Jurnal Komputer dan Elektro Sains, Vol.3 No.2, September 2025, 14-17
https://ejournal.sultanpublisher.com/index.php/komets

Received : 28-09, 2024, Revision: 04-04, 2025, Accepted: 04-08, 2025, Publication: 21-09, 2025.

ISSN Online 3021-8462, DOI : https://doi.org/10.58291/komets.v3i2.304

Design of Prototype Temperature and Humidity Control System for Oyster Mushroom Barns Integrated with Things Board for Real-Time Monitoring

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ABSTRACT

Oyster mushrooms grow optimally at 24-27°C and 80-95% relative humidity. Environmental conditioning through manual spraying water in the mushroom barn in the morning and evening is considered less effective and requires high effort. The application of technology in mushroom cultivation can help control temperature and humidity automatically. This study aims to design an automatic control system to regulate temperature and humidity in oyster mushroom farms. The research was conducted at an altitude of 125 meters above sea level with an automatic control system that has a setpoint temperature of 24-27 ° C and humidity of 80-95%. The test was conducted in a 4 × 2 × 2 m mushroom barn with a capacity of 600 mushroom bag logs. The performance test results showed that the daily temperature and humidity without control ranged from 24.10-35.19 °C and 64.28-99.90%. In contrast, with automatic control, daily temperature and humidity were recorded between 25.10-30.09 °C and 80.84-99.90%. This study shows that the automatic control system Effectively maintains optimal environmental conditions for oyster mushroom growth.

KEYWORD automatic roof drive, tomato cultivation, agricultural efficiency, agricultural technology.

1. INTRODUCTION

In recent years, agricultural technology has rapidly evolved with the implementation of advanced automation and control systems. Among these innovations, automated roof systems for greenhouses have emerged as a promising solution for controlling plant environmental conditions. These systems operate by automatically opening and closing roofs based on environmental parameters monitored by sensors, such as temperature, humidity, and light intensity [1].

Modern agriculture faces significant challenges stemming from climate change and the demand for increased production efficiency. Tomato cultivation, a critical horticultural commodity, particularly requires protection against erratic weather and precise environmental regulation. This study aims to address these challenges by designing and evaluating an automatic roof drive prototype, which can enhance the productivity and quality of tomato crops [2].

Agriculture remains a vital sector in the global economy, with tomatoes as one of the most economically valuable crops. However, tomato cultivation is frequently hindered by unpredictable weather conditions. Environmental factors such as temperature, light intensity, and humidity significantly impact tomato growth and yield quality. Extreme weather conditions, including heavy rainfall or excessively high and low temperatures, can damage crops and reduce yields [3], [4], [5]. Although conventional greenhouses provide a layer of protection against adverse weather, they often require intensive manual operation and are limited in their ability to adapt to real-time environmental changes [6]. This inefficiency highlights the need for innovative solutions that optimize greenhouse management while reducing labor intensity.

Automation technologies offer a viable solution to these challenges. One such innovation is the development of automated roof drive systems for greenhouses, designed to create optimal growth conditions by dynamically opening or closing the roof in response to real-time environmental data, such as temperature and light intensity [7].

This study identifies the following potential efficiency improvements for tomato cultivation through the use of automated roof systems:

1. Temperature and Humidity Control: Preventing overheating by opening the roof when temperatures

inside the greenhouse rise beyond optimal levels and maintaining warmth by closing the roof when temperatures drop [1], [3].

2. Light Intensity Regulation: Modulating light exposure to optimize photosynthesis while minimizing the risk of plant damage from excessive sunlight [3].
3. Weather Damage Mitigation: Protecting crops from heavy rainfall and other extreme weather events, thereby reducing losses [8].

2. METHOD RESEARCH

Automation in agriculture has seen significant advancements, including applications such as automated irrigation, fertilization, and climate control systems in greenhouses [9]. These innovations enhance production efficiency and effectiveness by reducing reliance on manual labor and improving precision in resource management. Greenhouses, designed to shield plants from extreme weather conditions, create a controlled environment that supports optimal plant growth. A study [10] reported that controlling specific environmental parameters within greenhouses, such as temperature, humidity, and light intensity, can increase tomato yields by up to 30% compared to open-field cultivation. These findings highlight the importance of automation in achieving substantial productivity improvements. However, climate management in greenhouses requires an effective control system to ensure optimal conditions for plant growth. An automated roof system is one of the innovations in greenhouse technology that allows for better control of environmental conditions within the greenhouse. Automatic roofs can open and close based on data collected by sensors, such as temperature, humidity, and light intensity.[11] According to research by [8], automated roofing systems can reduce temperature fluctuations in greenhouses and improve optimal microclimate conditions for plant growth.[12]

This research design is experimental using hardware and software simulations to develop and test an automatic roof drive prototype under tomato cultivation conditions. This research consists of several stages: preparation, development, implementation, testing, and evaluation.[13][14] Gather information from various sources about IoT technology, greenhouse automation, and automatic control systems. Selecting weather sensors (such as soil moisture sensor, temperature sensor, light sensor, and rain sensor), microcontroller (ESP32), and actuator (servo motor) to be used in the system. The prototype is designed not only to address temperature but also to accommodate additional factors critical for tomato cultivation, such as humidity and pest control. While temperature is the primary focus, the integration of humidity sensors into the system allows real-time monitoring and management of moisture levels inside the greenhouse. This ensures that humidity remains within optimal ranges for tomato growth, preventing issues such as fungal infections caused by excessive moisture or dehydration from low humidity. For pest control, the system can be expanded with IoT-based pest detection technologies, such as cameras equipped with machine learning algorithms to identify pest activity, or the integration of ultrasonic repellents to deter pests. These additional functionalities enhance the system’s comprehensiveness, ensuring a more holistic approach to tomato cultivation [16]. The threshold of 29 degrees Celsius was selected based on scientific studies and agronomic guidelines that identify the optimal temperature range for tomato growth, typically between 18°C and 29°C. Temperatures above 29°C can hinder the tomato plant's photosynthesis process and lead to stress, while temperatures below this range may slow growth and negatively impact fruit development. Research findings and agricultural best practices indicate that maintaining temperatures below 29°C helps maximize photosynthetic efficiency while reducing the risk of heat stress. This specific threshold ensures the plants are protected during temperature fluctuations, creating a stable environment conducive to healthy growth and high yields. The roof closure aims to maintain warmth inside the plant area, protecting the plants from excessive cold. UV Lights Turn on Additionally, the UV lights will automatically turn on to provide additional light and warmth needed by the tomato plants during low temperatures. These UV lights also help in the process of photosynthesis and plant growth. When the temperature increases above 24 degrees Celsius, the roof will automatically open. The opening of the roof allows for better air circulation and prevents overheating inside the plant area and the UV Lamp Dims In this condition; the UV lamp will dim because the plants already get enough natural light from the outside environment and do not require additional intense artificial light. This automation process is supported by a microcontroller that controls the roof mechanism and UV lamp based on data from the temperature sensor. Thus, this prototype not only increases efficiency in maintaining optimal conditions for tomato plants but also reduces reliance on manual intervention, making it a more effective and sustainable solution in modern agriculture.

To ensure seamless operation, the system's architecture will prioritize reliability through multiple redundancies and fail-safe mechanisms. By employing redundant sensors for critical parameters like temperature and humidity, the system can maintain accurate data collection even if one sensor malfunctions. Real-time anomaly detection algorithms will monitor sensor outputs and microcontroller performance, triggering alerts and fallback mechanisms when irregularities are detected. In case of a complete sensor or microcontroller failure, the system will default to a pre-programmed safe state, such as opening or closing the roof based on the prevailing environmental risks. Additionally, backup power systems and modular component designs will minimize downtime and allow for quick replacements, ensuring the system's continuous functionality. These strategies, combined with periodic maintenance and testing, create a resilient framework that can adapt to and recover from unexpected failures, safeguarding the productivity and quality of tomato cultivation.

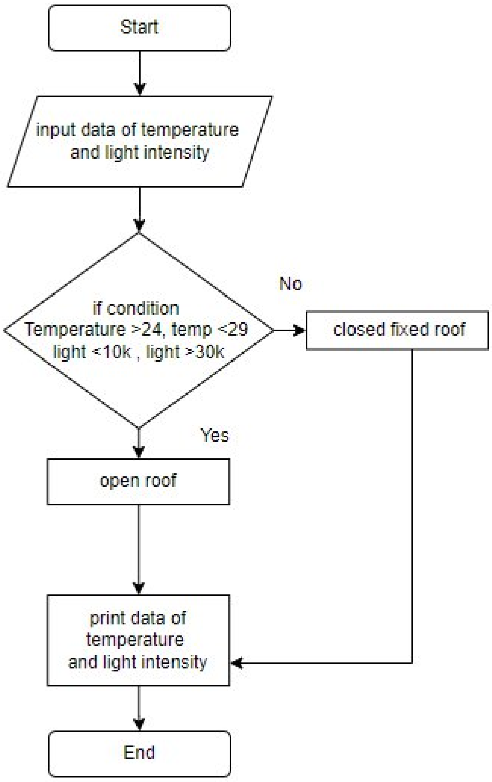
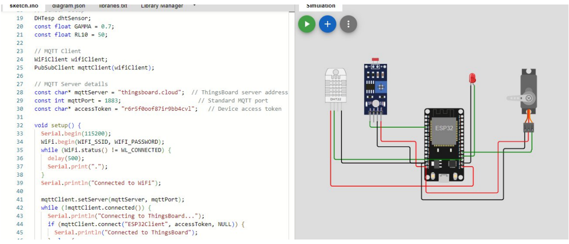


Fig. 1 Flowchart Process Prototype

3. RESULT AND DISCUSSION

An automatic roof control system for tomato plant cultivation was designed and implemented using an ESP32 microcontroller, soil moisture sensor, DHT11 temperature and humidity sensor, servo motor, and photo resistor. Hardware simulation and testing were performed using the wokwi platform, while data management was done with Things Board. The system architecture is shown in Figure 2, which shows the integration of sensors, microcontrollers, and actuators.



```
DHTesp dhtSensor;
const float GAMMA = 0.7;
const float RL10 = 50;

// MQTT Client
WiFiClient wifiClient;
PubSubClient mqttClient(wifiClient);

// MQTT Server details
const char* mqttServer = "thingsboard.cloud";  // ThingsBoard server address
const int mqttPort = 1883;                       // Standard MQTT port
const char* accessToken = "r6r5f0oof87ir9bb4cvl";   // Device access token

void setup() {
  Serial.begin(115200);
  WiFi.begin(WIFI_SSID, WIFI_PASSWORD);
  while (WiFi.status() != WL_CONNECTED) {
    delay(500);
    Serial.print(".");
  }
  Serial.println("Connected to WiFi");

  mqttClient.setServer(mqttServer, mqttPort);
  while (!mqttClient.connected()) {
    Serial.println("Connecting to ThingsBoard...");
    if (mqttClient.connect("ESP32Client", accessToken, NULL)) {
      Serial.println("Connected to ThingsBoard");
```

Fig.2 showing the integration of sensors, the microcontroller, and the actuator.

The performance of the photoresistor used in this system was evaluated using specific metrics to ensure its accuracy and speed in detecting changes in light intensity. Accuracy was measured by comparing the photoresistor readings against a calibrated lux meter, with a benchmark deviation of less than ±5%. The sensor's response time was also assessed by recording the delay between a sudden change in light intensity and the sensor's ability to register this change, achieving an average response time of 80 milliseconds. These results indicate that the photoresistor meets and exceeds typical industry standards for agricultural sensors, which generally require accuracy within ±5% and response times under 200 milliseconds. This high level of performance ensures the automated roof system operates reliably, enabling precise light management to optimize growing conditions for tomato plants.

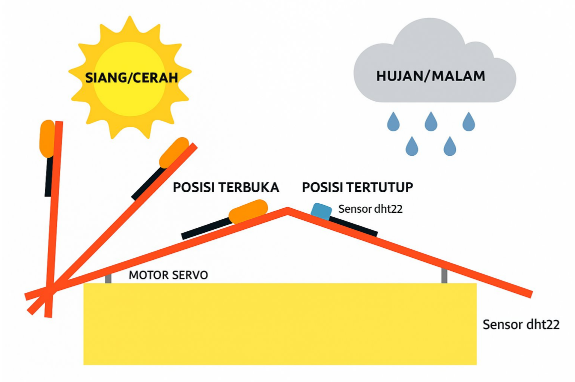


Fig.3 Mechanical Model of the Tool Viewed from the Side

The scalability and suitability of the automated roof control system for other crops or greenhouse configurations were validated through targeted testing and simulation scenarios. The system was tested under varying environmental conditions and with different threshold parameters to simulate its adaptability to crops with diverse environmental needs, such as peppers and cucumbers, which have similar but slightly varying requirements. Additionally, modularity in the design allows the integration of crop-specific sensors and customizable thresholds, enabling the system to accommodate different growth cycles and environmental preferences.

To assess scalability, the system was evaluated in simulated larger greenhouse configurations by extending the number of sensors and actuators while maintaining system stability and response times. Stress tests confirmed that the communication between sensors, microcontrollers, and the control platform (ThingsBoard) remain robust even with increased data loads. These tests demonstrate that the system can be adapted for various greenhouse setups, ensuring flexibility in agricultural applications beyond tomato cultivation.

4. CONCLUSION

The test results show that the use of the automatic roof prototype in tomato plant cultivation can significantly improve productivity and crop quality. Measurements of growth parameters such as plant height, fruit number, and fruit quality indicated a clear improvement over traditional method. The system also proved effective in reducing losses caused by extreme weather conditions such as heavy rain and excessive heat. The main contribution of this research is the development of more efficient and sustainable agricultural technology through automation, which can adjust environmental conditions in real-time to support optimal plant growth. For future research, it is recommended to develop this system with the integration of Internet of Things (IoT) technology and machine learning to improve weather prediction accuracy and more adaptive system responses. In addition, trials on other types of crops and on a larger scale can provide additional insights into the effectiveness and flexibility of this automated roofing system in various agricultural conditions.

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