Design Build Temperature and Humidity Monitoring Internet of Things based for Optimization Oyster Mushroom Growth

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Abstract— Oyster mushroom (Pleurotus ostreatus) cultivation in Indonesia faces challenges in maintaining stable temperature and humidity in the growing room, particularly because monitoring is still performed manually, which increases the risk of errors. To address this issue, Sasya Puteri Setyahadi and Alsah Nur Laila designed an Internet of Things (IoT)-based temperature and humidity monitoring system that can be accessed in real time and remotely. The system uses the SHT31 sensor for data acquisition, an ESP32 microcontroller as the main processor, and the Firebase platform for data storage and visualization. Data are displayed through a web application and are integrated with an automatic watering response when parameter values fall outside the optimal range of 16–30 °C for temperature and 80–95% for humidity. Testing results showed that the system is capable of reading and transmitting data accurately and quickly. The main contribution of this study is the development of an environmental monitoring system for oyster mushroom cultivation with an automatic notification feature based on threshold values, which can serve as a foundation for future automated control systems. Comparative testing showed that the SHT31 sensor had an average temperature measurement error of 1.427% (accuracy 98.573%) and an average humidity measurement error of 2.017% (accuracy 97.983%) compared to the HTC-1 reference instrument. Meanwhile, the JSN-SR04T water level sensor achieved an average error of 2.076% (accuracy 97.924%). Furthermore, the system demonstrated an average data transmission delay of 1488.89 ms and an average jitter of 11.588 ms. Overall, the high accuracy across tests, combined with relatively low delay and jitter values, indicates that the system performs effectively and reliably in maintaining the mushroom house environment within the ideal range required to support optimal oyster mushroom growth.

Keywords : IoT, Oyster Mushroom , Temperature , Humidity , ultrasonic .

1. Introduction

Oyster mushrooms (Pleurotus Ostreatus) in experience growing on wood weathered , like wood tree sengon, rubber, dadap, kapok, and durian. In addition, mushrooms this can also cultivated in various organic media, including powder saw, waste straw, waste cotton, paper, and material other organics [1]. Humidity in mushroom house must ensure that the mushrooms produced own characteristics superior, namely size big, thick, sturdy, free pests and diseases, as well as growth perfect [2].

Oyster mushroom cultivation requires humidity control in two main aspects: substrate humidity and air humidity within the mushroom house. The substrate must be kept moist to support mycelium growth, while air humidity is necessary to stabilize the microclimate and prevent the fruiting bodies from drying out. Optimal conditions for mushroom growth are a temperature of 10–32 °C with 85–95% humidity [3]. Other sources cite a temperature range of 16–30 °C and 80–90% humidity as ideal conditions for fruiting body formation [4]. The optimal temperature for cultivation mold oyster is 10–25 °C with humidity 85–92% [5]. Range This become reference for farmer in guard condition mushroom house . Settings environment done through watering or fogging in accordance with condition temperature, so that required tool gauge temperature for ensure proper control inside mushroom house mold.

Condition fluctuating environment consequence change weather and seasons make things difficult farmer in guard temperature and humidity mushroom house remains ideal. This is aggravated with limitations time supervision Because activity others, so that watering and management environment often less than optimal. For overcome problem mentioned, it is necessary system automatic capable adapt temperature and humidity without involvement direct farmers. Technology *Internet of Things* (IoT) is becoming solution Because allows monitoring and control environment in real-time and integrated . With design get up IoT-based monitoring system, management mushroom house mold can done more efficient, stable, and sustainable, at the same time increase productivity. System this also provides information condition mushroom house in a way distance away so that the temperature and humidity still awake so that results harvest mold more optimal. Based on background the back that has been described, formulated problem in study This is as following :

a. Mushroom house mold No monitored optimally.
b. Watering No done regularly so that growth mold become No maximum and partial No produce fruit.
c. Growth mushrooms are also inhibited by conditions temperature that is not controlled in a way accurat.
d. Yields less than optimal.

2. Literature review

The system design in this final project was developed based on a literature review of several previous studies. Reference [6] presented an irrigation monitoring and automatic water filling system for mushroom cultivation using an IoT-based approach. The system utilized the SHT31 sensor to detect temperature and humidity, connected to the ESP32 TTGO-TCALL SIM800 microcontroller, and was controlled via SSR relays to activate pumps, nozzles, sprayers, and solenoid valves in the water reservoir. Reference [7] developed an IoT-based monitoring and control prototype for oyster mushroom houses ready for harvest, employing DHT22 sensors, ESP32-CAM, Arduino Uno, NodeMCU, and various actuators (blower, mist sprayer, pump, and incandescent lamps), all controlled according to environmental conditions. Temperature, humidity, and mushroom development information were displayed in real time via an I2C LCD and an Android application. Both studies became the foundation for the system design in this final project.

Further, study [8] developed a temperature and humidity monitoring system using DHT22 and ESP32 sensors, where data were sent to Firebase and displayed through an Android application. Research [9] designed an IoT-based temperature and humidity control system using a DHT22 sensor, Arduino Mega, and actuators such as incandescent lamps and nozzles, although it showed weaknesses in terms of relatively high delay. The most recent reference [10] optimized oyster mushroom growth using NodeMCU ESP8266, a DHT22 sensor, a humidifier, and lamps, with monitoring results displayed on an I2C LCD.

Based on these studies, the research gap addressed in this final project is the addition of a logic system for reading temperature and humidity from three sensors placed at different points to independently control watering across three branches. Furthermore, the system provides real-time information on a web-based platform regarding watering activity in each branch and the filling status of the water reservoir.

3. Research methods

Study this use prototype method, namely method development a system that focuses on creating an initial model (*prototype*) of the system that will built for then tested, evaluated, and refined based on input from user. *Prototype* method is iterative, meaning developed system will experience repair in a way gradually until fulfil need users optimally.

3.1. Identification Need

Stage identification need done through observation, interviews, and studies system similar For formulate need user. Found that farmer Still depend on tool analog such as thermometers and hygrometers, so often happen delay watering or fogging moment outside temperature and humidity ideal range. Delay This due to limitations time farmers who also have other activities outside cultivation mold .

Condition environment mushroom house as in figure 1 measuring 4.6 × 6 meters with shelves baglog mold demand arrangement the right temperature and humidity for mycelium grow optimally. Problems This impact on quality and quantity harvest, so that farmer need automatic monitoring system that is capable of measure, regulate, and display temperature data as well as humidity in real-time and can accessible distance far through cell phone or computer. With system this, farmer no only can monitor condition mushroom house, but also supervise response automatic like watering or fogging when environmental parameters go out from the optimal limit. Identification results need this become base design system automatic use prototype method.

Fig 1. Oyster Mushroom Shelf

3.2. Initial System Design

Stage design beginning system is necessary steps noticed in designing system automation for cultivation mold oysters. In the phase this, arranged draft basics and design system based on identification needs analysis problems, and desired target achieved. This design covering aspect device hardware and devices software, including selection of sensors, actuators, microcontrollers, and design architecture network and flow work system. The purpose of stages this is give description comprehensive about method work and structure the system that will developed, so that make things easier implementation at the stage implementation and testing next.

3.2.1. System Block Diagram

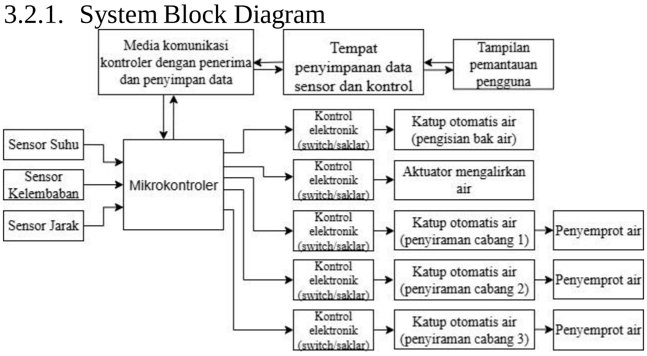

Fig 2. System Block Diagram

From figure 2, the system this designed for in a way automatic monitor and control temperature, humidity and water level in the mushroom house mold oyster through integration of sensors, actuator, microcontrollers, communication media, and databases. Temperature-humidity sensors and ultrasonic sensors provide processed data microcontroller for control actuator like pump and solenoid valve match logic control. control unit electronic functioning as switch for water filling, distribution, and irrigation. Valves automatic arrange supply from the water source, while pump spray water on mushroom house system equipped communication wireless for real-time sensor data delivery and display monitoring for users. Thus, cultivation mold can ongoing more efficient and consistent controlled even though farmer No always be at the location.

3.2.2. Design System

The system architecture was designed to perform specific functions, as illustrated in Figure 3. At this stage, the components used in the system design were determined to ensure optimal functionality. In this project, several microcontrollers and sensors were employed, including the ESP32 as the central control unit, the SHT31 sensor to detect temperature and humidity, and the JSN-SR04T ultrasonic sensor to measure the water level in the tank as the basis for automatic refilling. An SSR relay was used as a component to automatically control the connection and disconnection of electric current. The system was built with an access point connection, utilizing Firebase as a database, and a Progressive Web App (PWA)-based website as a monitoring platform. The system workflow begins with the JSN-SR04T ultrasonic sensor detecting the water level in the tank. If the water level reaches ≥32 cm, the ultrasonic sensor sends information to the ESP32 to activate the SSR relay, allowing water to flow into the tank. Once the water level reaches the specified lower limit of ≤28 cm, the ultrasonic sensor sends a “full” status to the ESP32, which then instructs the SSR relay to stop the water flow.

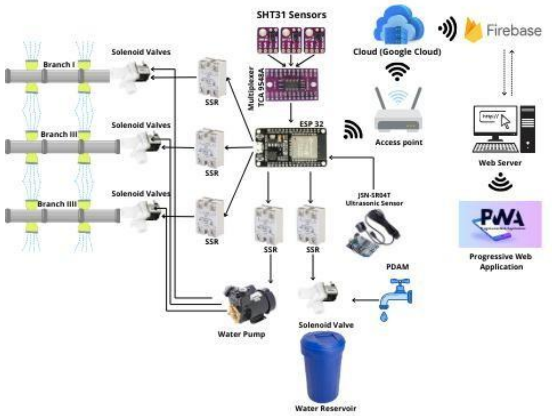

Fig 3. Design System

In addition to the water refilling process, the system is also equipped with an automatic watering feature that activates when the SHT31 sensor detects a temperature of ≥30 °C. Sensor data are transmitted to the ESP32, which controls the water pump via the SSR and opens specific solenoid valves as needed. Water is then distributed and sprayed in the form of mist onto the mushroom baglogs to maintain ideal temperature and humidity conditions. Information regarding temperature, humidity, and water volume is sent to the database and displayed on the website/PWA.

3.2.3. Wiring

The series consists of the ESP32 as the central controller, several sensors, an SSR, solenoid valves, a water pump, and a power supply. All components are interconnected through data cables and power cables to operate the automatic monitoring and control system of the mushroom house, as shown in Figure 4.

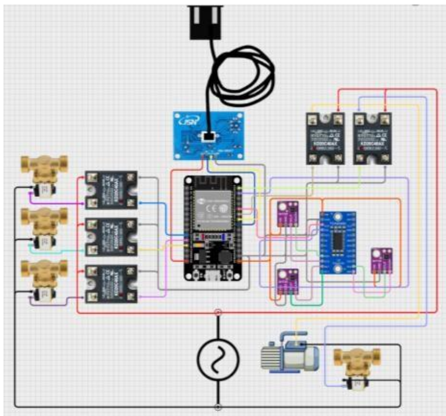
Fig 4. System Wiring

The wiring begins from the ESP32 by assigning the appropriate pins for each sensor and actuator. The ESP32 reads data from the JSN-SR04T ultrasonic sensor to measure the water level. At the same time, the ESP32 collects data from three SHT31 sensors, each connected to a different channel of the TCA9548A multiplexer (CH0, CH1, and CH2). Table 3.2 presents the wiring of the SHT31 sensors and the TCA9548A multiplexer. For actuator control in response to the obtained data, five SSRs were added, with their input pins connected to the ESP32 GPIO pins. The SSR outputs are connected to AC loads (pump or solenoid valve) in each branch, powered through an AC power source.

3.2.4. Flow diagram

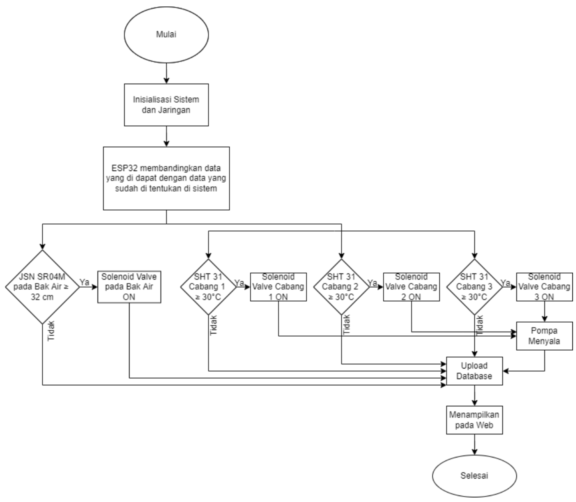

Fig 5. Flowchart

As shown in Figure 5, the system workflow begins with ESP32 initialization and network connection to the database. The ESP32 then reads data from SHT31 sensors (temperature and humidity) and the JSN-SR04T ultrasonic sensor (water level). The data are compared with threshold values: if the water level is ≥32 cm, the tank solenoid valve is activated; if branch temperature is ≥30 °C, the branch solenoid valve is activated. When any solenoid valve is active, the pump turns on to supply water. All sensor data and actuator status are sent in real time to the database and displayed via the web interface. This process repeats periodically for accurate and efficient monitoring.

3.2.5. Construction

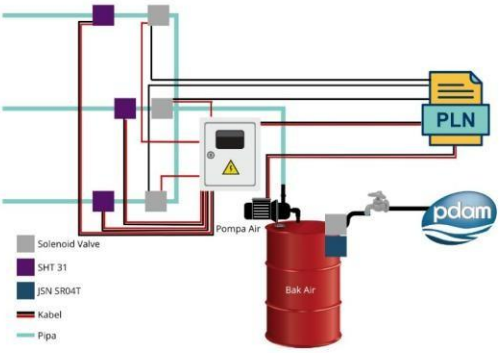

Fig 6. Construction

Figure 6 illustrates the design, connection, and physical installation of the monitoring system for temperature, humidity, and water level to support optimal oyster mushroom growth. The system uses an ESP32 microcontroller as the central controller, connected to sensors and actuators via cables and pipes. The SHT31 sensor (purple) measures temperature and humidity at each monitoring point through the TCA9548A multiplexer on the I2C line. The JSN-SR04T sensor (blue) monitors the water level in the storage tank using ultrasonic principles, enabling automatic refilling from the PDAM supply. Water flow is regulated by solenoid valves (grey) controlled by the microcontroller, while a water pump sprays mist in the cultivation room to lower temperature or increase humidity when thresholds are exceeded. All devices are controlled through an electrical panel (white) equipped with SSRs/relays and powered by PLN. Clean water from PDAM is stored in the tank, then pumped into the cultivation room, with the water level monitored in real time by the ultrasonic sensor.

3.3. Making *Prototype*

This research method is at the prototype development stage, focusing on the direct construction of the system according to the predetermined design. The process includes hardware assembly, sensor and actuator integration, as well as microcontroller and database programming, resulting in a functional model that can be tested. This stage aims to produce a working prototype according to the requirements, serving as the basis for system performance testing and comprehensive evaluation.

3.3.1. Making *Website*

The website development process involves the design and implementation of a web-based monitoring interface that displays environmental data collected from the oyster mushroom cultivation system. This website uses Firebase for hosting and as a real-time database, enabling continuous data visualization for monitoring temperature, humidity, and water level. In addition, the website is developed as a Progressive Web Application (PWA), making it easily accessible through both desktop and Android devices, either via a browser or as an installable application.

3.4. Evaluation Users

Testing was carried out to comprehensively evaluate system performance. At this stage, several types of tests were conducted to ensure that each part of the system functioned in accordance with the design.

4. Test Results and Analysis System

4.1. Implementation Results Design and Assembly Device Hard

The results of the design and assembly process can seen in Figures 8 to 17. The results are realized in form a system node consisting of from a number of component main, namely ESP32 microcontroller, sensors, modules control, and component supporters others. This system node functioning For read data from sensors, process it, and send it the result to the database in real-time.

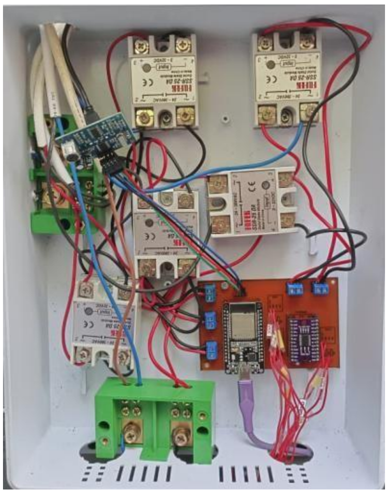

Fig 7. Electrical Panel


Fig 8. In the Mushroom Barn


Fig 9. Appearance Front of the Mushroom Mushroom Prototype


Figure 10. Appearance Front Mushroom Hut (Closed Roof)


Fig 11. Appearance Behind the Mushroom Mushroom Prototype

4.2. Display Results *Web Interface*

The dashboard page, as shown in Figures 12 and 13, serves as the main interface feature that displays real-time data on temperature, humidity, and water level. In addition, the page is equipped with graphs that illustrate the variations in temperature, humidity, and water level over time.

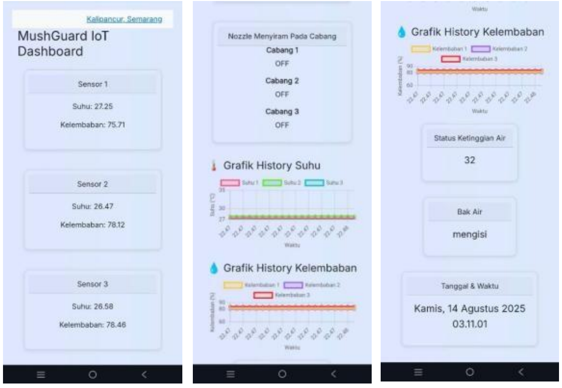

Fig 12. Display of Progressive Web App (PWA) and Website on Android Devices

Fig 13. Dashboard view for PC

4.3. Analysis of Temperature Sensor Accuracy Against Reference Measuring Instruments

Table 1. Temperature Results Compared to Reference Instruments

No	**Date**	**Time**	**Sensor (°C)**	**Meters (°C)**	**Difference (°C)**	***Error* (%)**	**Accuracy (%)**
1	06/8/2025	08.25	29.44	28.3	1.14	4,028	95,972
2	06/8/2025	08.29	29.54	28.3	1.24	4,382	95,618
3	06/8/2025	12.15	34.24	33.1	1.14	3,444	96,556
4	09/8/2025	12.57	30.08	31.5	1.42	4,508	95,492
5	09/8/2025	20.02	28.2	28.2	0	0	100
6	09/8/2025	23.41	27.25	27.3	0.05	0.183	99,817
7	10/8/2025	12.33	31.68	31.8	0.12	0.377	99,623
8	10/8/2025	16.32	30.32	31.2	0.88	2,821	97,179
9	10/8/2025	19.17	28.1	28.6	0.5	1,748	98,252
10	21/8/2025	11.59	27.5	27.4	0.1	0.365	99,635
11	21/8/2025	16.43	26.33	26.5	0.17	0.642	99,358
12	21/8/2025	16.55	27.12	27.4	0.28	1,022	98,978
13	22/8/2025	13.46	28.57	28.5	0.07	0.246	99,754

14	22/8/2025	14.00	25.45	26.7	1.25	4,682	95,318
15	22/8/2025	17.42	25.51	26.8	1.29	4,813	95,187
	Average				0.41	1,427	98,573

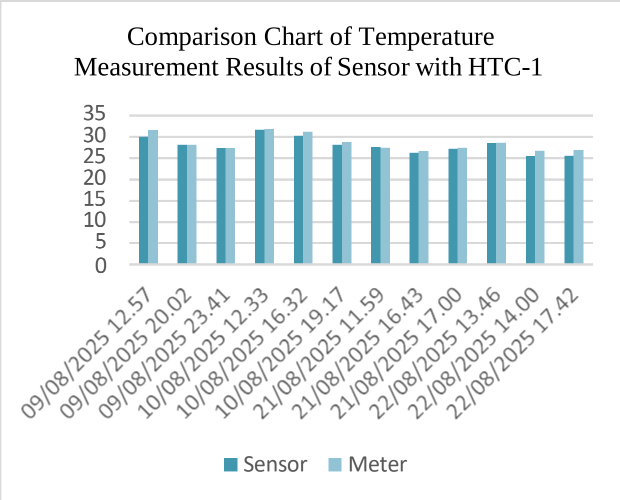

Fig 14. Graph Comparison Measurement Temperature sensor with HTC-1

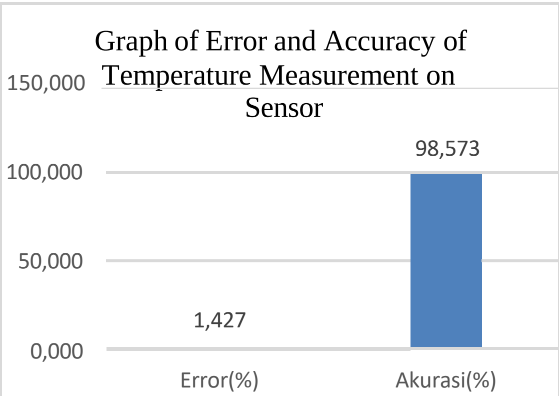

Fig 15. Error and Accuracy Graph Measurement Temperature on Sensor

The error percentage was determined from the difference between the sensor readings and the reference values, while accuracy was calculated as 100% minus the error value. The temperature measurement differences ranged from 0 to 1.42 °C, with the highest error recorded at 4.51% (95.49% accuracy) and the lowest error at 0% (100% accuracy). The average difference was 0.41 °C, corresponding to an error of 1.427% and an accuracy of 98.573%. These results indicate that the SHT31 sensor has very high accuracy, with most error values below 5%. Furthermore, the graphs in Figures 14 and 15 confirm the reliability of the sensor in measuring temperature with a low margin of error.

4.4. Analysis of Humidity Sensor Accuracy Against Reference Measuring Instruments

Table 2. Humidity Results Compared to Reference Instruments

No	**Date**	**Time**	**Sensor (%)**	**Meters (%)**	**Difference (%)**	***Error* (%)**	**Accuracy (%)**
1	06/8/2025	08.25	77.65	77	0.65	0.844	99,156
2	06/8/2025	08.29	77.25	77	0.25	0.325	99,675
3	06/08/2025	12.15	55.85	56	0.15	0.268	99,732
4	09/08/2025	12.57	64.47	65	0.53	0.815	99,185
5	09/08/2025	20.02	69.2	72	2.8	3,889	96,111
6	09/08/2025	23.41	75.71	73	2.71	3,712	96,288
7	10/08/2025	12.33	60.54	61	0.46	0.754	99,246
8	10/08/2025	16.32	62.67	66	3.33	5,045	94,955
9	10/08/2025	19.17	72.7	79	6.3	7,975	92,025
10	08/21/2025	11.59	79.3	78	1.3	1,667	98,333
11	08/21/2025	16.43	84.44	83	1.44	1,735	98,265
12	08/21/2025	17.00	80.52	81	0.48	0.593	99,407
13	08/22/2025	13.46	86.16	85	1.16	1,365	98,635
14	08/22/2025	14.00	89.48	89	0.48	0.539	99,461
15	08/22/2025	17.42	95.3	96	0.7	0.729	99,271
	Average				1,516	2,017	97,983

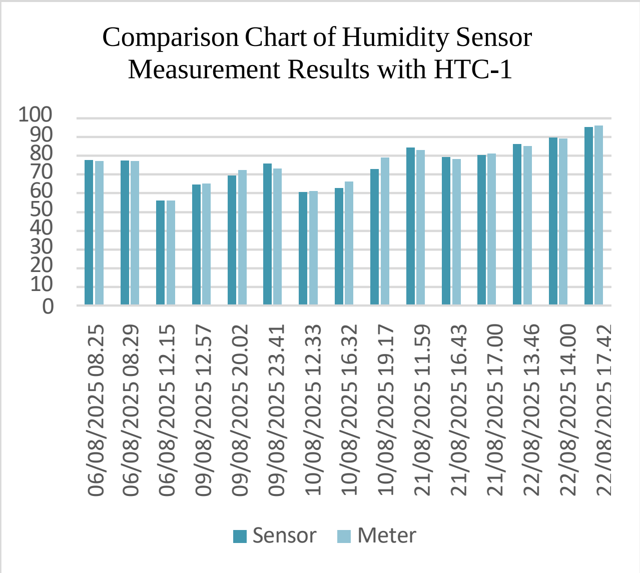

Fig 16.Comparison of Measurement Results Humidity Sensor with HTC-1

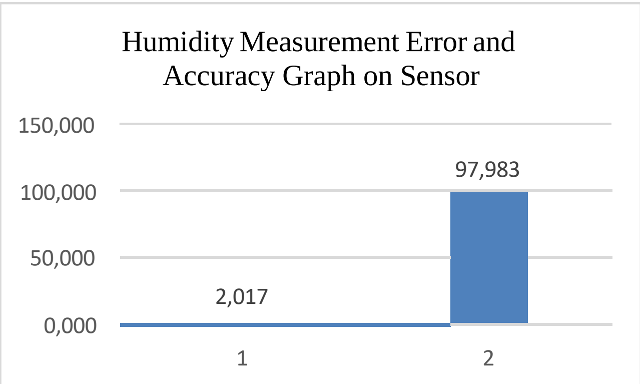

Fig 17. Error and Accuracy Graph Measurement Moisture on the Sensor

The average difference in humidity between the sensor and the reference instrument was 1.516%, with the highest accuracy recorded at 99.845% and the largest error at 7.754%. Overall, the sensor demonstrated good performance with a low average error of 2.017% and a high accuracy of 97.983%. The results presented in Table 2 and the graphs in Figures 16 and 17 further confirm that the humidity sensor is reliable, consistent, and closely aligned with the HTC-1 reference values, making it valid for use in the monitoring system.

4.5. Analysis of Water Level Sensor Accuracy Against Reference Measuring Instruments

Table 3. Water Level Sensor Results Compared to Reference Instruments

No	Sensor (cm)	Meter (°cm)	Difference (°cm)	*Error* (%)	Accuracy (%)
1	31	30.08	0.92	3,059	96,941
2	26	25.35	0.65	2,564	97,436
3	29	27.9	1.1	3,943	96,057
4	33	32.15	0.85	2,644	97,356
5	30	28.65	1.35	4,712	95,288
6	27	26.5	0.5	1, 887	98,113
7	36	35.2	0.8	2,273	97,727
8	30	29.4	0.6	2,041	97,959
9	28	28.2	0.2	0.709	99,291
10	32	31.8	0.2	0.629	99,371
11	31	31.25	0.25	0.800	99,200
12	34	33.5	0.5	1,493	98,507
13	32	32.1	0.1	0.312	99,688
14	41	39.8	1.2	3,015	96,985
15	28	28.3	0.3	1,060	98,940
	Average		0.635	2,076	97,924

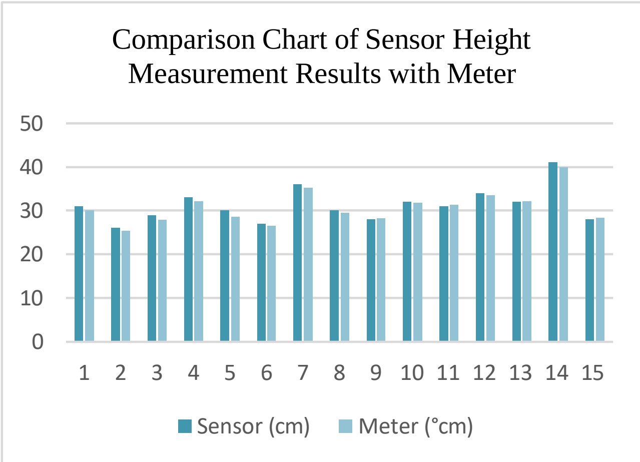

Fig 18. Graph Comparison of Sensor Measurement Results with Meter

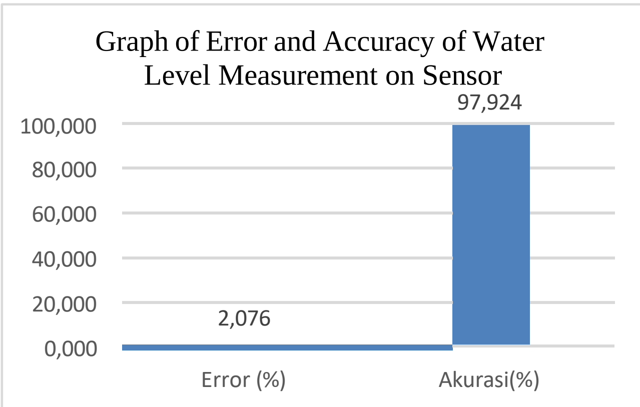

Fig 19. Error and Accuracy Graph Measurement Water Level on Sensor

Testing of the JSN-SR04T ultrasonic sensor showed a measurement difference ranging from 0.1 to 1.35 cm, with the largest error of 4.712% (95.288% accuracy) and the smallest error of 0.312% (99.688% accuracy). Across 15 trials, the average difference was 0.635 cm, resulting in an average error of 2.076% and an accuracy of 97.924%. The graphical results in Figures 18 and 19 confirm that the differences compared to the reference instrument are not significant, demonstrating that the sensor is consistent and reliable in measuring distance.

4.6. Measurement *Delay*

Based on the test results in Table 4, the data transmission delay ranged from 1000 ms to 3000 ms. The lowest delay was 1000 ms, while the highest, 3000 ms, occurred during the 8th test.

Table 4. Delay Measurement Data

No	Send Time	Reception time	*Delay* (ms)
1	19:12:00	19:12:02	2000
2	19:12:01	19:12:03	2000
3	19:12:03	19:12:05	2000
4	19:12:05	19:12:07	2000
5	19:12:07	19:12:08	1000
6	19:12:08	19:12:10	2000
7	19:12:10	19:12:11	1000
8	19:12:11	19:12:14	3000
9	19:12:14	19:12:15	1000
10	19:12:16	19:12:17	1000
11	19:12:17	19:12:18	1000
12	19:12:18	19:12:20	2000
13	19:12:20	19:12:21	1000
14	19:12:22	19:12:23	1000
15	19:12:23	19:12:24	1000
16	19:12:24	19:12:26	2000
17	19:12:26	19:12:27	1000
18	19:12:27	19:12:29	2000
19	19:12:29	19:12:31	2000
20	19:12:31	19:12:32	1000
21	19:12:32	19:12:34	2000
22	19:12:34	19:12:35	1000
23	19:12:36	19:12:37	1000
24	19:12:37	19:12:38	1000
25	19:12:39	19:12:40	1000
26	19:12:40	19:12:42	2000
27	19:12:42	19:12:43	1000
28	19:12:43	19:12:44	1000
29	19:12:45	19:12:47	2000
30	19:12:47	19:12:48	1000
31	19:12:48	19:12:50	2000
32	19:12:50	19:12:52	2000
33	19:12:52	19:12:54	2000
34	19:12:54	19:12:55	1000
35	19:12:55	19:12:57	2000
36	19:12:57	19:12:58	1000
37	19:12:59	19:13:00	1000
38	19:13:00	19:13:02	2000
39	19:13:01	19:13:03	2000
40	19:13:03	19:13:05	2000
41	19:13:05	19:13:06	1000
42	19:13:07	19: 13:08	1000
43	19:13:08	19:13:09	1000
44	19:13:09	19:13:11	2000
45	19:13:11	19:13:12	1000
	Average		1488.89

The average delay across eight tests was 1488.89 ms (≈1.49 seconds). This indicates that data transmission from device to destination is relatively fast, with minor variations due to factors such as Wi-Fi stability, server load, and processing time. With an average delay below 2 seconds, the system can still be categorized as responsive for monitoring applications, as data is updated almost in real time without significant interruption.

3.1. Measurement *Jitter*

Jitter testing was conducted to determine the extent of time variation (delay) between data packets received by the system. Low jitter indicates stable data communication, while high jitter reflects fluctuations in transmission time that may affect the performance of real-time systems, as shown in Table 5.

Table 5. Jitter Measurement Data

Total Variation *Delay*	Total Packets Received	*Jitter* (ms)
511.11	45	11.36
511.11	45	11.36
511.11	45	11.36
511.11	45	11.36
488.89	45	10.86
511.11	45	11.36
488.89	45	10.86
151.11	45	33.58
488.89	45	10.86
488.89	45	10.86
488.89	45	10.86
511.11	45	11.36
488.89	45	10.86
488.89	45	10.86
488.89	45	10.86
511.11	45	11.36
488.89	45	10.86
511.11	45	11.36
511.11	45	11.36
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511.11	45	11.36
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511.11	45	11.36
511.11	45	11.36
488.89	45	10.86
488.89	45	10.86
488.89	45	10.86
511.11	45	11.36
488.89	45	10.86
Average		11,588

Based on the measurements in Table 5, most jitter values ranged from 1.36 ms to 10.86 ms, indicating stable data transmission. However, occasional spikes of up to 33.58 ms were observed, likely caused by Wi-Fi network disturbances, microcontroller processing load, or queued data delivery to Firebase. The average jitter was 3.017 ms, which is still considered good for an ESP32-based IoT monitoring system, as jitter tolerance for non-critical applications can reach 10 ms without affecting performance. Overall, the results show that the system is capable of maintaining relatively stable data transmission despite occasional fluctuations.

4. Conclusion

Based on the stated objectives, it can be concluded that this project has successfully developed an automated monitoring and control system for oyster mushroom cultivation using Internet of Things (IoT) technology. The achievement is not only limited to the design and construction of automatic watering and water tank refilling devices but also includes the implementation of a comprehensive monitoring system. The system is capable of providing real-time information on environmental conditions in the mushroom house, including temperature, humidity, and water level, as well as the operational status of the devices. Through IoT connectivity, this data can be accessed remotely, offering flexibility and convenience for farmers in managing their cultivation. Furthermore, a series of tests have demonstrated that the system is effective and reliable in maintaining the environmental conditions of the mushroom house within the ideal range required for optimal oyster mushroom growth. Thus, this project not only provides an innovative technological solution but also contributes to improved efficiency and potential yields in the modern agricultural sector.

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