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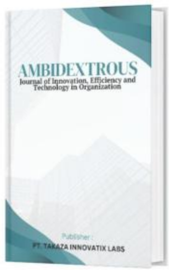

Design and Construction of a Rice Drying System Using Microcontroller-Based Canopy Control

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Abstract : *Rice drying is an important post-harvest process for maintaining grain quality. However, conventional sun-drying methods depend heavily on weather conditions and require continuous manual supervision, particularly to protect the grain from sudden rainfall. This study aims to design and develop a microcontroller-based rice drying system equipped with an automatic canopy and remote monitoring functionality. The research employed a Research and Development (R&D) approach consisting of needs identification, system design, implementation, testing, and evaluation. The proposed system uses an ESP32 microcontroller integrated with a DHT22 sensor for temperature and humidity measurement, a Light Dependent Resistor (LDR) for light intensity detection, and an FC-37 rain sensor for rain detection. A servo motor is used to control the canopy, while a DC blower supports air circulation during the drying process. An I2C LCD provides local information, and a Telegram Bot enables real-time remote monitoring. The test results showed that the DHT22 produced temperature measurement errors ranging from 0.98% to 1.38% and humidity measurement errors ranging from 1.33% to 1.54% compared with reference instruments. The LDR and FC-37 sensors successfully detected environmental conditions and triggered the canopy and blower according to the programmed control logic. The system automatically opened or closed the canopy based on light and rain conditions, while the blower operated during the drying process and was deactivated when rain was detected. The Telegram Bot also successfully transmitted system status information in real time. These results demonstrate that the proposed system can integrate environmental sensing, automatic canopy control, and IoT-based monitoring to support rice drying and reduce the need for continuous manual supervision.*

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Introduction

Rice is a major food commodity in Indonesia, playing a strategic role in maintaining national food security. The quality of the rice harvest is significantly influenced by post-harvest stages, one of which is the drying process of the unhusked rice. At the farmer level and in small-scale rice mills, the most widely used drying method is conventional sun-drying. This method is relatively simple and inexpensive, but it is highly dependent on volatile and unpredictable weather conditions, requires an uncertain drying time, and carries the risk of reducing the quality of the unhusked rice due to rain or high humidity. During the drying process, farmers must remain vigilant to ensure the unhusked rice is immediately secured in case of rain; if careless, the dried unhusked rice risks re-wetting (Bahri & Ristian, 2023).

The development of sensor and microcontroller technology opens up opportunities for the implementation of automated monitoring and control systems that can reduce direct human involvement in supervision, while simultaneously streamlining time and energy through Internet of Things (IoT)-based monitoring accessible via smartphone (Suhu et al., n.d.). One solution that can be implemented is the use of canopies as protection for the drying area. Canopies function to protect grain from rain and excess moisture, while still allowing the drying process to take place when weather conditions are favorable (Kobandaha et al., 2018). By utilizing a microcontroller-based control system, canopy operation can be carried out automatically based on environmental conditions detected by sensors, and drying process parameters can be monitored continuously through an IoT platform (Hiendro et al., 2025).

A review of previous research indicates that there are still gaps that have not been fully addressed. First, most automated canopy systems use only one or two sensors, typically rain and light sensors, so the accuracy of weather recognition is less than optimal. Second, most similar systems rely on third-party applications like Blynk for control, which rely on external connections and accounts. Third, not many systems integrate humidity sensors, even though this parameter is crucial for ensuring air conditions after rain (Kustiawan et al., 2025). Previous research on automated canopies has also generally focused on residential comfort or general crop protection (Rizkiana et al., 2025; Nugroho et al., 2024; Surya, 2023; Walke et al., 2026), without specifically targeting the post-harvest stage of rice, which is sensitive to rain and requires a combination of light, temperature, humidity, and rain parameters simultaneously.

Based on these problems, this study aims to design and build a rice drying system using ESP32 microcontroller-based canopy control that integrates DHT22, LDR, and FC-37 rain sensors simultaneously, equipped with manual control mode via push button, and utilizes Telegram Bot as a remote monitoring medium without relying on paid third-party applications. This system is expected to be a more effective and affordable alternative solution for farmers to reduce the risk of grain damage due to weather changes while reducing dependence on manual supervision.

Research methods

This research uses the Research and Development (R&D) method to design, develop, and test a prototype of a rice drying system using microcontroller-based canopy control. The research stages include: (1) identification of efficiency and automation problems in rice drying management; (2) literature review of previous research, sensor technology, and ESP32-based automation systems; (3) prototyping through sensor and actuator integration to test initial functionality; (4) hardware and software design; (5) component assembly according to the schematic; (6) tool testing; and (7) data analysis to draw conclusions.

System Design

The system is designed with ESP32 as the main control unit that receives, processes, and analyzes data from all sensors. The DHT22 sensor reads temperature and humidity, the LDR sensor detects light intensity, and the FC-37 rain sensor detects the presence of rainwater. Control logic: if rain is detected, the canopy is automatically closed, the blower is turned off, and the buzzer is activated. If it is not raining, the system checks the LDR value; above the threshold of 1500 (bright conditions) the canopy is opened and the blower is activated, below or equal to 1500 (dark/night conditions) the canopy is closed but the blower remains active to help with unfinished drying. Push buttons are provided as manual control mode, a 16×2 I2C LCD for local monitoring, and a Wi-Fi-connected Telegram Bot to send data on temperature, humidity, light, rain, canopy status, and blower status in real-time.

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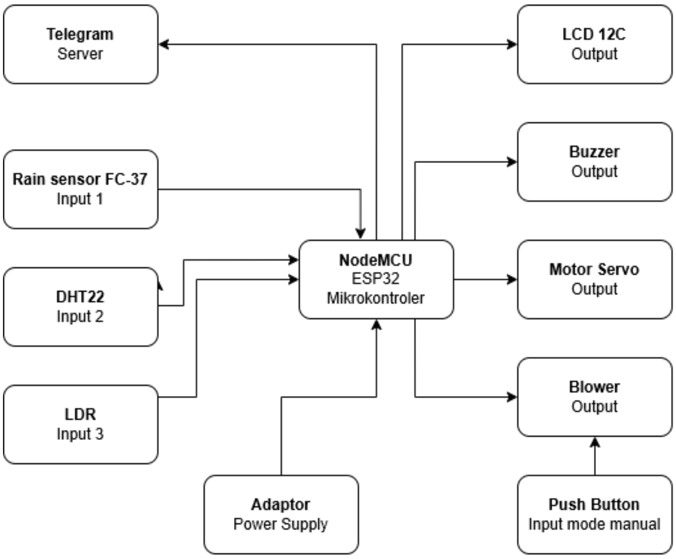

Figure 1. System block diagram

The hardware was realized in a small-scale prototype consisting of a wooden frame and base, a drying chamber, an automatic canopy, environmental sensors, actuators, and an electronic control room. The canopy is driven by a servo motor, a rain sensor is installed on the upper canopy, the control room contains an ESP32, a relay, and an I2C LCD, while the drying chamber contains a DHT22 sensor, an LDR, a 12V DC blower, and a buzzer as a warning indicator.

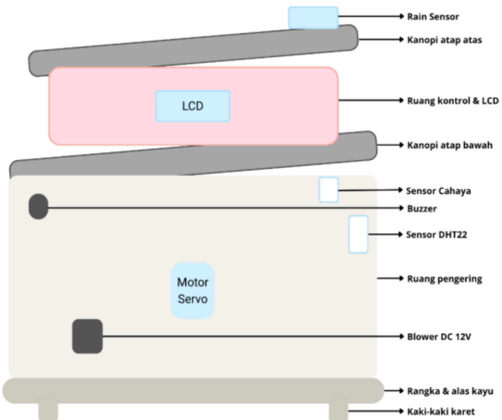

Figure 2. System prototype design

Components and Software

The system components include an input/sensor group (DHT22, FC-37 rain sensor, LDR, push button), an actuator group (servo motor, I2C LCD, buzzer, 12V DC blower), an ESP32 microcontroller, and Arduino IDE, Telegram, and Wokwi software for circuit simulation before implementation on hardware.

Testing Scenario

Testing was conducted to determine whether the sensors, actuators, and monitoring system functioned according to program logic and were integrated into both automatic and manual functions. Scenarios were developed based on sunny, rainy, and nighttime conditions, with observations of sensor readings, servo movements, blower/buzzer/LED conditions, LCD displays, and Telegram notifications. The accuracy of the DHT22 was calculated as the percentage error against the benchmark:

$$Error(\%) = [(Sensor - Comparator)/Comparator] \times 100\%$$

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Results and Discussion

DHT22 Temperature and Humidity Sensor

The test was conducted 10 times at different times. The temperature readings compared to a digital thermometer (Table 1) showed an error of 0.98%–1.38%.

Table 1. DHT22 temperature sensor test results

No	Time	DHT22(°C)	Thermo(°C)	Err(%)
1	07.55	27.7	29.0	1.38
2	07.57	27.7	29.8	1.34
3	08.12	27.4	30.9	1.29
4	08.15	27.5	32.0	1.25
5	08.30	27.5	32.7	1.22
6	13.01	28.0	33.4	1.20
7	13.17	28.0	32.9	1.22
8	18.11	23.3	29.5	1.26
9	18.20	23.7	34.0	0.98
10	19.03	23.7	34.0	1.36

Humidity readings compared to a digital hygrometer (Table 2) show an error of 1.33%–1.54%. The small error range in both tables indicates the DHT22's accuracy is sufficient for monitoring environmental conditions in a rice drying system.

Table 2. DHT22 humidity sensor test results

No	Time	DHT22(%)	Hygro(%)	Err(%)
1	07.55	74	72	1.33
2	07.57	72	72	1.37
3	08.12	70	75	1.41
4	08.15	68	75	1.45
5	08.30	66	75	1.49
6	13.01	64	62	1.54
7	13.17	66	62	1.49
8	18.11	69	32	1.43
9	18.20	71	34	1.39
10	19.03	73	34	1.35

LDR Sensor

The ADC value decreased as light intensity decreased (Table 3). The system consistently opened the canopy when ADC > 1500 and closed it when ADC ≤ 1500, thus the LDR proved reliable as a basis for canopy position control.

Table 3. Light sensor (LDR) test results

No	Time	ADC	Condition	Status
1	07.55	3250	Bright	Succeed
2	07.57	3180	Bright	Succeed
3	08.12	3025	Bright	Succeed
4	08.15	2890	Bright	Succeed
5	08.30	2750	Dim	Succeed
6	13.01	1800	Dark	Succeed
7	13.17	1200	Dark	Succeed
8	18.11	950	Dark	Succeed
9	18.20	780	Dark	Succeed

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No	Time	ADC	Condition	Status
10	19.03	650	Dark	Succeed

FC-37 Rain Sensor

Ten tests under dry (HIGH) and wet (LOW) conditions showed the sensor accurately detected changes in conditions (Table 4). When rain was detected, the canopy automatically closed, the blower turned off, and the buzzer activated; once dry, the system returned to following the LDR readings.

Table 4. Test results of the FC-37 rain sensor

No	Time	Mark	Condition	Status
1	08.10	HIGH	Dry	Succeed
2	08.25	LOW	Wet	Succeed
3	08.48	HIGH	Dry	Succeed
4	09.00	LOW	Wet	Succeed
5	09.20	HIGH	Dry	Succeed
6	10.15	LOW	Wet	Succeed
7	10.20	HIGH	Dry	Succeed
8	14.20	LOW	Wet	Succeed
9	14.30	HIGH	Dry	Succeed
10	17.44	LOW	Wet	Succeed

System Test Results Analysis

All sensors and actuators functioned well and were integrated with each other. The DHT22 sensor read temperature and humidity stably with minimal error, and the data was successfully displayed on the I2C LCD and sent to the Telegram Bot. The LDR sensor and the FC-37 rain sensor consistently provided canopy and blower control responses that matched the program logic in all scenarios. The servo motor opened/closed the canopy properly, both automatically and manually via push button. The blower was active during drying and remained on at night if the grain was not yet dry, and turned off when rain was detected. The Telegram Bot integration worked well in sending all system status information in real-time.

These findings reinforce similar research that shows the combination of environmental sensors with automated microcontroller control is effective in protecting crops from weather changes (Hariyanto et al., 2024; Hiendro et al., 2025), while also addressing the shortcomings of previous systems that generally rely on only one or two sensor parameters (Kustiawan et al., 2025) or focus on residential comfort rather than post-harvest rice (Rizkiana et al., 2025; Nugroho et al., 2024). By integrating three types of sensors simultaneously and a Telegram Bot that does not rely on paid third-party applications, this system offers a more comprehensive and accessible approach for small-scale farmers.

Conclusion

A rice drying system using a microcontroller-based canopy control was successfully designed and implemented using ESP32 as a control center, capable of automatically controlling the opening and closing of the canopy based on environmental conditions, as well as providing a manual mode via push button. The DHT22 sensor, LDR, and FC-37 rain sensor work according to their functions with a DHT22 reading error in the range of 0.98%–1.54%, and sensor data is used as the basis for controlling the servo motor, blower, buzzer, and LED indicator. An IoT-based monitoring system using Telegram Bot was successfully implemented so that users can receive information on system conditions in real-time via smartphone. All components work in an integrated manner so that the system is able to support the rice drying process to be more effective, efficient, and reduce the risk of grain damage due to unpredictable weather.

Further research is recommended to add a grain moisture sensor, a larger capacity canopy drive motor, data logging features, and alternative energy sources such as solar panels so that the system can operate independently in rice fields far from electricity sources.

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