Design of temperature and humidity control system on oyster mushroom plant house based on Internet of Things (IoT)

D A Setiawati*, S G Utomo, Murad and G M D Putra
Studies Program of Agricultural Engineering, Faculty of Food and Agroindustrial Technology, University of Mataram, Mataram, West Nusa Tenggara, Indonesia

*Corresponding author: dihajengs@unram.ac.id

Abstract. Oyster mushrooms are generally cultivated in kumbung covered by black colored plastic. This condition results in high temperatures and low humidity, so mushroom cultivation's failure rate is very high. This research aimed to design and test temperature and humidity control systems' performance based on the Internet of Things (IoT) on Oyster mushrooms kumbung. This study used an experimental method by controlling the microclimate inside the kumbung in Tanjung Karang Permai Sub-District, Sekarbelia District, Mataram City. Research data were analyzed using the Microsoft Excel application. DHT 11 temperature sensor calibration on hygrometer with warm water showed a linear equation of $y = 1.0402 x - 0.1423$ and $R^2 = 0.9905$, whereas using cold water was $y = 1.081x - 1.7457$ and $R^2 = 0.973$. For the humidity calibration linear equation of $y = 1.1203x - 8.3253$ and $R^2 = 0.8606$ was observed. Mean Absolute Percentage Error (MAPE) for warm water and cold water was 3.48% and 3.58%, respectively. In comparison, MAPE for RH was 0.082%. The temperature and humidity control system had been tested at a set point temperature of 28°C and humidity of 85%. The test results showed that mushrooms without a control system were yellowish, dry, and hard texture. Whereas with treatment, the fungus appeared white, wet, and soft texture. The number of mushrooms with treatments was higher and grew more evenly than without treatment. Based on these, it can be concluded that the control system could regulate microclimate inside mushroom kumbung, also successfully monitor it through mobile phones using the Blynk application.

Keywords: Blynk application; control system; oyster mushroom; relative humidity; temperature

1. Introduction
Oyster mushroom is a type of wood fungus with a higher nutrient content than other wood fungus types. They contain higher protein, fat, phosphorus, iron, thiamin, and riboflavin compared to other types of mushrooms also 18 kinds of amino acids needed by the human body and do not contain cholesterol [1]. Therefore, mushroom cultivation is a widely open business for all. Cultivating mushrooms in a small-scale industry is very easy because it does not require many facilities and equipment. The facilities needed is a place for mushroom cultivation, usually known as kumbung. Regular maintenance is needed so that the fungus can grow properly. Generally, the substrate used in the cultivation of oyster mushroom is sawdust [2,3]. Currently, many farmers use baglog as media for oyster mushroom growth. Baglog is a place for breeding mushroom fruit bodies in which there is already media and nutrients that support mushroom growth [4]. The optimal composition of the planting medium for oyster mushroom growth is wood dust (70%), bran (22.5%), lime (6%), and gypsum (1.5%) [5].
In mushroom cultivation, the climatic condition is a required parameter to be considered. Areas with high temperatures have a significantly higher risk of failure than areas with cold climates. Oyster mushrooms can grow and develop well in areas that have low temperatures with high humidity. Spraying water could be applied to maintain the temperature and humidity in the kumbung or cultivation room [6]. According to Rochman [7], the humidity needed in oyster mushroom cultivation is 80% - 90%, with the water condition in the plant substrate between 60% - 65%. Generally, this fungus can grow at temperatures of 24°C - 28°C. This temperature range is required for optimal oyster mushroom growth. These factors cause regions in Indonesia to become ideal places for the growth of various species of fungi.

Oyster mushroom cultivation inside kumbung made from black plastic covers has been commonly practiced [8]. The lack of black plastic cover is high temperature and low humidity during the dry season, especially if planted in the lowlands. This condition results in a very high failure rate of mushroom cultivation. Therefore, efforts are needed to maintain temperature and humidity to comply with mushroom growth using the control system.

Research on temperature and humidity control has been conducted, such as Triyanto & Nurwijayanti [9], which study the simulation stage and has not been applied to mushroom cultivation. Other researchers [10] tried to use the Blynk application for mushroom control based on the fuzzy logic method. There has not been much research combining the two previous systems following the mushroom growth observation. Therefore, this research aimed to design and test the temperature and humidity control system's performance based on the internet of things (IoT) on oyster mushroom kumbung.

2. Methodology
This research was conducted in November 2019 in Tanjung Karang Permai Village, Sekarbela District, 8°35'22.4"S and 116° 04'27.3" E, Mataram City. The experiments were conducted on two series, without the control system and with the control system. Each series was conducted for around three days of observation.

2.1 Materials
The tools used in this research were workshop equipment and simple manufacturing, android mobile phones, laptops, hygrometers, buckets, water pumps, and stationery. The materials used to make kumbung mushrooms included mild steel, bolts, and plastic mulch. The materials for temperature and humidity control circuits included the Arduino Wemos D1 microcontroller, jumper cables, resistors, PC817 optocouplers, DHT 11 sensors, PCBs, hoses, and nozzles. Water was used as a medium to create fog in the mushroom kumbung. Baglog of pre-conditioned oyster mushroom seeds was used as the test material in this study.

2.2 Methods
The method used in this research is an experimental method with direct observation in the field on the kumbung prototype. The design of the temperature and humidity control system tested on the kumbung is shown in Figure 1.
Figure 1. Design of temperature and humidity control system: (1) Arduino Wemos D1 Microcontroller, (2) Temperature and humidity sensor, (3) Relay, (4) Exhaust fan, (5) Optocoupler PC817, (6) Resistor, (7) Humidifier, (8) Dynamo.

2.3 Research Parameter

2.3.1 Mean Absolute Percentage Error (MAPE). The error of the actual and predicted data of the designed control system is necessary to be observed. The equation used for calculating the temperature and humidity sensor's error on the calibration process shows in equation 1.

\[
\text{MAPE} = \left( \frac{100\%}{n} \right) \sum_{t=1}^{n} \frac{|X_t - F_t|}{X_t}
\]

Where:
- \(X_t\) = actual data on t period
- \(F_t\) = prediction data on t period
- \(N\) = number of data

2.3.2 Temperature (T). The temperature was measured using HTC-1 thermohygrometer (accuracy: 1°C or 2°F) and DHT11 sensor. Measurements were applied in the morning (6 am) and afternoon (6 pm) for 3 days of observation.

2.3.3 Relative humidity (Rh). Relative humidity was measured using HTC-1 thermohygrometer (accuracy: 5% RH) and DHT11 sensor. Measurements were applied in the morning (6 am) and afternoon (6 pm) for 3 days of observation.

2.3.4 Oyster mushroom yield. Measurement of oyster mushroom growth was conducted by calculating the number of oyster mushrooms every evening (for 3 days observation) and measure the surface area of oyster mushrooms on the harvest day (3rd days) by using a millimeter block method.

2.4 Experimental Procedure

The procedure of this research can be seen in Figure 2. First, the prototype of the mushroom kumbung was made. After that, the tools, materials, and software needed to create a temperature and humidity control circuit were prepared. The Arduino program language was then created and tested for the DHT11 sensor. If the sensor could work properly, then proceed with sensor calibration. Sensor calibration was conducted by comparing the sensor readings with the thermohygrometer data. Both tools were immersed in water from high temperature to low temperature.
The next process was to determine the setpoint adjusted to mushroom growth conditions, i.e., a temperature of 28°C and humidity of 85%. If the system could not work correctly, then the programming language needed to be rewritten. Furthermore, the temperature and humidity control tests were carried out on the prototype of the mushroom kumbung, and then the research parameter monitoring trials were carried out. The most crucial stage in this research was the trial of temperature and humidity control with the Blynk application connected through Wi-Fi.

When the DHT 11 sensor reads a temperature value of more than 28°C, the information will be forwarded to the microcontroller to command the relay to turn on the nozzle. Conversely, when the temperature sensor was less than 28°C, the sensor sends data to the microcontroller, and the microcontroller ordered the relay to turn off the nozzle. Furthermore, when the sensor reads Rh less than 85%, data was sent to the microcontroller so that the microcontroller orders the relay to turn on the humidifier. Contrarily, when the Rh sensor was more than 85%, data was sent to the microcontroller so that the microcontroller orders the relay to turn off the humidifier.

3. Results & Discussion

3.1 Sensors calibration

3.1.1 DHT 11 Temperature Sensor Calibration. Sensor calibration was conducted to determine the accuracy of the sensor in reading temperature fluctuations. Figure 3 shows the value of the temperature reading from the DHT 11 sensor and thermohygrometer.
Figure 3 shows the comparison of the warm water temperature reading between the DHT 11 temperature sensor and the hygrometer is slightly different. The coefficient determination for both calibrations was nearly achieved 1, which indicates the temperature reading by the DHT 11 temperature sensor was nearly similar to the temperature reading by the hygrometer. These results are in line with the research results. The difference between sensor and thermohygrometer readings can be due to the sensitivity level of the sensor. Handi et al. [10] showed linear DHT 11 temperature data and showed a positive trend of measurement results using a thermometer.

Based on the sensor calibration data in warm water (30-53°C), the Mean Absolute Percentage Error (MAPE) is 3.6%. As for the reading of cold water temperature, the MAPE value is 3.48%. The MAPE results from these two measurements are relatively small, with both results showing a value of less than 10%. According to Pakaja et al. [11], in general, the ability to forecast is excellent if the MAPE value is less than 10% and has good forecasting ability if the MAPE value is less than 20%. This study's MAPE value was much smaller than the DHT 11 calibration results in the previous study of 4.07% [9].

3.1.2 DHT 11 Temperature Sensor Calibration. Calibration was applied by comparing the humidity reading inside the kumbung between the DHT 11 sensor and the hygrometer. The air humidity (RH) was measured between 9 am - 10 pm.

Based on Figure 4, the reading of air humidity inside the kumbung using DHT 11 is relatively similar to the hygrometer. These data comparisons showed a linearity equation of \( y = 1.1203x - 8.3253 \) with a correlation coefficient of \( R^2 = 0.8606 \), nearly achieves 1, indicating the RH from the DHT11 almost close to the hygrometer reading. The difference between sensor and thermohygrometer readings might be affected by the sensitivity level of the sensor. Therefore, it can be concluded that DHT 11 has high accuracy to read air humidity. Based on data calculations, the Mean Absolute Percentage Error (MAPE)
value is 0.812%. The MAPE generated from this calibration is relatively small, less than 10%. Therefore, it can be stated that the sensor monitoring results are close to the actual conditions.

### 3.2 Test performance control system

Figure 5 shows that the average temperature outside the kumbung was 30.1°C, while the average temperature inside the kumbung was 30.2°C. The humidity inside the kumbung was 84.3%, and the humidity outside the kumbung was 70%. The mushroom growth results from the first day to the third day on the kumbung prototype using a temperature control system are presented in Figure 6. It could be seen that the results of the mushrooms are fresher and white compared to untreated mushrooms, where the results of the mushrooms are slightly yellowish, hard texture, and look wilted.

![Figure 5. Temperature and Relative Humidity with control system: (a) Rh inside the kumbung, (b) Temperature outside the kumbung, (c) Temperature inside the kumbung, (d) Rh outside the kumbung.](image)

![Figure 6. Oyster mushroom growth with temperature and relative humidity control system.](image)

Based on Table 2, the highest number of mushrooms was in baglog 3 with 14 mushrooms, then in baglog 1 with 12 mushrooms, and baglog 2 with 9 mushrooms. The total harvested mushrooms were 35 mushrooms, higher than without the control system. The average area of mushrooms under the control system conditions was 32.2 cm². This value was smaller than the area of mushrooms produced without the control system treatment. This condition might happen because the number of mushrooms was higher in the treatment with a control system. Therefore the nutrients requirement also increased that
induced nutrients competition. This condition might cause the growth of the fungus area (hood) to be inhibited.

Table 1. Comparison of the number of mushroom yield and surface area with the control system.

| Bagel | Number of mushrooms | Average mushroom surface area (cm²) |
|-------|---------------------|-------------------------------------|
| 1     | 12                  | 14.0                                |
| 2     | 9                   | 12.3                                |
| 3     | 14                  | 17.7                                |

3.3 Performance of Blynk Application
The test performance was conducted by activating and monitoring the temperature and humidity control system's remotely using cellphones. This research used the Blynk application, a platform for the Mobile OS application (iOS and Android), to monitor temperature and humidity conditions. The primary mechanism of the Blynk application started with the sensor readings that could be read by Android by coordinating through the ESP8266 module installed on the NodeMCU. Furthermore, the reading of each sensor's value by the ESP8266 module was sent to the Blynk server on Android via the Wi-Fi internet network. The Blynk application was functioning when a green symbol appears. Figure 7 shows the Blynk application that displays sensor readings for temperature and humidity inside and outside the kumbung prototype.

The limit of temperature and humidity monitoring distance in this study was only 10 meters from the observations. This condition happened due to the connection between the microcontroller was still using cellphone tethering. Previous research [14] shows a similar thing; the farther the distance, the weaker the Wi-Fi signal. Therefore, for monitoring from a radius of more than 10 m, an additional mini Wi-Fi device must be placed near the device to strengthen the signal. This application's utilization was also successful in previous research by Astutik et al. [15] for Greenhouse monitoring. Future development and utilization of this remote monitoring system eventually will lead to the sustained production of oyster mushroom that contributes to maintaining food security in the community and supporting environmental sustainability.

4. Conclusion
The temperature and humidity control system in the oyster mushroom kumbung has been successfully designed and could work according to the program. The sensor calibration shows that the DHT 11 sensor reading has good accuracy for measuring temperature and humidity. The performance of the mushroom kumbung control system has successfully conducted remotely using the Blynk application.
References

[1] Steviani S 2011 *Pengaruh penambahan molase dalam berbagai media pada jamur tiram putih (Pleurotus ostreatus)*. Skripsi. Fakultas Pertanian Universitas Sebelas Maret Surakarta

[2] Hariadi N, Setyobudi L, and Nihayati E 2013 *Studi pertumbuhan dan hasil produksi jamur tiram putih (Pleurotus ostreatus) pada media tumbuh jerami padi dan serbuk gergaji*. Jurnal Produksi Tanaman, 1(1) 47–53

[3] Suhaeni, Yunus,N M, Nurjannah S, and Sari A 2018 *Pertumbuhan dan Produktivitas Jamur Tiram Putih (Pleurotus ostreatus) pada Media Tanam Sabut Kelapa Sawit (Elaeis guinensis) dan Kulit Durian (Durio zibethinus)*. Prosiding Seminar Nasional Megabiodiversitas Indonesia, April 26–30

[4] Yulianto S 2011 *Budidaya Jamur Tiram (Pleurotus ostreatus) di Balai Pengembangan dan Promosi Tanaman Pangan dan Hortikultura (BPPTPH) Ngipiksari Sleman, Yogyakarta*. Skripsi. Fakultas Pertanian Universitas Sebelas Maret Surakarta

[5] Istiqomah N and Fatimah S 2014 *Pertumbuhan dan Hasil Jamur Tiram Pada Berbagai Komposisi Media Tanam Zira'ah Majalah Ilmiah Pertanian 39(3) 95–99

[6] Djarijah NM and Djarijah AS 2001 *Budidaya Jamur Tiram Pembibitan, Pemeliharaan, dan Pengendalian Hama Penyakit* (8th ed.). Kanisius

[7] Rochman A 2015 *Perbedaan Proporsi Dedak Dalam Media Tanam TeRhadap Pertumbuhan Jamur Tiram Putih (Pleurotus florida)*. Agribis 11(13) 56–67

[8] Putra GMD and Hunaepi H 2014 *Pengaruh penggunaan evaporative pad teRhadap iklim mikro pada rumah jamur tira* (Pleurotus ostreatus) berdinding jerami di musim kemarau. Jurnal Ilmiah Biologi “Bioscientist” 2(1) 88–99

[9] Triyanto A and Nurwijayanti KN 2016 *Pengatur Suhu dan Kelembapan Otomatis Pada Budidaya Jamur Tiram Menggunakan Mikrokontroler ATMega16 Jurnal Teknik Elektro 18(1). doi: 10.24912/tesla.v18i1.292

[10] Handi, Fitriyah H, and Setyawan, GE 2019 *Sistem Pemantauan Menggunakan Blynk dan Pengendalian Penyiraman Tanaman Jamur Dengan Metode Logika Fuzzy*. Jurnal Pengembangan Teknologi Informasi Dan Ilmu Komputer, 3(4), 3258–3265

[11] Pakaja, F, Naba A, and Purwanto 2012 *Peramalan Penjualan Mobil Menggunakan Jaringan Syaraf Tiruan dan Certainty Factor. Eecis 6(1), 23–28

[12] Martiani E, Murad, and Putra GMD 2017 *Modifikasi dan Uji Performansi Alat Pengering Hybrid (surya Biomassa) Tipe Rak. Jurnal Ilmiah Rekayasa Pertanian dan Biosistem 5 (1), 339–347

[13] Kenanga P, Pambudi A, and Puspitasari RL. *Perbandingan Pertumbuhan Jamur Tiram Putih di Kumbung Ciseeng dan Universitas Al-Azhar Indonesia Jurnal Biologi Al-Kauniyah, 7(2), 94–98

[14] Yuliza Y and Panigarbuan H 2016 *Rancang Bangun Kompor Listrik Digital IoT Jurnal Teknologi Elektro 7(3), 187–192. doi:10.22441/jte.v7i3.897

[15] Astutik Y, Murad, Putra GMD, and Setiawati DA 2019 *Remote monitoring systems in greenhouse based on NodeMCU ESP8266 microcontroller and Android. AIP Conference Proceedings, 2199(December). doi:10.1063/1.5141286