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Monitoring and Automation of Temperature Control Based on Mobile Application Technology (MAT) for Precision Oyster Mushroom Cultivation

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ABSTRACT

Oyster mushrooms can usually be found in the forest and grow on rotten logs with temperatures ranging from 21-28℃. The farmers are used the feeling method to measure the range of air temperature in the oyster mushroom cultivation area so that faced the difficulty for controlling the temperature conventionally. This research describes an intelligent device to regulate the air temperature automatically using Peltier TEC-1 12706, which was assisted with ice cubes and aluminum water blocks as cool temperatures automatically online and in real-time. The online system uses the Wi-Fi module type ESP8266-01, and the reading result converts to the digital number as the mobile application shown on the LCD display. Data storage on things speak as a cloud. This research indicates that the level of accuracy of this system compared with similar measuring devices on the market has a standard deviation of error of 0.21 from the total of 30 data in a 1-hour trial. This research was compared with the conventional product (HTC-2) for knowing the sensor accuracy. The experiment result indicated that the sensor accuracy was 93.7%. SHT31 sensor as temperature sensor proved capable to monitor and automatic oyster mushrooms temperature.

1. INTRODUCTION

Oyster mushrooms have been an important food source since ancient times. Enthusiasts have increased daily because this type of food tastes quite delicious as an ingredient of consumption. In addition, oyster mushrooms also have an essential role in human health and promoting quality of life, namely as medicines [1, 2]. Pleurotus sp. or oyster mushrooms, rank second among mushrooms that can be consumed worldwide because of their nutritional value and drug content [3]. This type of mushroom has a good source of non-starch carbohydrates, with high dietary fiber content with a moderate amount of protein and most of it contains amino acids, minerals, and vitamins. The protein content varies from 1.6 to 2.5%, and the niacin content is around ten times higher than other types of wood fungus [4-6]. In biotechnology, oyster mushrooms present a great chance and suitable solution for solving environmental issues that use as myco-remediation, bio-fermentation, biofertilizer, and bioenergy source [7].

The increasing interest in this type of food automatically leads to an increase in the number of requests in the community at both local and international markets. Therefore, cultivating oyster mushrooms to meet market needs is very lucrative [8-11]. Oyster mushrooms can usually be found in the forest and grow on logs that have weathered with certain air temperature conditions. as their original habitat, they do not require much sunlight for stem growth oysters cannot grow in a dark room without sunlight. Oyster mushrooms also need good air circulation to meet the supply of CO_2 [12]. Likewise, various types of fungi require different climatic conditions, so people think mushroom farming is not beneficial because of some of these natural factors [13].

Currently, various mushrooms have been cultivated by farmers who live in areas with temperatures ranging from 21-28℃ [12] and farmers who live in low-lying areas. Farmers living in the lace plains still use conventional methods to regulate the temperature of oyster mushroom cultivation. The farmers only estimate the temperature by looking at the temperature on the part of the mushroom chamber. Oyster mushroom production is not optimal, costs are higher, and yields are not optimal [14]. Hence, some researchers have taken more attention to this field to help the farmer improve innovative technology. According to Abbasi et al. [15] and Karar et al. 16] the increase in world population causes food demand to rise and pushes traditional agriculture to smart agriculture such as IoT, cloud computing, Big data and analytics (BDA), system integration (SI), wireless sensor network (WSN), etc. Smart agriculture can also increase production efficiency and reduce agricultural costs. Smart agriculture applications are developed by Bokingkito and Caparida [17] to monitor water quality in real-time based on a mobile application, detect protein and phosphorus quality using NMR sensor technology [18], nitrogen decision by using GIS [19], mobile devices in intelligent agriculture for nitrogen detection [20], communication technology in IoT-based agriculture [21-24], rainfall modification by ultrasonic sensor [25, 26] and others. Smart agriculture provides many benefits for farmers in realizing sustainable agriculture [27-29].

Many researchers have developed the implementation of mobile application technology on oyster mushrooms by using WSN. Sulistyanto et al. [30] developed the oyster mushrooms cultivation by using fuzzy logic to support the system and control the temperature and humidity. Cikarge and Arifin [31] reported the automatic humidity control through fuzzy logic and Arduino ATM238. Kaewwiset and Yodkhad [32] also reported the temperature and moisture automatic control using Fuzzy logic for mushrooms nursery. Bayrakdar [33] and Pacco [34] reported the monitoring and controlling of agriculture using an online interface. Based on the literature above, the fuzzy method requires a single systematic approach to solve problems in the system. In addition, the fuzzy logic control system needs to be updated regularly and the fuzzy logic algorithm requires a lot of testing for validation and verification. In this study, we use a simple algorithm to read the data and display the data in digital form.

With precision agriculture technology, the farmers must switch to using agricultural technology to grow oyster mushrooms. One of them is by utilizing the internet of things (IoT) technology in the form of a mobile application to conduct online monitoring [11, 35-38]. Several ways can apply appropriate technology for remote monitoring, such as SMS gate way and server computer. However, the SMS gate way has the disadvantage of only sending information in text messages while the server computer has many advantages, such as displaying graphics and storing data on a database [39]. Furthermore, this research aims to create a smart device for automatically regulating air temperature using Peltier TEC-1 12706. this device is equipped with a server computer with a thing speak platform as a database (cloud) and thing view to display temperature data. The online system is done by using the Wi-Fi module type ESP8266-01 that was described in Figure 5 which the working system based on the internet connection. The working of the temperature sensor (SHT31) was described in this experiment. Moreover, the sensor accuracy was calculated by mean, standard deviation, and coefficient correlation.

Furthermore, this research successfully displayed sensor values in the mobile application on the thing-view linked to the thing-speak database. The mathematic approach for determining the sensor accuracy was developed in this study including mean, standard deviation, and coefficient correlation. For knowing the sensor accuracy, this research was compared with conventional products in the market (HTC-2), and the correlation between the SHT31 sensor (this prototype) and HTC-2 (conventional product) was significant. In addition, the comparison result also was calculated with mean and standard deviation with an error value of 0.21. The sensor accuracy in this research is 93.7%.

2. PROPOSED DESIGN

In this section, the oyster mushrooms were controlled and monitored using mobile application technology (MAT) equipped with Sensor SHT31 as a temperature sensor on oyster mushrooms, Arduino Uno, and ESP8266-01 as a microcontroller, and Peltier Fan to regulate air temperature. The Monitoring and Automation of Oyster Mushroom Cultivation Temperature Control begin with three steps: input, process, and output. In the detail, the proposed design can be seen in Figure 1.

Based on Figure 1, The effort to realize this research has begun with determining the material to be used in the study, then designing the system based on the desired work method, and ending with testing to find out the system's accuracy created. Good arrangement in presenting a research result includes several essential things, including hardware design (including research material and system design), research steps, testing tools, and data processing. Figure 1 shown the proposed design in this experiment that including Arduino Uno combined with ESP8266-01, SHT31 sensor, relay, Peltier and fan, thingspeak, and smartphone android. Arduino Uno is used as a microcontroller board based on the datasheet. Arduino Ono has 14 digital input/output pins. SHT31 sensor is a sensor for measuring and reading the temperature of the sample (oyster mushroom). Peltier also called thermo electric cooler (TEC) is used to create a flow of heat / cold at the junction between the two plates. Thingspeak is a cloud system on the internet of things (IoT) system. Relay system is used to control and distribute electricity or known as switch system. Thingview is as a system to visualize the results of thingspeak.

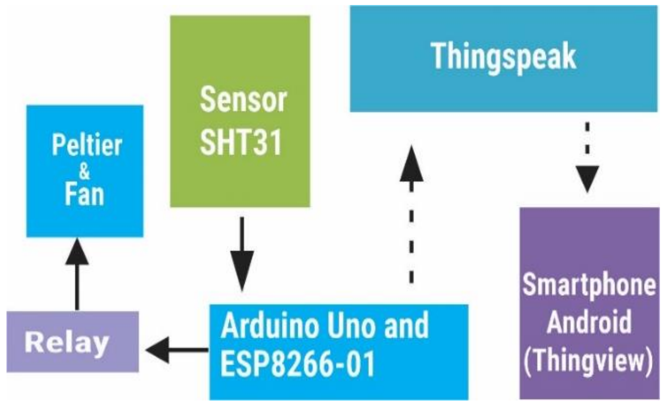


Figure 1. Proposed design of monitoring and automatic temperature control

3. HARDWARE AND SOFTWARE DESIGNING MATERIALS

In this study, the researchers have completed this project with several of the main components of the hardware and software. Hardware construction was included Arduino Uno as a microcontroller board to process data from sensors and provide triggers on temperature regulators, SHT31 Sensors as temperature sensors to read the temperature of oyster mushrooms in real-time, ESP8266-01 as the sender of data to the thing speak database as a cloud, 2-channel relay to regulate Peltier TEC-1 12706, Peltier TEC-1 12706 and aluminum water block to regulate temperature. Software construction was installed with several algorithms for running the computer program. In this study, mobile applications are derived from Thing-speak.

3.1 Hardware DESIGN

Figure 2 shows a block diagram of a monitoring and automatic temperature control applied to oyster mushrooms cultivation. Firstly, the SHT31 sensor reads the temperature in oyster mushrooms cultivation and sends the data to Arduino Uno as a microcontroller which this step is called an input signal process. Secondly, the data from the sensor determined the on / off condition of the relay. When the detected temperature data is more than the set point of 23°C, the temperature control relay will be active so that the cooling system or Peltier will work. The relay will not be active if the temperature is below the set point in this case, Peltier is assisted with ice cubes added to the flow of water that passes through the aluminum water block to absorb heat on one side of the Peltier so that the cooling system is more optimal. The data from the SHT31 will be sent and stored in a thing speak database that can be accessed using a smartphone to display on the mobile application thing view online as long as the system is connected to an internet connection.

From Figure 2, the researcher was created a flowchart of the system which the system starts from the sensor reading the temperature value if it exceeds the set point, the temperature regulator will be active. Data from SHT31 sensor readings was displayed on the mobile application Thing-view. the baseline temperature is 23°C which this temperature is a minimum temperature the oyster mushroom to growth. There are two instructure with code 'Yes' and 'No'. The hardware flowchart can be seen in Figure 3(a). In Mini-system Schematic, the voltage of system can be calculated which this part is designed to be integrated with several circuits in the electrical board. The power supply circuit to power the mini-system with a voltage lowered by ic lm7805 from 12V DC (Volt Direct Current) tos 5V DC, then a relay socket to connect a regulator relay temperature with a mini-system, SHT31 and ESP8266-01 gets a 3.3VDC voltage from the Arduino Uno pin. The electrical supply in detail can be described in Figure 3(b).

3.2 Software design

The software used is called thingview, a mobile application derived from thingspeak that works based on an internet connection. Figure 4 is a flowchart of thingview that starts from the initialization in the program listing then sets the WiFi module ESP8266-01 so that it is configured properly next connects to the nearest WiFi network or internet and sends sensor data to the database to be displayed on the mobile application thingview.

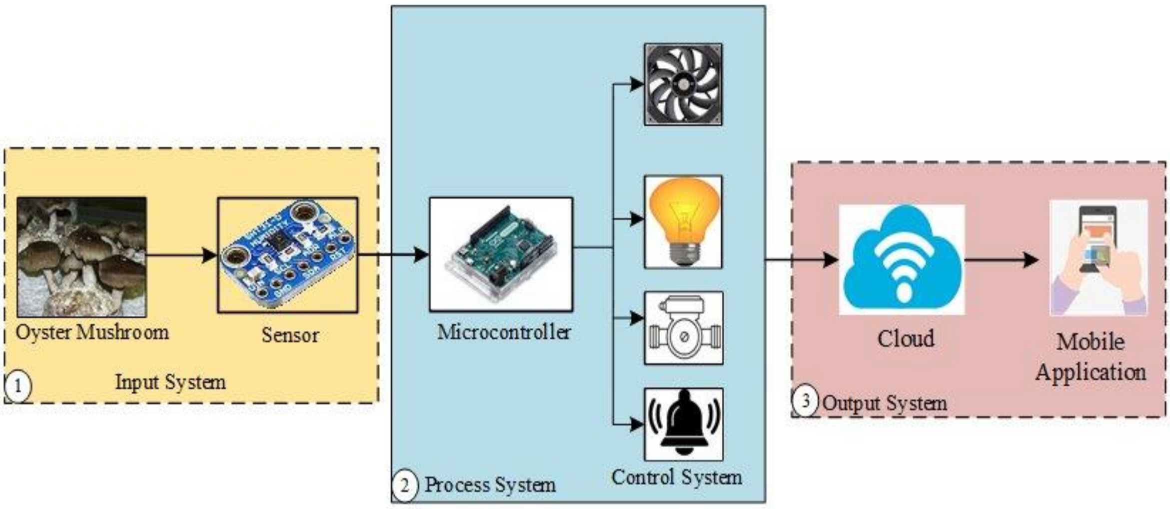


Figure 2. Hardware design block diagram

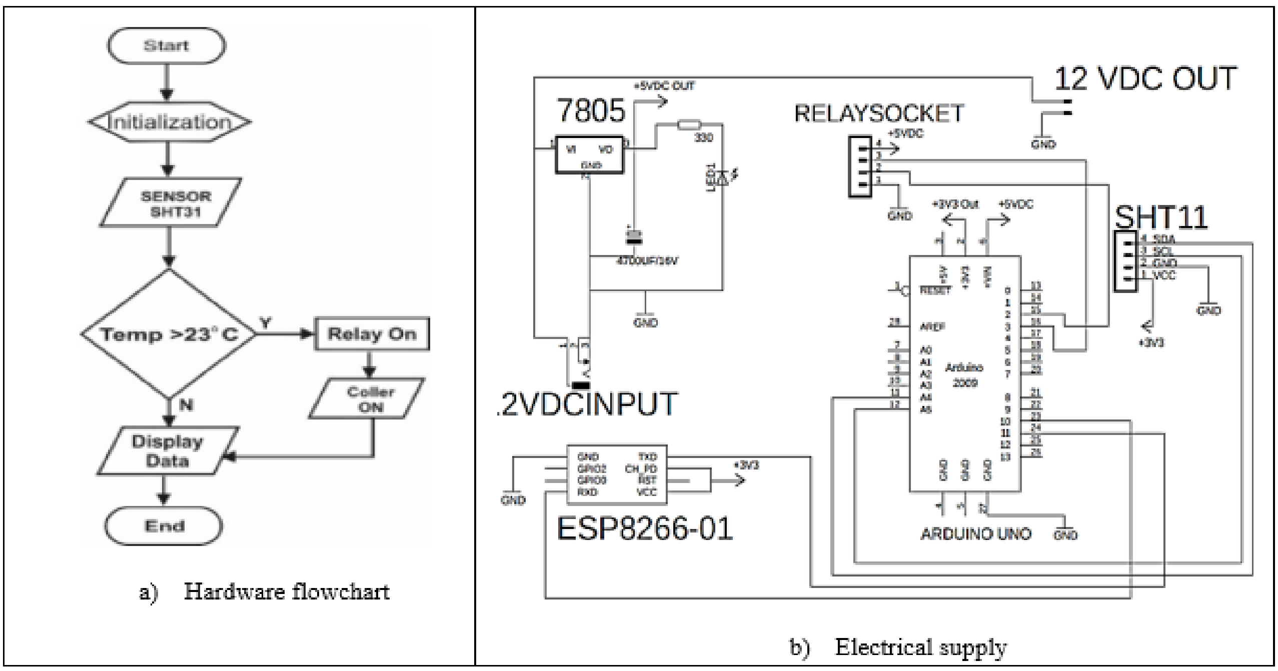


Figure 3. The implementation of hardware in the system: a) hardware flowchart; b) electrical supply

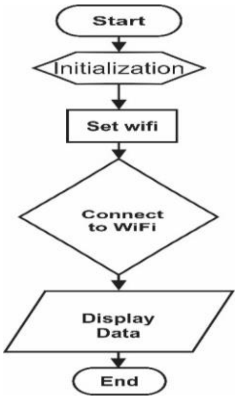


Figure 4. Software flowchart

4. ACCURACY SENSOR APPROACH

4.1 Average formula

Average formula is a term to calculate the central value from data or sample using function average. This term is also called as Mean or middle number in data/sample. average value is used to represent a group that represents the data as a whole. This value can be used to compare the quality of a group of data with other data groups, represent the condition of a group of data, briefly explain the condition of a group of data. In this study, the system was also calculated the error calculation to improve the quality of sensor. As detail, the error calculation formula can be seen in Eq. (1) and the average formula can be seen in Eq. (2).

$$e = |x - y| \tag{1}$$

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i = \frac{e1 + e2 + e3 + e4 + e5}{n} \tag{2}$$

where:
e: Error / difference in sensor measurement
y: Thermo Hygrometer Clock (HTC-2) measurement results
x: The measurement results with the SHT31 sensor
en: Number of measurements with sensors
n: The number of measurements
$\bar{x}$: Average calculation results

4.2 Standard deviation

Standard deviation is generally used to indicate the size of variation or dispersion, this is because the value of the standard deviation has a unit of measure from the source data. the square root of variance by determining each data point's deviation relative to the mean can be calculated by standard deviation. The calculation of standard deviation can be divided into: 1) Determining the value of the variance as Eq. (3). 2) Determining the square root of the variance as Eq. (4).

$$s^2 = \frac{1}{n-1}\sum_{i \cong 1}^{n} (xi - \bar{x})^2 \tag{3}$$

$$s = \sqrt{\frac{1}{n-1}\sum_{i \cong 1}^{n} (xi - \bar{x})^2} \tag{4}$$

where:
s2: Variety or variant of the sample
s: Standard deviation
n: Amount of data
i: Data number (i = 1,2,3, ... n)
xi: data to-i (i = 1,2,3, ... n)
$\bar{x}$: Sample averages

Mathematic approach in this project was relevant with previous work from [40, 41] for determining the time to failure data. The mean and standard deviation are described the failure number in the same graph.

5. RESULT AND DISCUSSION

5.1 Prototype implemented on oyster mushroom

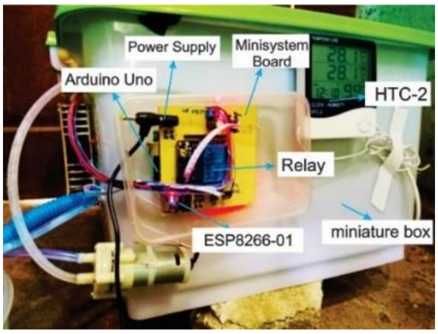
The SHT31 sensor as a temperature sensor and HCT-2 as a hygrometer thermometer is connected with Arduino, as detail can be described in Figure 5. The HCT-2 is used for the comparison between the SHT-13 sensor and HTC-2 which the accuracy of sensor was known from calculation with the equation below. The hardware in this study consists of a mini-system, Arduino Uno, power supply, relay, ESP8266-01, small box, water jet pump, SHT31 sensor, spray nozzle, fan, aluminum block, Peltier and HTC-2. The miniature box was created to do this research with 30 cm of height, 45 cm of width, and 20 cm length. Oyster mushroom was put in the box to create a suitable environment. In the inside box, SHT31 sensor was installed in the middlebox to capture the temperature area. Peltier TEC-1 12706, Fan and water Aluminium block are installed in the inside box. A DC motor rotated the cooling fan according to the operation signal from a computer program. To know the accuracy temperature sensor, the system was installed the HTC-2 to compare data. Mini-system board consists of a power supply, Arduino Uno, ESP8266-01, and relay system. When the sensor starts to read the temperature area, the data sending to Arduino Uno as a microcontroller. SHT31 sensor works with a single serial interface. All of the data can be seen in the mobile application.

According to Figure 5, the miniature box of system was equipped with software system as the program computer that have installed. The result of software testing can be seen in Figure 6(a) which shown a graph of temperature data along with the latest data number sent through ESP8266-01 while a mobile application thing view that can be seen on a smartphone as Figure 6(b).

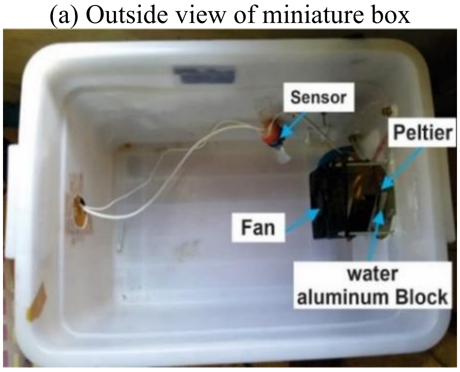
In the temperature controller testing, the results of the temperature control test shown in the different Arduino IDE serial monitor images as detail can be seen if Figure 7(a) and 7(b). When the temperature exceeds the 23°C set point, the words "Cooler Active" will appear and when the temperature is less than the set point the "Cooler" will appear Inactive "as planned in the previous Figure 3.

5.2 Sensor accuracy

The accuracy of the SHT31 sensor was compared to the HTC-2 as the conventional product in the market. The tests carried out in the morning with a frequency of data retrieval 30 times in 1 hour. Then, the test results obtained as in Table 1 contain ($\bar{x}$) error values that are calculated using Eq. (1) and Eq. (2). From the calculation, the average temperature obtained $(\overline{x})$ error sensor comparison between SHT31 and HTC-2 of 0.18.

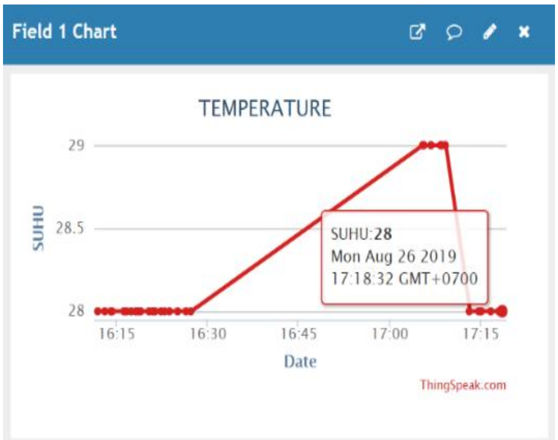


(a) Outside view of miniature box

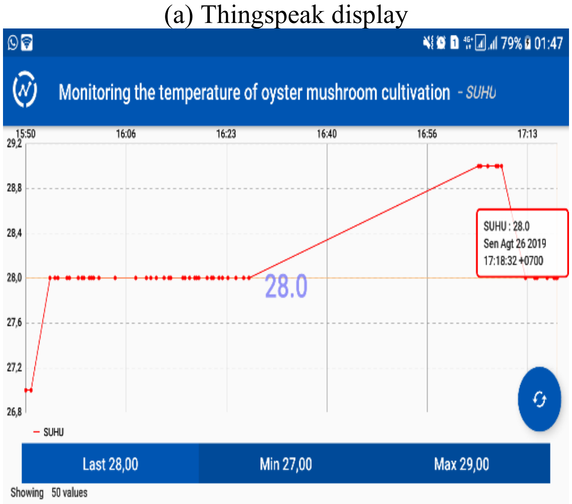


(b) Inside view of miniature box

Figure 5. Miniature box in this study

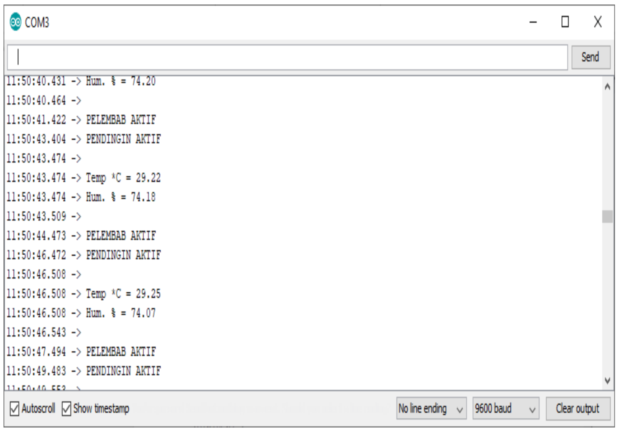


(a) Thingspeak display

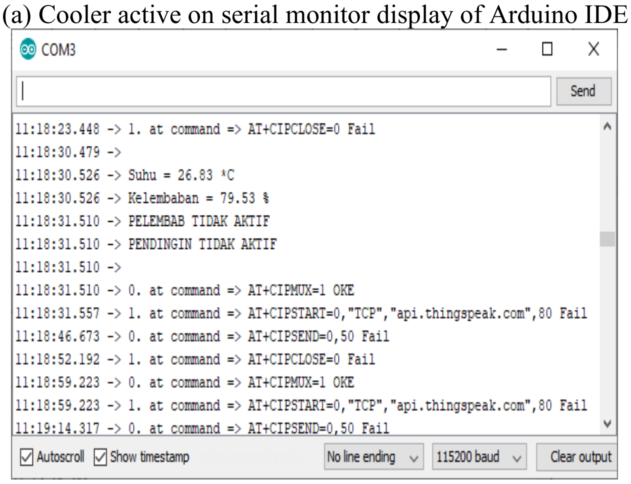


(b) Thingview display

Figure 6. (a) Thing speak display; (b)Thing view display on smartphone



(a) Cooler active on serial monitor display of Arduino IDE



(b) Cooler not active on serial monitor display of Arduino

Figure 7. The different of Arduino IDE serial monitor

From the data in Table 1, the calculation of variance in error variants of temperature (S2) is 0.043 and the standard deviation error of temperature is 0.21. Then, the calculation of the correlation between sensor SHT31 (Prototype) and HTC-2 (Conventional Product). This calculation is to determine the sensor accuracy. The relationship between the sensor reading from the prototype (SHT31) and HTC-1 (conventional product in market) from the equation applies. The coefficient of determination (R2) quantifies the magnitude of the variability of the dependency variables that the model in Eq. (5).

$$R^2 = \frac{SST}{SSE} - 1 \tag{5}$$

where, *SSE* is the sum of squared errors (squared residuals). *SST* is the sum of the squared variation of a dependent variable. the regression model refined the analysis by the R-squared (R^2) value of the coefficient of determination from 0% to 100% as the range of R-squared. A higher explanation of the response data is the higher R-Square (R^2). Furthermore, the determination of the significant difference between sensor SHT31 (Prototype) and HTC-2 (Conventional Product in market) was calculated in statistical analysis using the P-value (Chi-Square test), which P value represents as an analysis of a nonparametric comparison test on two variables (independent variable). The model of P-value can be described in Eq. (6).

$$X^2 = \sum \frac{(Oi - Ei)^2}{Ei} \tag{6}$$

where, Chi square value is X^2, observed value is O^i, and expected value is E^i. In this project, the sensor accuracy found that the R-squared (R^2) value correlation between sensor SHT31 (this prototype) and HTC-2 (Conventional product in market) is 0.937. It means a significant correlation. While, P-value from this study is 0.093 of temperature sensor (SHT31). The correlation in this prototype is linear and the prototype output is an acceptable value. The correlation between sensor SHT31 (this prototype) and HTC-2 (Conventional product in market) can be seen in Figure 8.

Some researchers have been similar way to determine the sensor accuracy with the calculation of the correlation between prototype sensor and conventional sensor in the market. This calculation is available and suitable for determining the accuracy sensor. The previous researches that have used similar way to determine the sensor accuracy can be seen in Table 2.

Table 1. Measurement results and errors

Data number	Time	Temperature (°C)		Error	Variance in error			
		SHT31	HTC-2		xi	$\overline{X}$	xi - $\overline{X}$	(xi - $\overline{X}$)2
1	07:26	25.96	26.25	0.29	0.29	0.18	0.11	0.0121
2	07:28	25.79	26.04	0.25	0.25	0.18	0.07	0.0049
3	07:30	25.55	25.81	0.26	0.26	0.18	0.08	0.0064
4	07:32	25.34	25.54	0.2	0.2	0.18	0.02	0.0004
5	07:34	25.2	25.4	0.2	0.2	0.18	0.02	0.0004
6	07:36	25	25.18	0.18	0.18	0.18	0	0
7	07:38	24.92	25.19	0.27	0.27	0.18	0.09	0.0081
8	07:40	24.83	24.97	0.14	0.14	0.18	-0.04	0.0016
9	07:42	24.76	24.84	0.08	0.08	0.18	-0.1	0.01
10	07:44	24.72	24.81	0.09	0.09	0.18	-0.09	0.0081
11	07:46	24.49	24.69	0.2	0.2	0.18	0.02	0.0004
12	07:48	24.58	24.71	0.13	0.13	0.18	-0.05	0.0025
13	07:50	24.51	24.74	0.23	0.23	0.18	0.05	0.0025
14	07:52	24.37	24.51	0.14	0.14	0.18	-0.04	0.0016
15	07:54	24.14	24.34	0.2	0.2	0.18	0.02	0.0004
16	07:56	24.08	24.2	0.12	0.12	0.18	-0.06	0.0036
17	07:58	24.02	24.21	0.19	0.19	0.18	0.01	0.0001
18	08:00	23.89	23.94	0.05	0.05	0.18	-0.13	0.0169
19	08:02	23.73	23.89	0.16	0.16	0.18	-0.02	0.0004
20	08:04	23.78	23.9	0.12	0.12	0.18	-0.06	0.0036
21	08:06	23.68	23.87	0.19	0.19	0.18	0.01	0.0001
22	08:08	23.59	23.66	0.07	0.07	0.18	-0.11	0.0121
23	08:10	23.55	23.61	0.06	0.06	0.18	-0.12	0.0144
24	08:12	23.54	23.66	0.12	0.12	0.18	-0.06	0.0036
25	08:14	23.48	23.58	0.1	0.1	0.18	-0.08	0.0064
26	08:16	23.3	23.46	0.16	0.16	0.18	-0.02	0.0004
27	08:18	23.36	23.43	0.07	0.07	0.18	-0.11	0.0121
28	08:20	23.39	23.4	0.01	0.01	0.18	-0.17	0.0289
29	08:22	23.39	23.4	0.01	0.01	0.18	-0.17	0.0289
30	08:24	23.39	24.6	1.21	1.21	0.18	1.03	1.0609
$\overline{X}$		24.27	24.46	0.18		∑		1.2518

Table 2. The comparison for determining the sensor accuracy from previous studies

Name of researcher	Finding	Ref
A. F. Bin Omar and M. Z. Bin MatJafri, 2009	The correlation between the actual and measured volume in urine volume. This study was applied to automatically measure the urine volume and turbidity using photodetector sensor. The sensor accuracy is 95.51%.	[42]
G. Rajesh and A. Chaturvedi, 2019	The correlation coefficients were compared based on their estimated values with true values calculated using the slope of the regression line of the data points. The analysis is performed for two typical multivariate environmental sensor network scenarios, namely positive correlation and negative correlation.	[43]
A. Yudhana et al.2021	The correlation between three sensor (ammonia, turbidity, pH) and calculated sensor was applied for measuring the quality human urine. The accuracy sensors are 97.69% of pH sensor, 98.32% of ammonia sensor, and 97.09% of turbidity sensor.	[44]
Q. Xu et al, 2020	The relationships between There DSWP sensor output and water content are significant correlation with R2 of 0.974.	[45]
P. Wang, C. Chen, Y. Wang, D. Cheng, H. Piao, and X. Pan, 2022	Determining the sensor accuracy between sensor CH_4 and CO_2 sensor by using state equivalence correction (SEC) with result 99.79% for CH4 and 99.77% for CO.	[46]
This study	Automatic temperature regulation on miniature oyster mushroom by using SHT31 and compared with HTC-2 (conventional product in market). The sensor accuracy is 83.7% and standard deviation with error value of 0.21. This prototype was successfully applied to regulate air temperature automatically using Peltier TEC-1 12706.	

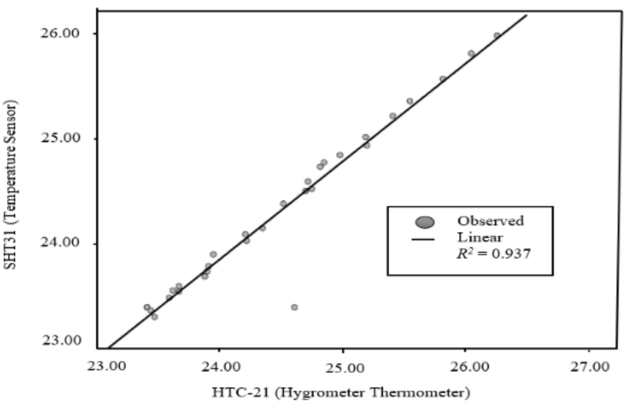


Figure 8. The correlation between sensor SHT31 (this prototype) and HTC-2 (Conventional product in market)

6. CONCLUSION

This study was described the monitoring and automation of temperature control in oyster mushroom. The automatic temperature regulation was applied with a Peltier TEC-1 12706 for helping the ice tube and spray water maintain a temperature in a range from 21 to 28℃. Furthermore, this research successfully displayed sensor values in the mobile application on the thing-view linked to the thing-speak database. The mathematic approach for determining the sensor accuracy was developed in this study including mean, standard deviation, and coefficient correlation. For knowing the sensor accuracy, this research was compared with conventional products in the market (HTC-2), and the correlation between the SHT31 sensor (this prototype) and HTC-2 (conventional product) was significant. In addition, the comparison result also was calculated with mean and standard deviation with an error value of 0.21. The sensor accuracy in this research is 93.7%. The limitation of this study is the installation of the algorithm on the sensor still needs to be improved because the algorithm is very important to improve the quality of sensor work. In addition, the use of the chamber is less flexible so that temperature control and automation is still disturbed by conditions from outside the room.

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