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A SMART KUMBUNG FOR MONITORING AND CONTROLLING ENVIRONMENT IN OYSTER MUSHROOM CULTIVATION BASED ON INTERNET OF THINGS FRAMEWORK

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ABSTRACT
Oyster mushroom (Pleurotus Ostreatus) is a fungus-like plant that is often cultivated in Indonesian agriculture. Oyster mushroom is raised by manipulating environmental parameters, so that it can grow in the provided Kumbung. Oyster mushroom requires a temperature that is used, which ranges from 23°-28°C, for humidity used between 70% -90% and for light intensity it requires light of ±300 lux. In this study, a system was designed to carry out automatic monitoring and control in real time based on the Internet of Things (IoT) which integrates DHT22 humidity and temperature sensors, BH1750 light intensity sensors and NodeMCU as a microcontroller with measurement results sent to the Firebase database. In addition, a water pump connected to the sprayer nozzle is installed in this system to maintain the humidity of the oyster mushroom curd. From the test results, the system can work automatically to stabilize temperature, humidity, and light intensity according to the ideal parameters.
Keywords: *Oyster Mushroom, Kumbung, Monitoring, Control, Food Security, Resilient Agricultural Practices*

1. Introduction

Oyster mushrooms are one type of mushroom that is widely cultivated and processed into food products in Indonesia. Based on data from the Central Statistics Agency (Statistik, B. P., 2018), mushrooms are vegetable crops with the highest production and even the results are exported (Khusnul, 2022). The potential of mushroom farming business in Indonesia has increased since the COVID-19 pandemic (Laraspati, 2021). Oyster mushrooms have a high nutritional content, rich in proteins and vitamins, as well as complete mineral elements needed by the human body (Adebayo & Oloke, 2017) (Bhatia, Neeraj, & Bhatia, 2023). The Central Statistics Agency noted that mushroom production in Indonesia amounted to 63.16 tons in 2022 (Statistik, Produksi Tanaman Sayuran 2022, 2022). This number decreased by 30.15% compared to the previous year which was 90.42 tons (Rizaty, 2023). The cause of the decline in oyster mushroom production is crop failure due to microorganism contamination that inhibits the development of oyster mushrooms (Aeni, 2023).

Currently, oyster mushroom cultivation can be developed outside its natural habitat, namely by planting in production houses or Kumbung (Ainan, Pranoto, & Marhendi, 2022). Kumbung protect mushroom growing media (baglog) from rain and direct sunlight as well as the possibility of unwanted entry of other mushroom spores and disrupt the growth and development of the oyster mushroom (Kencanawati, 2017).

In oyster mushroom cultivation, special treatment is needed so that it can develop optimally. It needs regular watering so that the temperature and humidity are maintained, minimal light are factors that affect the quality and quantity of production. In practice, it was concluded that the environmental aspects that need to be considered in oyster mushroom cultivation are temperature, humidity, and light intensity. In general, a good temperature for the development of oyster mushrooms is between 23 ℃ to 28 ℃ while the air humidity is between 70% to 90% (Yudhana, Akbar, Mufandi, & Larombia, 2022) (Sihombing, Astuti, Herriyance, & Sitompul, 2018). The light intensity required for the growth of oyster mushrooms is ±300 Lux (Firmansyah, et al., 2022), (Mohammed, et al., 2018).

At the moment, traditional farmers generally still use manual methods in oyster mushroom cultivation, including by watering and spraying water every morning and evening (Setiawan, Tarnadi, & Surfani, 2021), (Akbar, Gunawan, & Utama, 2020). Meanwhile, to get the beam of light, farmers usually open the cover of the Kumbung. This traditional technique is certainly not effective because it will take a lot of time and energy, and if there is an unexpected change in weather, the growth of oyster mushrooms will be disrupted.

2. Literature Review

IoT has emerged as the latest technologies used widely in different industries and services (Sam, T. H. et al., 2021). According to a survey by (Pravinthraja, Rozario, Nagarani, Kavitha, & Kumar, 2018) IoT technology has been developed and applied for mushroom cultivation since 2017. Research by (Marzuki & Ying, 2017) controls the mushroom farm environment with a mobile application based on ThingSpeak for temperature, humidity, carbon dioxide concentration and light intensity. A remote monitoring system with the ThingSpeak IoT platform was also developed by (Mahmud, Buyamin, Mokji, & Abidin, 2018). This system uses temperature and humidity sensors DHT11 and carbon dioxide sensors MQ135 as well as sensor nodes and ESP8266 controllers to observe the cultivation environment in oyster mushroom houses. The remote monitoring application with Blink was developed by (Setiawati, Utomo, Murad, & Putra, 2021) to control the temperature and humidity inside and outside the Kumbung in oyster mushroom cultivation. This system uses the Wemos D1 microcontroller and DHT11 sensor, humidifier, and exhaust fan. Another research paper applied an IoT-based automatic system for controlling humidity, temperature, and light as well as training in oyster mushroom cultivation in a laboratory room (Islam, Islam, Miah, & Bhowmik, 2022). A remote control and monitoring system for temperature, humidity, light intensity, and soil moisture level for mushroom cultivation based on the Internet of things (IoT) was developed by (Chong, Chew, Peter, Ting, & Show, 2023). This system can be monitored and controlled via mobile or web applications. Research by (Ariffin, et al., 2021) designed an oyster mushroom house control system using DHT22 temperature and humidity sensors and MCU nodes based on fuzzy logic to control the use of fans and water pumps. The system can be monitored via a web application (Najmurrokhman, et al., 2020). Another system developed by (Adhiwibowo, Daru, & Hirzan, 2020) implemented the Cayenne API to provide temperature and humidity information using the DHT22 sensor. Smart mushroom monitoring system developed by (Pravinthraja, Rozario, Nagarani, & Kavitha, 2018) can measure and control temperature, humidity, and CO_2 in the mushroom farm. Another study by (Kassim, Mat, & Yusoff, 2019) added a light intensity sensor that can be controlled via wireless sensor network.

Other studies related to monitoring systems for the main parameters of oyster mushroom cultivation (Surige, et al., 2021), (Saraswati, Putra, Masjudin, & Alimuddin, 2022). In these studies, monitoring of environmental factors was carried out including temperature and humidity in the mushroom house (Rahman, et al., 2022). Data from sensors is sent to the internet cloud for further display on the application. Even in research by (Surige, et al., 2021), the proposed system can predict harvest time with 92% accuracy. However, these studies only help monitor the situation in the Kumbung or the surrounding environment, but do not support a control system if there are changes in environmental factors that may occur unpredictably. There is also research that monitors humidity and temperature based on WSN and IoT for several Kumbung (Wajiran, et al., 2020). Another study by (Sihombing, Astuti, Herriyance, & Sitompul, 2018) has realized a prototype system for monitoring environmental factors and controlling the temperature of a mushroom house. However, the controls made are limited to spraying water when the temperature exceeds the required threshold.

Therefore, in this study designed a system to monitor and control the temperature, humidity, and light intensity in the Oyster mushroom Kumbung so that the room conditions remain ideal. In the previous research, we have developed a web dashboard that control water quality parameters for Bok Choy hydroponic plants using pH, turbidity, and temperature sensors (Irawati, Ramadan, & Hadiyoso, 2022). In this follow-up research, we are oriented towards Oyster mushroom plants. Mushroom cultivation is influenced by environmental factors which can be measured and monitored and controlled via Android using the MiI App Inventor remotely. This can make it easier for farmers to monitor temperature, humidity, and light intensity. The proposed system uses DHT22 to detect temperature and humidity in Kumbung (Yulizar, et al., 2023), (Bastari, Sembodo, & Wahyudi, 2022). The sensor readings are used to automate temperature and humidity settings by spraying water and controlling the fan. This system can also control the light intensity of the LED lights to maintain ideal light conditions.

3. Research Methods

Fig. 1. shows the design model of proposed system. The proposed system consists of 2 main components: hardware and software. Hardware includes sensing, data collection, data processing and control actions. Meanwhile, the software is responsible for connecting to the Firebase database and displaying data via MiT App Inventor.

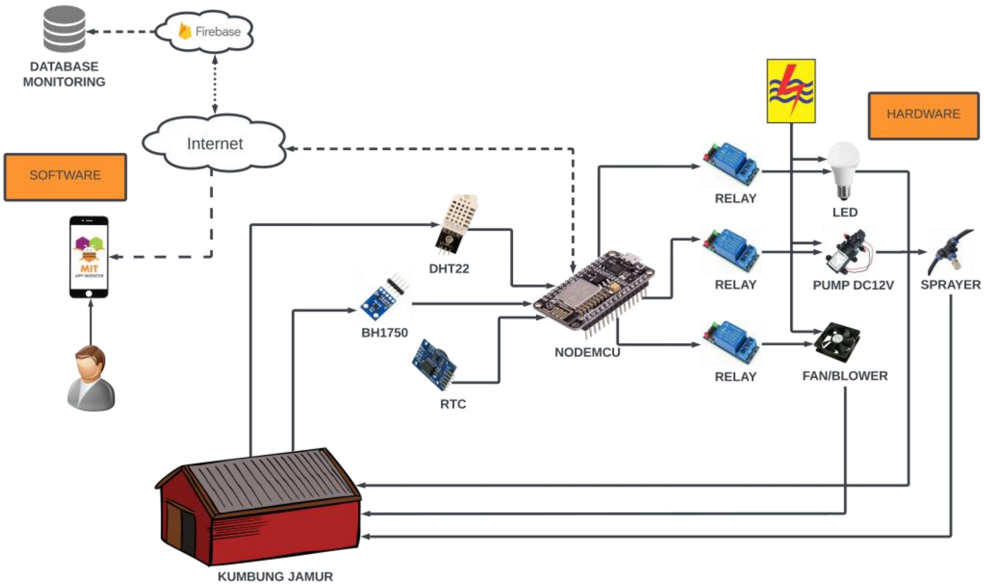

Fig. 1. The Model Design of Proposed System

The following are details explanation of the proposed system presented in Fig. 1.

a. The Hardware

The device to be made is a combination of several components, namely the Real Time Clock (RTC) module, temperature and humidity sensors, light intensity sensors, and relays, then all of these components are controlled using a microcontroller, namely NodeMCU, on the microcontroller the data that has been taken by each component will be collected then will be displayed on the software display which integrated with Firebase. The following is an explanation of each part of the hardware:

1. DHT22 is used to measure temperature and humidity (Adhiwibowo, Daru, & Hirzan, 2020), BH1750 is used to measure light intensity (Yuan et al., 2020), and RTC based NE555 is used to keeps time accurate when the power supply is off. The all installed sensor will provide data that will be sent to nodeMCU for further processing. The DHT22 has been calibrated in its manufacture so that it provides fairly accurate temperature and humidity readings (Awaludin et al., 2021). The DHT22 datasheet shows humidity readings have a tolerance of 2-5% accuracy and temperature readings have a tolerance of ±0.5°C at 0 to 50°C. DHT22 has a sampling frequency of 0.5 Hz. The BH1750 has linear characteristics regarding changes in light which are represented in lux with a calibration factor of 1.2 used for measurement accuracy.
2. The data from the sensors is then collected and processed by NodeMCU. NodeMCU also manages sending data to mobile phones using Wifi communication. Data from the sensors is sent every five minutes.
3. The component of output include relay, led, pump, and fan. A relay is used to activate the dc fan, pump, and led. If the temperature is more than threshold it will turn on the fan to set back the temperature. If the humidity is less than the threshold then the pump will flow water to the sprayer to spray water to adjust humidity. If the light intensity is less than the predetermined

value then the led will be turned on. Furthermore, data from the microcontroller that is connected using a wifi hotspot will be sent to the smartphone via an application designed using the MiT app inventor to monitor and display the data.

b. The Software

The application created using MiT App Inventor which will be integrated with the Firebase database. The application will display data from the sensor, so that the user can monitor the environment parameter inside the Kumbung anytime and anywhere using a smartphone. The application has a digital switch that is useful for manual control if you want to do watering or turn on the LED when the user wants to get the ideal conditions inside the Kumbung.

Figure 2 shows the wiring diagram of the proposed hardware that functions to measure and control the environmental parameters of the Kumbung. The prototype in this study uses components that are easily available in the market with low prices so that it is easy to develop. The size of the device is also an important concern to produce a device with small dimensions so that it is easy to move. The components of this device consist of NodeMCU as a processor, DHT22 temperature and humidity sensor, light sensor BH1750, 4 Channel relay, DC fan, 12 V water pump, and 5-watt LED.

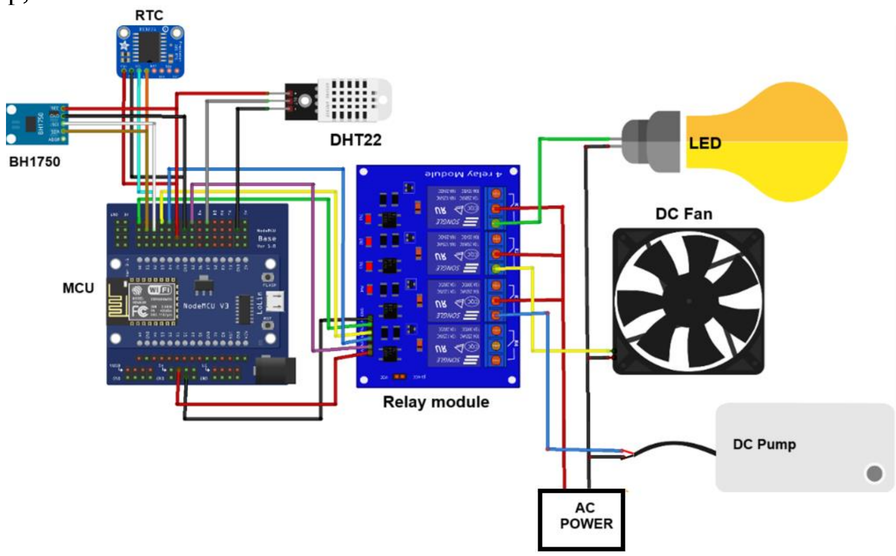

Fig. 2. Wiring Diagram of Proposed Hardware

The workflow of the proposed system is presented in Figure 3. Initially, each component is initialized and followed by connection startup between the ESP8266 and the firebase database via specified internet network. Firebase real time database is a cloud server that can be accessed for free. The application developer initially registers on Firebase to get the database address which we then write to the ESP8266 program. All data is stored as JSON objects. After the communication protocol between Firebase and the microcontroller has been created, Firebase will be connected with HTML, CSS, and JavaScript to display the user interface as a web page. Web pages can be hosted using domains provided by Google Cloud.

Furthermore, the DHT22 sensor and BH1750 sensor will read the temperature, humidity, and light intensity inside the Kumbung. The read data is then processed on the microcontroller to be detected based on the minimum and maximum values of temperature, humidity, and light intensity that have been determined as presented in Table 1. At the same time data from NodeMCU is sent to the Firebase database for storage. The data stored in the Firebase database is then displayed in the application using MiT App Inventor. Figure 4 shows the proposed system that has been implemented in Kumbung.

Table 1 - Defined Rules To Control The Parameters of The Kumbung Environment.

Number	Environment parameter			Device State		
	Temperature	Humidity	Light intensity	Fan	Pump	LRD
1	>23°-28°C	>70%-90%	>300	ON	OFF	OFF
2	<23°-28°C	<70%-90%	<300	OFF	ON	ON
3	>23°-28°C	<70%-90%	>300	ON	ON	OFF
4	<23°-28°C	>70%-90%	<300	OFF	OFF	ON
5	=23°-28°C	=70%-90%	=300	OFF	OFF	OFF

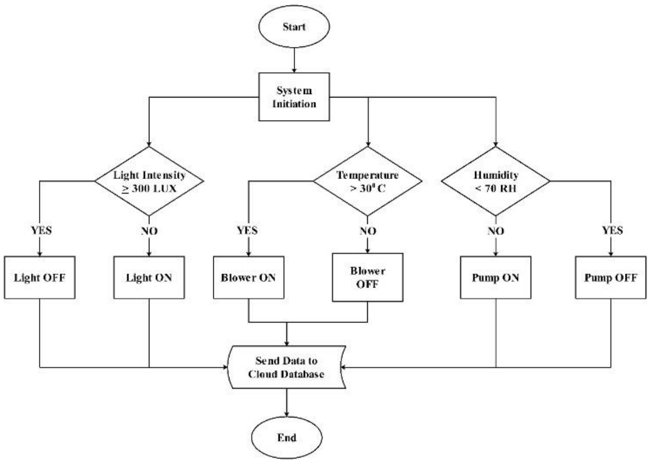

Fig. 3. The Workflow Of Proposed System

4. Results and Discussions

This section contains all scientific findings obtained as research data and followed by brief discussion. This section is expected to provide a scientific explanation that can logically explain the reason for obtaining those results that are clearly described, complete, detailed, integrated, and systematic. The measurement results by the sensor are compared with standard measuring instruments. The results of the performance of each sensor are presented in the following subsection.

A. DHT22 Test Results

In this test, the temperature and humidity read by the DHT22 are compared with the HTC hygrometer. Testing is carried out by placing the sensor and hygrometer in the same room for some time and recorded periodically. From this test, an error value is obtained by calculating the difference in value between the sensor and the hygrometer. Each test was carried out 10 times. Table 2 and Table 3 show the test results of DHT22.

Table 2 - Temperature Test Results

Number	Temperature		Delta	Error (%)
	DHT22	Hygrometer		
1	27.3	27.3	0.0	0.00
2	27.2	27.3	0.1	0.36
3	27.3	27.5	0.2	0.72
4	27.2	27.3	0.1	0.36
5	27.2	27.3	0.1	0.36
6	28.3	28.5	0.2	0.70
7	27.8	28.0	0.2	0.71
8	27.9	28.0	0.1	0.35
9	28.0	28.4	0.3	1.40
10	28.0	28.3	0.2	1.06
Mean Error				0.60

Table 3 - Humidity Test Results

Number	Humidity		Delta	Error (%)
	DHT22	Hygrometer		
1	74	75	1	1.3
2	75	77	2	2.5

3	78	77	1	1.3
4	76	76	0	0.0
5	66	65	1	1.5
6	68	69	1	1.4
7	64	65	1	1.5
8	69	68	1	1.4
9	74	75	1	1.3
10	75	76	1	1.3
Mean Error				1.35

The measurement results from the temperature sensor and hygrometer obtained an average error of 0.6%. The error produced by the DHT22 sensor is relatively small as reported in (Budisanjaya & Sucipta, 2019; Mas et al., 2022). The error can be caused by the sensitivity of the sensor. From the measurement results obtained several variations of the error value. The highest error value obtained is 0.4°C. According to the sensor datasheet, this temperature value is still within the DHT22 error tolerance limit (±0.5°C). So, the sensor still works properly. While the test results from the humidity sensor obtained an average error of 1.35%. The highest error value obtained is 2%. According to the sensor datasheet, the humidity value is still within the DHT22 error tolerance limit (±2%). So that the sensor still works properly to be implemented into the system.

B. Light intensity sensor test result

In the light intensity sensor test, the BH1750 sensor read the light intensity. The results are compared to the lux meter standard. The BH1750 and Lux meter are placed in the same place and use the same light source, namely a 5 watt LED. Table 4 shows the results of testing the light intensity readings by the BH1750 and the lux meter.

Table 4 - BH1750 Sensor Testing

Number	Light intensity		Delta	Error (%)
	BH1750	Lux meter		
1	225	218	8	3.21
2	272	270	2	0.70
3	252	260	8	3.07
4	264	256	8	3.12
5	270	265	5	1.88
6	266	272	6	2.20
7	270	274	4	1.45
8	268	267	1	0.37
9	235	241	6	2.48
10	266	268	2	0.74
Mean Error				1.92

The measurement results from the BH1750 and lux meter obtained an average error of 1.92%. The highest error value is obtained when the light intensity is 8 lux. According to the sensor data sheet, the lux value is still within the BH1750 error tolerance limit (± 20%). So that the sensor still works well and is feasible to be implemented into the system as reported in Budisanjaya & Sucipta, 2019).

C. Testing of Automatic Monitoring and Control Functions

The purpose of the functional test of the device is to find out whether the fan, pump and LED as actuators in automatic control are functioning properly. The actuator can adjust temperature, control humidity, and maintain light intensity in the range of 300 lux. This test also aims to determine the time needed to reach the ideal state of the prototype Kumbung with dimensions of 100 x 50 x 100 cm as shown in Figure 4. The test is carried out by turning on the tool for 10 minutes to find out the changes that occur in the Kumbung. Parameter control and monitoring of Kumbung is carried out using a mobile application as shown in Figure 5.

Details of the test results for each actuator are presented in the following sections.

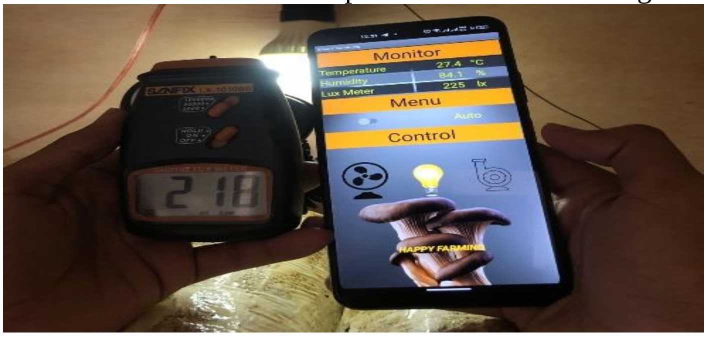

Fig. 5. Control Application Of Environmental Factors In Kumbung

Table 5 presents the results of testing the light intensity control. The test was carried out within 10 minutes with different starting times. From this test it is known that the LED can maintain the light intensity in the Kumbung with an average of ± 300 Lux.

Table 5 - Light Intensity Control Test Results

Test number	t_0	t_1	Δ_t (minute)	$I_0\,(lx)$	$I_1\,(lx)$	$\Delta I\,(lx)$
1	06.00	06.01	1	295	295	0
	06.01	06.02	1	295	294	1
	06.02	06.03	1	294	294	0
	06.03	06.04	1	294	296	2
	06.04	06.05	1	296	298	2
	06.05	06.06	1	298	300	2
	06.06	06.07	1	300	299	1
	06.07	06.08	1	299	298	1
	06.08	06.09	1	298	297	1
	06.09	06.10	1	297	296	1
2	12.00	12.01	1	225	225	0
	12.01	12.02	1	225	226	1
	12.02	12.03	1	226	227	1
	12.03	12.04	1	227	227	0
	12.04	12.05	1	227	225	2
	12.05	12.06	1	225	225	0
	12.06	12.07	1	224	224	0
	12.07	12.08	1	224	225	1
	12.08	12.09	1	225	225	0
	12.09	12.10	1	225	225	0
3	18.00	18.01	1	266	266	0
	18.01	18.02	1	266	265	1
	18.02	18.03	1	265	267	2
	18.03	18.04	1	267	265	2
	18.04	18.05	1	265	263	2
	18.05	18.06	1	263	262	1
	18.06	18.07	1	262	261	1
	18.07	18.08	1	261	261	0
	18.08	18.09	1	261	260	1
	18.09	18.10	1	260	261	1
4	23.50	23.51	1	298	298	0
	23.51	23.52	1	298	296	2
	23.52	25.53	1	297	297	0
	23.53	25.54	1	297	295	2
	23.54	25.55	1	295	295	0
	23.55	25.56	1	295	296	1
	23.56	25.57	1	296	296	0
	23.57	25.58	1	296	297	1
	23.58	25.59	1	297	298	1
	23.59	00.00	1	298	298	0

Symbol description:

t_0 : start time; t_1 : end time; Δ_t : delta time;

I_0 : initial intensity; I_1 : final intensity; ΔI : delta intensity.

Another test is the temperature and humidity control system in the Kumbung using a blower fan. The test was carried out within 10 minutes with different start times. The test results are presented in Table 6. From the test, the most significant temperature change occurred at 12.00 with a temperature of 28.4°C and experienced a change of up to 26.1°C at 12.10 while the slowest temperature change occurred at 07.00 with the temperature of 25.3°C changed to 24.8°C at 07.10. The most likely thing is that the higher the temperature inside the Kumbung, the fan can lower the temperature faster. When the temperature inside the Kumbung gets lower, the adjustment process will also take longer.

Table 6 - Temperature And Humidity Control Test Results

Number	t_0	t_1	T_0 (°C)	T_1 (°C)	ΔT (°C)	H_0 (%)	H_1 (%)	ΔH (%)
1	07.00	07.01	25.3	25.1	0.2	95.4	94.5	0.9
	07.01	07.02	25.1	25.0	0.1	94.5	92.9	1.6
	07.02	07.03	25.0	25.0	0.0	92.9	91.2	1.7
	07.03	07.04	25.0	25.1	0.1	91.2	89.1	2.1
	07.04	07.05	25.1	25.2	0.1	89.1	87.9	1.2
	07.05	07.06	25.2	25.0	0.2	87.9	86.0	1.9
	07.06	07.07	25.0	24.9	0.1	86.0	84.2	1.8
	07.07	07.08	24.9	25.0	0.1	81.9	78.3	3.6
	07.08	07.09	25.0	24.9	0.1	78.3	75.0	3.3
	07.09	07.10	24.9	24.8	0.1	75.0	72.1	2.9
2	12.00	12.01	28.4	28.2	0.2	98.4	97.0	1.4
	12.01	12.02	28.2	28.0	0.2	97.0	94.1	2.9
	12.02	12.03	28.0	27.8	0.2	94.1	92.1	2.0
	12.03	12.04	27.8	27.6	0.2	92.1	90.0	2.1
	12.04	12.05	27.6	27.2	0.4	90.0	87.1	2.9
	12.05	12.06	27.2	27.0	0.2	87.1	85.7	1.4
	12.06	12.07	27.0	26.8	0.2	85.7	83.2	2.5
	12.07	12.07	26.8	26.6	0.2	83.2	80.1	3.1
	12.08	12.08	26.6	26.2	0.4	80.1	77.9	2.2
	12.09	12.10	26.2	26.1	0.1	77.9	75.8	2.1
3	15.00	15.01	28.0	28.0	0.1	94.5	93.0	1.5
	15.01	15.02	28.0	27.8	0.2	93.0	90.0	3.0
	15.02	15.03	27.8	27.7	0.1	90.0	89.7	0.3
	15.03	15.04	27.7	27.6	0.1	89.7	88.0	1.7
	15.04	15.05	27.6	27.6	0.2	88.0	87.5	0.5
	15.05	15.06	27.6	27.5	0.1	87.5	86.7	0.8
	15.06	15.07	27.5	27.4	0.1	86.7	86.0	0.7
	15.07	15.08	27.4	27.4	0.2	86.0	86.0	0.0
	15.08	15.09	27.4	27.3	0.2	86.0	85.7	0.3
	15.09	15.10	27.3	27.2	0.2	85.7	84.7	1.0
4	00.00	00.01	25.7	25.5	0.2	92.7	92.0	0.7
	00.01	00.02	25.5	25.3	0.2	92.0	91.7	0.3
	00.02	00.03	25.3	25.3	0.0	91.7	90.1	1.6
	00.03	00.04	25.3	25.2	0.1	90.1	88.8	1.3
	00.04	00.05	25.2	25.2	0.0	88.8	87.6	1.2
	00.05	00.06	25.2	25.1	0.1	87.6	86.0	1.6
	00.06	00.07	25.1	25.1	0.0	86.0	80.2	5.8
	00.07	00.08	25.1	25.0	0.1	80.2	78.3	1.9
	00.09	00.10	25.0	24.9	0.1	78.3	75.4	3.3
	00.10	00.11	24.9	24.7	0.2	75.4	72.8	3.4

Another result obtained is that the effect of the fan on changes in humidity is quite significant. The most significant change in humidity occurred at 07.00 with a humidity level of 95.4% and experienced a change of up to 72.1% at 07.10 while the longest change in humidity occurred at 15.00 with a humidity of 95.5% and experienced a change of up to 84.7% at 15.10. This happens because the wind that is blown by the fan will affect the humidity in the air inside the Kumbung and cause the dew inside the Kumbung to dry, thereby reducing the humidity inside the Kumbung.

Tests on temperature control show that the fan can stabilize the temperature in a few minutes where the highest temperature change occurs at 12.00 with a temperature of 28.4°C and takes 3 minutes to reach a stable temperature of 27.9°C at 12.03. Variations in temperature at the start of the test are caused by weather conditions in the measurement environment.

Temperature control can also be done by providing water through a nozzle that is sprayed in the Kumbung. The results are presented in Table 7. Based on functional pump testing that has been carried out for 10 minutes with different test times, the nozzle sprayer can produce dew which is used to increase humidity significantly. The fastest change occurred at 15.00 for 66.7% humidity and it took 3 minutes to reach a stable humidity of 75% at 15.03.

Table 7 - Temperature And Humidity Control By Nozzle Test Results

Number	t_0	t_1	T_0 (°C)	T_1 (°C)	ΔT (°C)	H_0 (%)	H_1 (%)	ΔH (%)
1	06.00	06.01	25.3	25.1	0.2	74.2	76.1	1.9
	06.01	06.02	25.1	24.9	0.2	76.1	77.8	1.7
	06.02	06.03	24.9	24.9	0.0	77.8	79.2	1.4
	06.03	06.04	24.9	24.6	0.3	79.2	81.2	2.0
	06.04	06.05	24.6	24.4	0.2	81.2	84.0	2.8
	06.05	06.06	24.4	24.2	0.2	84.0	86.5	2.5
	06.06	06.07	24.2	24.0	0.2	86.5	87.4	0.9
	06.07	06.08	24.0	23.7	0.3	87.4	89.4	2.0
	06.08	06.09	23.7	23.5	0.2	89.4	92.0	2.6
	06.09	06.10	23.5	23.2	0.3	92.0	95.4	3.4
2	12.00	12.01	29.0	28.9	0.1	74.3	75.0	0.7
	12.01	12.02	28.9	28.5	0.4	75.0	77.2	2.2
	12.02	12.03	28.5	28.3	0.2	77.2	77,9	0.7
	12.03	12.04	28.3	28.2	0.1	77.9	79.0	2.9
	12.04	12.05	28.2	28.1	0.1	81.3	85.0	3.7
	12.05	12.06	28.1	28.0	0.1	85.0	87.2	2.2
	12.06	12.07	28.0	27.9	0.1	87.2	92.3	5.1
	12.07	12.08	27.9	27.7	0.2	92.3	95.9	3.6
	12.08	12.09	27.7	27.5	0.2	95.9	96.4	0.5
	12.09	12.10	27.5	27.4	0.1	96.4	98.4	2.0
3	15.00	15.01	28.7	28.5	0.2	66.7	69.4	2.7
	15.01	15.02	28.5	28.3	0.2	69.4	73.5	4.1
	15.02	15.03	28.3	28.1	0.2	73.5	75.3	1.8
	15.03	15.04	28.1	28.0	0.1	75.3	79.8	4.5
	15.04	15.05	28.0	27.8	0.2	79.8	80.2	0.4
	15.05	15.06	27.8	27.8	0.0	80.2	82.5	2.3
	15.06	15.07	27.8	27.7	0.1	82.5	88.3	5.8
	15.07	15.08	27.7	27.5	0.2	88.3	90.2	1.9
	15.08	15.09	27.5	27.4	0.2	90.2	92.4	2.2
	15.09	15.10	27.4	27.0	0.4	92.4	94.5	2.1
4	00.11	00.12	25.8	25.3	0.5	71.8	72.6	0.8
	00.12	00.13	25.3	25.3	0.0	72.6	74.0	1.4
	00.13	00.14	25.3	25.2	0.1	74.0	76.8	2.8
	00.14	00.15	25.2	25.2	0.0	76.8	83.6	6.8
	00.15	00.16	25.2	25.1	0.1	83.6	85.7	2.1
	00.16	00.17	25.1	25.1	0.0	85.7	87.4	1.7
	00.17	00.18	25.1	25.0	0.1	87.4	88.6	1.2
	00.18	00.19	25.0	25.0	0.0	88.6	90.1	1.5
	00.19	00.20	25.0	24.9	0.1	90.1	92.7	2.6
	00.20	00.21	24.9	24.9	0.0	92.7	94.0	1.3

D. Delivery-performance time testing

The process of displaying sensor measurement results to the application is the final stage of testing the functionality of the monitoring and automatic control system. The mobile application can display data in real time and allows the user to control the actuator either automatically or manually. Interested users can open the "smart Kumbung" application on their android phone to monitor temperature, humidity and light intensity and control the actuator either automatically or manually. This test is carried out using a stopwatch to measure the average delay of sending data from the device until the data can be displayed on the database and application is 1.8 seconds. Table 8 shows the results of the delayed test.

Table 8 – Delivery-Performance Time Testing

Test number	Delay (s)

1	2.8
2	1.8
3	2.3
4	1.5
5	1.9
6	1.7
7	0.9
8	2.3
9	1.0
10	2.2
Average	1.8

E. Oyster Mushroom Growth Test in Kumbung

Technical performance testing has been carried out including sensor accuracy, automatic control and monitoring, and delay. The final stage of testing was carried out to find out how oyster mushrooms grow in Kumbung. Oyster mushroom seeds are placed in the Kumbung and automatic control is activated. The growth progress of the oyster mushroom inside the Kumbung was observed from the length of the stem and the width of the body. Table 9 shows the growth of oyster mushrooms in the Kumbung until the 14th day. The first week is the incubation period for oyster mushrooms in baglog (Karmila et al., 2020). In this period, fungal growth is not visible until on day 10 the fungus has a stem length of 2 cm with a body width of 0.5 cm. Overall, it can be seen that the growth of oyster mushrooms placed in the Kumbung can grow well. Maintaining humidity with regular watering has a significant effect on the growth of oyster mushrooms as reported in a study by Saputera et al (Saputera et al., 2020).

Table 9 – Oyster Mushroom Growth Progress

No.	Lifetime (day)	Stem Length (cm)	Fruit Body Width (cm)	Description
1	Day-1	0	0	The new baglog is placed in the Kumbung and is still tightly closed
2	Day-7	0	0	The baglog cover has been removed and mushroom shoots start to grow small around the baglog
3	Day-10	2	0.5	Mushroom shoots grow, fruit bodies have begun to take shape and will become the forerunners of mature mushrooms
4	Day-12	5	7	Adult oyster mushrooms have entered the period for harvesting
5	Day-14	6	10	Oyster mushroom is ready to be harvested

5. Conclusion

In this research, a system for monitoring and controlling environmental factors has been realized in Kumbung for oyster mushroom cultivation. Environmental parameters that are measured and controlled include temperature, humidity, and light intensity. From testing the proposed system, it is known that all parameters can be read by the sensor, processed and forwarded to the database. The designed MiT app inventor can be integrated with the database so that users can monitor and control the parameters of the Kumbung environment. The control system consists of three actuators, including LED, fan, and water pump. When conditions are not ideal, the actuator will work to maintain ideal conditions for the Kumbung environment. From the test results of sending data from the tool to the database, the average value of sending data is 1.8 seconds. This device can be integrated with android applications that have been designed using the MiT app inventor. Real tests on oyster mushrooms show that the mushrooms can grow well. This system is expected to help oyster mushroom farmers in maintaining the quality and quantity of production. Future research requires developing the dimensions of Kumbung to a larger size.

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