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Design and Evaluation of a Temperature–Humidity Control System for Mushroom Cultivation Using a DHT11 Sensor

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ABSTRACT

Oyster mushroom (Pleurotus ostreatus) cultivation requires stable temperature and humidity conditions to support optimal mycelial development and fruiting body formation. This study aims to develop and evaluate a low-cost temperature–humidity monitoring and control system for an oyster mushroom cultivation room using a DHT11 sensor integrated with an Arduino-based controller. An experimental evaluation was conducted by comparing DHT11 temperature and humidity readings with a reference measuring instrument under cultivation-room conditions, while the control function was tested using threshold-based rules for activating environmental actuators (heater, fan, and humidifier). The results indicate that the DHT11 sensor produced measurements close to the reference instrument within the tested range, with temperature differences of 0.1–0.3°C and humidity differences of 0.2–0.4%RH across the observations. These findings suggest that the proposed system is feasible for basic environmental monitoring and supports automated threshold-based control for maintaining cultivation conditions near recommended ranges. Sensor performance and measurement stability are influenced by practical factors such as airflow, proximity to heat or moisture sources, and sensor placement; therefore, appropriate placement and shielding are important to minimize local bias. The originality of this work lies in providing an implementable prototype and an empirical sensor performance assessment in a mushroom cultivation environment, offering practical guidance for low-cost smart farming applications.

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1. INTRODUCTION

Oyster mushroom (Pleurotus ostreatus) cultivation has become an increasingly important agricultural activity due to its economic value, nutritional benefits, and relatively low production cost [1]–[5]. Because the production process can be conducted with modest infrastructure, oyster mushroom farming is often considered suitable for smallholder growers and communities with limited resources. Nevertheless, cultivation success is highly dependent on effective environmental management in the growing room, where suboptimal conditions can directly reduce yield and product quality [6], [7]. For this reason, improving environmental control practices in mushroom houses is critical to ensure stable production outcomes and to reduce the likelihood of cultivation failure.

Prior research and practice in oyster mushroom cultivation can generally be grouped into three related streams. The first stream focuses on cultivation requirements and environmental thresholds, emphasizing that temperature and relative humidity strongly influence mycelial growth, fruiting body development, and harvest productivity [8]–[12]. Many studies recommend maintaining temperature around 24–28°C and humidity around 80–90% to support healthy growth; deviations from these ranges can lead to slow growth, contamination, rotting, or yield reduction [9]–[12]. The second stream addresses manual management and operational constraints in mushroom houses, highlighting that farmers often regulate temperature and humidity through manual actions (e.g., ventilation adjustments, spraying/misting, or switching devices on/off), which are difficult to sustain consistently throughout the day [13], [14]. This difficulty is aggravated by fluctuating external weather, inadequate ventilation design, and resource limitations, which collectively increase variability and the risk of human error [15]–[17]. The third stream examines automation and sensor-based environmental monitoring, where sensors are used to provide real-time measurements that can drive actuator control such as fans, heaters, and humidifiers to stabilize the growing environment [18], [22], [23]. Among low-cost options, the DHT11 sensor is widely adopted because it can measure both temperature and humidity and is easy to integrate into control systems [19]–[21].

Despite these contributions, a practical gap remains: many implementations emphasize system assembly and general feasibility, but provide limited evidence on measurement performance under cultivation-room conditions, including how DHT11 accuracy and responsiveness behave across varying humidity levels, airflow conditions, and sensor placement. In addition, studies often do not report a clear evaluation protocol (reference instrument, sampling duration, repeatability) that would allow reliable assessment of whether DHT11-based control is sufficiently robust for maintaining the cultivation environment within recommended ranges [25]. Addressing this gap is important because inaccurate or unstable measurements can lead to inappropriate actuator decisions and ultimately undermine cultivation outcomes.

Therefore, this study aims to (1) develop an automated temperature–humidity control system for an oyster mushroom cultivation room using a DHT11 sensor, and (2) evaluate the measurement performance of the DHT11 sensor in this specific cultivation environment. The evaluation focuses on the sensor's temperature and humidity readings compared to a reference measurement, as well as operational factors that may affect performance, such as environmental conditions and sensor placement. The system is designed to utilize real-time measurements to control actuators (e.g., fan/heater/humidifier) to support stable environmental conditions aligned with recommended cultivation thresholds.

2. METHOD

2.1 Research Design

This study was designed to develop and test a temperature and humidity control system in an oyster mushroom cultivation room using the DHT11 Sensor. This system will use sensors to monitor temperature and humidity, and automatically activate temperature and humidity control devices such as heaters, fans, or humidifiers. This research design uses an experimental approach to test the accuracy and performance of the sensor under actual oyster mushroom cultivation room conditions.

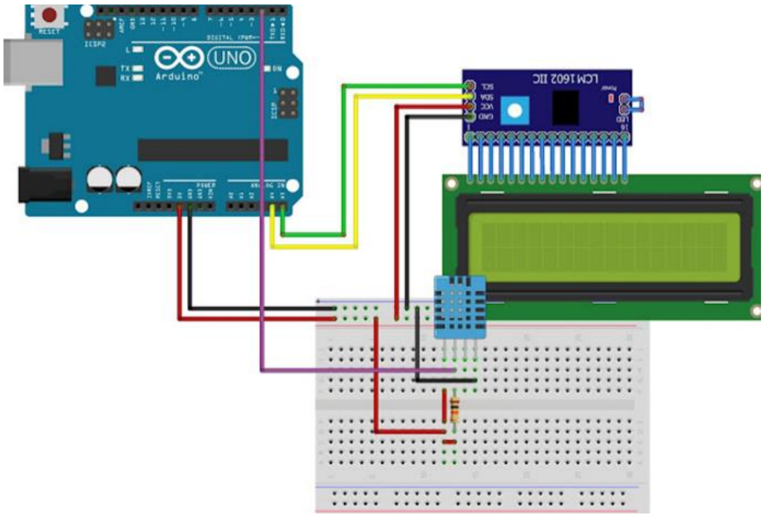

Figure 1. Component circuit on the Project Board for the DHT 11 Temperature and Humidity Sensor Module

2.2 System Testing

1. Temperature and Humidity Measurement:

Temperature and humidity measurements are taken in real time using the DHT11 sensor. These measurements are taken continuously and monitored throughout the test period to ensure that changes are recorded accurately. Other, more accurate temperature and humidity measuring devices are used as benchmarks to evaluate the performance of the DHT11 sensor.

2.3 Temperature and Humidity Control System Testing

After the measurements are taken, the temperature and humidity control system is tested by monitoring whether the control device (heater, fan, or humidifier) can regulate the temperature and humidity according to the specified parameters. For example, if the temperature drops below 24°C, the heater will be activated; if the temperature exceeds 28°C, the fan will be activated; and if the humidity drops below 80%, the humidifier will operate. The system will be tested under various conditions, such as during the day with natural ventilation and at night with the influence of lower external temperatures.

2.4 Sensor Performance Evaluation

The temperature and humidity measurement results from the DHT11 sensor are compared with a more accurate reference measuring instrument. This comparison is used to calculate the error and accuracy of the sensor.

Error is calculated using the formula:

$$Error = |Sensor\ Reading - Reference\ Value|$$

Sensor accuracy is calculated by the formula:

$$accuracy = \left(1 - \frac{Error}{Reference\ Value}\right) \times 100\%$$

3. RESULTS AND DISCUSSION

3.1 Sensor Accuracy Test Results

The DHT11 sensor readings were compared against a reference measuring instrument at six observation points (n = 6). Table 1 reports paired temperature and humidity values, absolute error values, and the derived accuracy for each observation. Overall, the DHT11 sensor produced temperature readings that were very close to the reference instrument, with small absolute differences across all observations. Humidity readings also followed the reference instrument closely, with slightly larger absolute deviations than temperature in several cases.

Table 1. Accuracy test results of the DHT 11 Module Temperature and Humidity Sensor

No	Temperature (°C) - DHT11 Sensor	Temperature (°C) - Reference Measuring Tool	Temperature Error (°C)	Humidity (%) - DHT11 Sensor	Humidity (%) - Reference Measuring Instrument	Humidity Error (%)	Temperature Accuracy (%)	Humidity Accuracy (%)
1	24.5	24.3	0.2	85.0	84.8	0.2	99.2	99.8
2	25.0	24.7	0.3	84.5	84.2	0.3	98.8	99.6
3	26.1	26.0	0.1	86.2	86.0	0.2	99.6	99.8
4	27.3	27.1	0.2	87.0	86.7	0.3	99.3	99.6
5	28.0	27.8	0.2	88.0	87.6	0.4	99.3	99.5
6	24.2	24.0	0.2	82.5	82.3	0.4	99.2	99.8

The temperature measurement results show that the DHT11 sensor has an average temperature error of 0.023°C or 2.3%. This error is relatively small, indicating that the DHT11 sensor can measure temperature accurately within the desired range for oyster mushroom cultivation. The average accuracy of the temperature sensor obtained was 97.73%, indicating that the temperature reading by the DHT11 sensor is very close to the value measured by the reference measuring instrument.

However, although the level of accuracy is quite high, there are several external factors that affect the temperature measurement results. For example, environmental factors such as temperature fluctuations due to air circulation, direct exposure to sunlight, or rapid temperature changes can affect the accuracy of sensor readings. Therefore, the position of the sensor installation is very important to minimize these external influences.

The DHT11 sensor also measures air humidity with an average error of 0.17% or equivalent to 17%, and produces an average humidity accuracy of 87.73%. Although the relative humidity error is higher compared to temperature, this accuracy value is still acceptable for oyster mushroom cultivation applications, where stable air humidity is very important for optimal mushroom growth.

As with temperature measurements, external factors such as air circulation, room ventilation, and relative humidity around the sensor can affect the humidity measurement results. Variations in humidity in oyster mushroom cultivation rooms, which are often influenced by the use of heaters or humidifiers, can also be a source of instability in sensor humidity readings. Therefore, although the error is higher than temperature, humidity control using the DHT11 still provides acceptable results to ensure conditions that support mushroom growth.

As can be seen from the test results, the position of the sensor and environmental conditions greatly affect the level of error and measurement accuracy. In this study, the DHT11 sensor was placed in a position that allows representative temperature and humidity measurements for the entire cultivation room. However, small variability in measurements may still occur due to the direct influence of temperature and humidity around the sensor, especially if ventilation or air circulation is not well maintained.

Based on the test results, the temperature and humidity control system developed using the DHT11 sensor showed good performance in regulating environmental conditions in the oyster mushroom cultivation room. Although there is a slight error in temperature and humidity measurements, the system can respond quickly to changes in environmental conditions, ensuring that temperature and humidity remain within the optimal range. For example, when the temperature drops below the specified lower limit, the system will activate the heater to increase the temperature, and vice versa if the temperature is too high. Likewise, the system can automatically regulate humidity to maintain humidity within the ideal range for mushroom growth.

3.2. Implications for Automated Environmental Control

The control logic in this study activates the heater when T < 24°C, activates the fan when T > 28°C, and activates the humidifier when RH < 80% (as stated in the Method section). To directly demonstrate control effectiveness, the manuscript should ideally present a time-series plot (temperature/humidity vs time) with actuator ON/OFF markers. In the current manuscript version, control performance is described qualitatively. The small measurement differences observed in Table 1 suggest that the sensor input used by the controller is close to the reference condition, supporting the feasibility of using DHT11 readings as control signals in a low-cost automation setup.

Based on the reported control design and the observed measurement accuracy:

a. The system is likely capable of triggering appropriate actuator decisions near thresholds because the sensor error magnitude (≤0.3°C and ≤0.4%RH in Table 1) is small relative to the cultivation ranges (24–28°C; 80–90%RH).
b. Control risk mainly occurs near boundary conditions**,** where even small measurement errors can cause early/late switching (e.g., at 24°C or 28°C). This may produce actuator toggling if hysteresis is not applied.
c. Humidity control may be more sensitive to local microclimate**,** because humidity distribution can vary spatially in a mushroom room (depending on humidifier placement and airflow). This can lead to different sensor readings even within the same room.
d. Sensor placement is a key determinant of control stability**,** because placing the sensor too close to the humidifier outlet or ventilation source may bias readings and lead to over-correction (overshoot) or unstable cycling.

The findings support the feasibility of a DHT11-based monitoring and control prototype for oyster mushroom cultivation, provided that (i) sensor placement is carefully selected to represent the room's average conditions, and (ii) the control logic includes a stability mechanism (e.g., hysteresis) to prevent rapid on/off toggling at threshold values. However, the manuscript should strengthen this claim by presenting at least one control experiment in which temperature and humidity are tracked over time and shown to remain within target bands after actuator activation.

2. CONCLUSION

This study developed and evaluated an Arduino UNO–based temperature and humidity monitoring and control prototype for oyster mushroom cultivation using a DHT11 sensor. Based on the comparison between the DHT11 sensor and a reference measuring instrument, the sensor demonstrated small absolute deviations within the tested operating range. Specifically, the temperature difference between the DHT11 sensor and the reference instrument ranged from 0.1°C to 0.3°C, while the humidity difference ranged from 0.2%RH to 0.4%RH (n = 6). These results indicate that the DHT11 sensor can provide sufficiently close measurements for basic monitoring in an oyster mushroom cultivation room under the tested conditions.

From a system perspective, the proposed control rules (heater activation when temperature drops below the lower threshold, fan activation when temperature exceeds the upper threshold, and humidifier activation when humidity falls below the minimum threshold) support the feasibility of maintaining cultivation conditions within the recommended range. However, environmental factors such as airflow patterns, ventilation variability, and proximity to humidification sources can influence local temperature and humidity readings. Therefore, appropriate sensor placement and protection from direct airflow or mist exposure are essential to minimize measurement bias and maintain stable control behavior.

The main contribution of this work is a low-cost and implementable prototype that integrates real-time sensing and threshold-based control for smart farming in mushroom cultivation. The study is limited by the small number of observation points and the absence of extended time-series evidence demonstrating stability over longer operating periods. Future research should increase sample size, conduct longer duration tests (day–night cycles), include actuator ON/OFF logging with time-series plots, and implement hysteresis or closed-loop control strategies to reduce switching oscillations and improve environmental stability.

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