission to a monitoring interface on LabVIEW. Additional automation components such as a water pump, solenoid valve, and servo motor-based fish feeder are also employed. A review of related literature shows that IoT integration in agriculture significantly improves efficiency and production quality. According to Zhang et al. (2020), the implementation of digital sensors in aquaponic systems enhances environmental monitoring and can increase crop yield by up to 20%. This reinforces the rationale that this project provides a practical solution with real impact for advancing smart agriculture in urban settings. Through this approach, the community service activity is expected to contribute to the development of environmentally friendly, efficient, and future-oriented water spinach cultivation systems in Indonesia.

LITERATURE REVIEW

The integration of the Internet of Things (IoT) in agriculture commonly referred to as smart farming—has gained significant traction in recent years due to its potential to enhance productivity, sustainability, and resource efficiency (Zhang et al., 2020). Numerous studies have demonstrated how IoT-based systems contribute to real-time monitoring and automation in crop and aquaponic systems. These technologies help farmers monitor environmental parameters such as temperature, humidity, pH, turbidity, and electrical conductivity (EC), thus improving decision-making and reducing reliance on manual intervention (Singh & Sharma, 2021).

One of the primary focuses in smart agriculture research is environmental condition control. For instance, Abid et al. (2019) implemented a greenhouse control system using DHT11 sensors and actuators managed via an Arduino microcontroller. While their system demonstrated effective control of ambient conditions, it lacked integration with water quality monitoring and did not consider plant-specific needs in aquaponic environments. This indicates a gap in holistic system integration for plant and aquatic life.

Several studies have incorporated aquaponics into IoT frameworks. Siregar et al. (2020) developed a semi-automated aquaponic model to maintain water pH and nutrient concentration levels for leafy vegetables. Although their system showed promising results in regulating water quality, it did not feature dynamic environmental condition feedback or remote monitoring interfaces, limiting its scalability. Additionally, real-time data transmission using modules like ESP8266 is often absent or underutilized in smaller-scale implementations.

The theoretical framework for this research draws upon principles of precision agriculture and control systems engineering. Precision agriculture emphasizes data-driven decision-making for optimized yield, while control systems enable automated responses based on sensor feedback. These frameworks underscore the importance of integrating sensor networks with responsive actuators and feedback loops to create a self-regulating cultivation system. Controversies and debates in current literature center around the cost-effectiveness and reliability of IoT solutions in low-to-middle-income settings. While some studies argue for the high initial investment in sensors and automation hardware (Rahman et al., 2021), others demonstrate that long-term gains in yield, resource savings, and labor reduction offset the setup costs. Furthermore, discrepancies exist in sensor accuracy and calibration under tropical climate conditions, particularly with low-cost modules such as the DHT11 or DS18B20, prompting further validation in localized agricultural contexts.

This study seeks to bridge multiple gaps identified in prior research: (1) the lack of an integrated system that simultaneously manages temperature, humidity, and water quality; (2) limited incorporation of real-time monitoring through mobile and desktop platforms; and (3) the absence of feedback-controlled irrigation and fish feeding mechanisms in small-scale aquaponics. By addressing these challenges, this research aims to offer a comprehensive and scalable IoT-based solution tailored to tropical environments like that of Indonesia.

METHOD

The method outlines the design of the activity, selection of the target audience, materials and tools used, the design and performance of the system, as well as the techniques for data collection and analysis. **1. System Design** The designed system integrates aquaponics with IoT-based monitoring and automation. The system consists of various sensors, actuators, and a control unit (Arduino Mega) connected to a WiFi module (ESP8266-01) for remote data transmission and monitoring

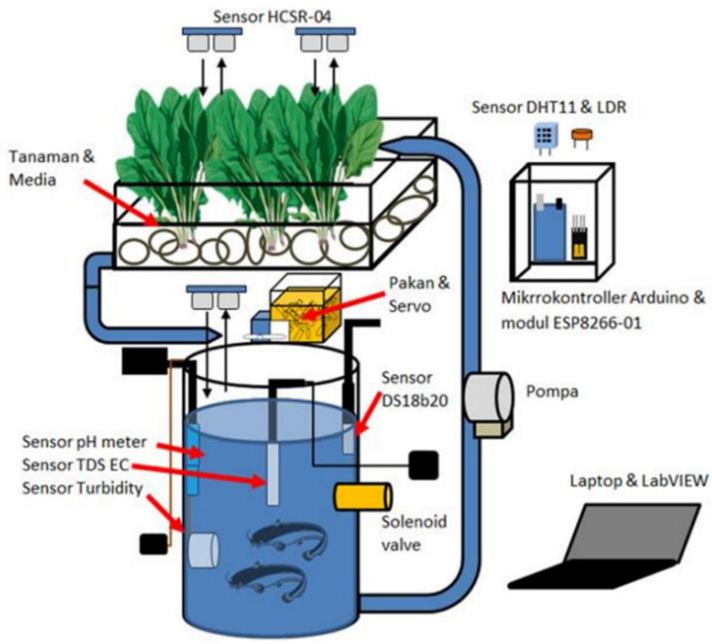

Image 1: System Design
(Image form https://openjournal.unpam.ac.id/index.php/jit/article/view/45329/22781)

The system combines plant cultivation and fish farming in a single, closed-loop environment. We used a variety of sensors to monitor key environmental and water parameters. These included the DHT11 to measure temperature and humidity, the HCSR-04 ultrasonic sensor to detect water volume and plant height, an LDR to measure light intensity, and several water quality sensors such as pH, TDS EC, turbidity, and water temperature (DS18b20) to ensure a balanced ecosystem.

At the heart of the system is the Arduino Mega, which serves as the main controller. It collects all sensor data and sends it to a laptop via the ESP8266-01 WiFi module. This laptop runs LabVIEW, which serves as the monitoring dashboard where users can see real-time data and respond to system conditions.

2. Block System Diagram

This diagram illustrates the workflow of an IoT-based smart aquaponics system designed to monitor and automate environmental and water quality conditions in real time.

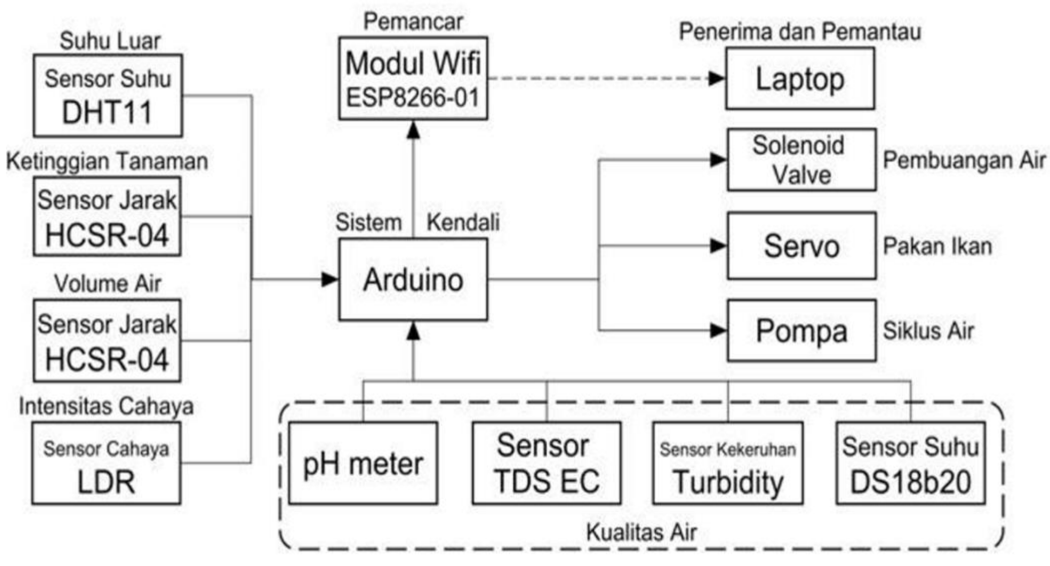

Image 2: Block System Diagram
(Image form https://openjournal.unpam.ac.id/index.php/jit/article/view/45329/22781)

At the heart of the system is an Arduino microcontroller, which acts as the central control unit. It receives input from various sensors that detect environmental conditions and water parameters. To monitor the external temperature and humidity, the system uses a DHT11 sensor. Two ultrasonic sensors (HCSR-04) are used—one to measure plant height, and the other to monitor the water volume. For detecting light intensity, the system uses an LDR (Light Dependent Resistor) sensor.

To assess water quality, the system is equipped with:

- pH meter to measure acidity levels,
- TDS EC sensor to detect the concentration of dissolved solids, turbidity sensor to measure water clarity, and
- DS18b20 temperature sensor to track water temperature.

All sensor data is processed by the Arduino, which then sends the information wirelessly via a WiFi module (ESP8266-01) to a laptop for real-time Arduino ambil data dari sensor- sensor (Variabel dari Suhu dan Kelembaban) ys data using a LabVIEW-based interface, allowing users to observe system status v

In addition to monitoring, the system can automatically respond based on sensor readings. The Arduino controls:

- water pump, which manages the water cycle between the fish tank and plants,
- servo motor, which automatically feeds the fish at scheduled intervals,
- and a solenoid valve, which releases excess water when needed.

This integrated and automated setup makes the aquaponics system more efficient, sustainable, and low-maintenance, eliminating the need for constant manual supervision. All components work together harmoniously to maintain a balanced environment for both fish and plants.

3. Arduino Mega Program Design

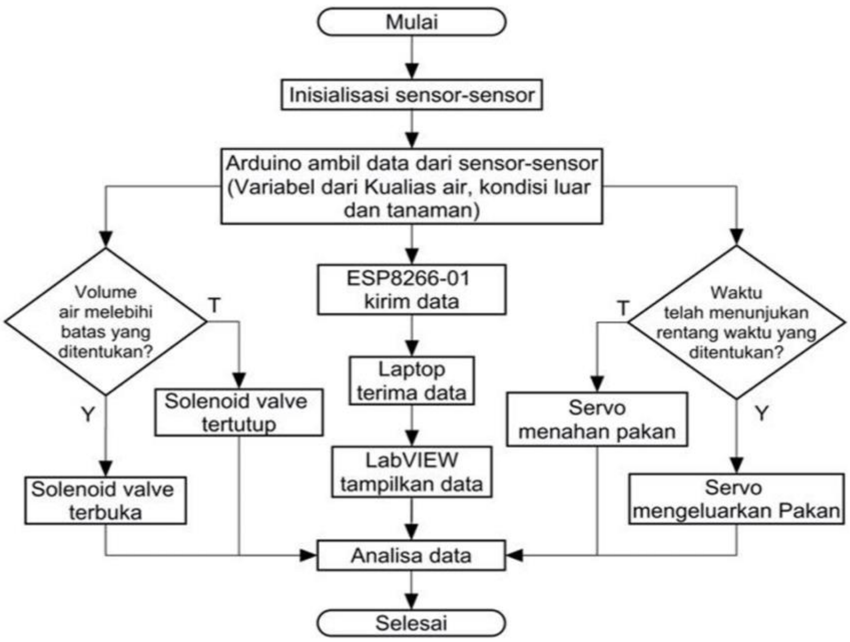

Image 3: Arduino Mega Program Design
(Image form https://openjournal.unpam.ac.id/index.php/jit/article/view/45329/22781)

The system starts with the initialization of all sensors involved in the process. Once the sensors are active, the Arduino Mega begins collecting data from various input sources, including those that monitor water quality, environmental conditions, and the state of the plants. This collected data is then transmitted wirelessly via the ESP8266-01 module to a laptop, where it is received and visualized using LabVIEW software.

While the data is being transmitted and displayed, the system simultaneously performs a series of decisions. It checks whether the volume of water exceeds a predefined threshold. If it does, the solenoid valve will open to release the excess water; otherwise, the valve remains closed to maintain the appropriate water level.

At the same time, the system also monitors the current time to determine whether it matches the specified feeding schedule. If the time falls within the designated range, the servo motor is activated to dispense the feed. If not, the servo continues to hold the feed in place. Once both the water management and feeding processes have been handled based on real-time data, the system proceeds to analyze the collected data for further interpretation and action. After this analysis is completed, the system ends its operation until the next cycle begins.

RESULTS AND DISCUSSION

This study involved the implementation and simulation testing of an IoT-based aquaponic monitoring and control system. The tests focused on evaluating sensor accuracy, real-time system response, and the performance of data transmission and actuation under tropical climate conditions representative of Tangerang Regency.

1. Waterproof Temperature

Table 1 shows the accuracy testing for the DS18B20 waterproof temperature sensor, which was used to monitor the water temperature in the fish tank. The sensor's readings ranged between 27.2°C and 28.4°C, while the reference thermometer recorded between 26.9°C and 27.9°C. The calculated percentage error remained below 1.9%, which supports the sensor's suitability for aquatic monitoring systems. Maintaining water temperature within this range is critical for supporting fish health and nutrient circulation, as noted in prior studies (Zhang et al., 2020). The data also confirmed that the sensor responded quickly to temperature fluctuations with minimal delay.

Table 1. Water Temperature Sensor Accuracy Test Results

No	Sensor Reading (°C)	Measurement Tool (°C)	Error (%)
1	27.6	27.1	1.850
2	27.8	27.3	1.830
3	28.1	27.6	1.810
4	27.5	27.2	1.100
5	28	27.5	1.820
6	27.4	27.1	1.110
7	28.2	27.8	1.440
8	27.9	27.5	1.450
9	27.7	27.3	1.470
10	28.3	27.8	1.800
11	27.2	26.9	1.120
12	27.8	27.4	1.460
13	28.4	27.9	1.790
14	27.3	27	1.110
15	28.1	27.6	1.810
16	27.7	27.2	1.840
17	27.5	27	1.850
18	28.2	27.7	1.810
19	27.4	27.1	1.110
20	28.3	27.8	1.800
	Average		**1.569**

2. Humidity Sensor

Based on Table 2, the DHT11 humidity sensor showed consistent readings compared to a digital hygrometer as the reference instrument. The measured humidity values ranged from 79.2% to 84.2%, with a calculated error between 0.60% and 0.86%. These values are within acceptable accuracy levels for low-cost humidity sensors. The relatively stable and low error rates confirm the DHT11's reliability in detecting ambient humidity within the optimal range for water spinach cultivation. These findings align with the results of Woro et al. (2022), who reported similar performance in smart greenhouse environments.

Table 2. Humidity Sensor Accuracy Test Results

No	Sensor Reading (°C)	Measurement Tool (°C)	Error (%)
1	82.1	81.5	0.740
2	80.3	79.8	0.630
3	83.5	82.9	0.720
4	81.2	80.7	0.620
5	84	83.5	0.600
6	79.5	78.9	0.760
7	82.7	82	0.850
8	81.8	81.2	0.740
9	80.9	80.3	0.750
10	83	82.5	0.610
11	79.2	78.6	0.760
12	82.4	81.7	0.860
13	80.1	79.6	0.630
14	81.6	81	0.740
15	84.2	83.6	0.720
16	80.6	80	0.750
17	83.3	82.7	0.730
18	82	81.5	0.610
19	79.8	79.2	0.760
20	81.9	81.3	0.700
	Average		**0.714**

3. Overall System Performance

The designed system integrates aquaponics with IoT-based monitoring and automation. The system consists of various sensors, actuators, and a control unit (Arduino Mega) connected to a WiFi module (ESP8266-01) for remote data transmission and monitoring

Table 3. Overall System Test Results

No	Time	Interval (s)	Temperature (°C)	Humidity (%)	Relay	IoT
1	8:00:00	20	27.5	81	ON	Success
2	8:00:20	25	27.8	80.7	ON	Success
3	8:00:45	25	28.1	80.4	ON	Success

4	8:01:10	30	28.4	80.2	ON	Success
5	8:01:40	25	28.3	80	ON	Success
6	8:02:05	25	28.1	80.3	ON	Success
7	8:02:30	25	27.9	80.6	ON	Success
8	8:02:55	25	27.7	80.8	ON	Success
9	8:03:20	20	27.5	81	ON	Success
10	8:03:40	25	27.6	81.3	ON	Success
11	8:04:05	30	27.8	81.1	ON	Success
12	8:04:35	40	28	80.9	ON	Success
13	8:05:15	25	28.2	80.7	ON	Success
14	8:05:40	25	28.3	80.5	ON	Success
15	8:06:05	25	28.1	80.3	ON	Success
16	8:06:30	20	27.8	80.6	ON	Success
17	8:06:50	35	27.6	80.9	ON	Success
18	8:07:25	25	27.7	81.1	ON	Success
19	8:07:50	25	28	80.8	ON	Success
20	8:08:15	25	28.2	80.6	ON	Success

Each data entry was transmitted in real-time to LabVIEW via the ESP8266-01 WiFi module, with all 20 transmissions marked as Success. The reliable transmission across different intervals (20s–45s) indicates the system's robustness in handling asynchronous sensor input, which is important for real-field deployment in smart farming. Furthermore, the system showed that it could adapt to slightly varied reading times without affecting the overall accuracy or system responsiveness.

The integration of accurate sensing, responsive actuation, and reliable wireless communication confirms that the developed IoT-based aquaponics system is technically feasible and effective for tropical agricultural applications. The findings support the work of Woro et al. (2022), who emphasize that embedded automation in agriculture improves both environmental stability and operational efficiency. However, one limitation observed was the potential delay from network congestion, which in future work could be optimized by implementing a more lightweight communication protocol like MQTT.

CONCLUSION

This research has successfully implemented an IoT-based aquaponics system to control temperature, humidity, and water quality in the cultivation of water spinach (Ipomoea aquatica), with a focus on optimizing growing conditions in the tropical climate of Tangerang Regency. As outlined in the introduction, the study aimed to provide an automated, efficient, and sustainable solution for urban farming through smart environmental control systems.

The results confirmed that the system was able to maintain stable environmental conditions with a low average error of 1.569% for water temperature readings using the DS18B20 sensor, and 0.714% for humidity readings using the DHT11 sensor. Additionally, the system's response to real-time data—via automatic control of relays and actuators demonstrated high reliability and precision. All data was successfully transmitted via ESP8266 to the LabVIEW interface with no packet loss, proving the system's communication stability. These findings support the system's technical feasibility and practical value in smart agriculture applications, particularly for small to medium-scale farmers and educational institutions. The integration of automated monitoring, responsive control, and IoT connectivity resulted in improved efficiency, minimal manual intervention, and the potential for higher crop and fish yield consistency. For future development, the system can be enhanced through cloud-based data logging, implementation of mobile notification systems, and the integration of solar power for energy sustainability. Adopting more efficient communication protocols like MQTT can also improve data transmission speed and reduce latency.

This development has the potential to scale further as a model for smart farming adoption across tropical and urban agricultural communities.

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