

Design and Construction of an Automatic Rice Crackers (Rengginang) Dryer Based on the Internet of Things

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Abstract

The traditional process of drying rice crackers still depends heavily on weather conditions, especially sunlight, which often becomes an obstacle during the rainy season. This research aims to design and develop an automatic rice crackers (rengginang) dryer based on the Internet of Things (IoT) that can operate autonomously and be monitored through a website. The system uses an ESP32 microcontroller as the main controller, a DS18B20 temperature sensor to detect temperature, heaters as heating elements, and fans to distribute and cool the air inside the drying chamber. Temperature control is performed automatically using a Decision Tree algorithm, allowing the system to turn the heaters and fans on or off according to the detected temperature conditions. The temperature data and system status are sent in real time to a Firebase-backed website, enabling users to remotely monitor the drying process. Based on testing results, the device can maintain a stable temperature between 55 and 80 degrees Celsius with a reliable control response, effectively reducing drying time to approximately four hours compared to the one-to-two-day duration required by the traditional manual method. This system is expected to assist small-scale businesses in increasing production efficiency, reducing weather dependency, and becoming an innovation in the application of IoT technology in the food-processing industry.

Keywords: Rice Crackers Dryer; Internet of Things; ESP32; DS18B20; Decision Tree; Website Monitoring

1. Introduction

Drying is a preservation method that has long been used in every stage of rice cracker processing. Drying, or dehydration, removes part of the water content from a cracker by evaporating most of the water it contains through the application of heat energy [1]. In practice, however, the traditional sun-drying process still faces significant obstacles, particularly during the rainy season, when unpredictable weather conditions frequently interrupt the drying schedule [2]. An innovative solution is therefore needed to overcome this weather dependency while still allowing remote monitoring and control of the drying process.

In the era of rapid technological development, the utilization of information technology has become a key element, and the Internet of Things (IoT) has generated growing demand for how this technology can benefit human activities and improve efficiency. An IoT-based cracker dryer offers added value by reducing the time required for drying and eliminating dependency on weather and sunlight conditions. In addition, using such a device in the drying process can reduce contamination risk, since the process relies on a controlled sensor-based temperature system rather than open-air exposure [3].

Several related studies have explored IoT-based automatic dryers for various food commodities. Puja Kusuma et al. [4] built a microcontroller-and-IoT-based banana (sale) dryer that controls temperature using a heater and fan and provides monitoring through the Thingier.IO platform, achieving a drying time of about 5 hours, faster than the traditional method, although the system used a simple on/off control without a web-based real-time monitoring and analysis system. Frans et al. [5] developed a solar-cell-powered salted fish and cracker dryer controlled by Arduino, improving efficiency and reducing dependency on conventional energy, but without a real-time data monitoring system. Prasetyo et al. [6] designed a rotary-type rice and corn dryer prototype using an ESP32, DS18B20 and DHT22 sensors, and PID control, achieving high precision in maintaining moisture content below the required thresholds, though the mechanical structure was relatively complex and costly. Sunarto et al. [7] built an IoT-based cracker sun-drying device using LDR, DHT11, and RTC sensors with Telegram notifications, which still depended on weather and light conditions rather than an enclosed, temperature-controlled oven. Alfian Bahrul Muhit and Widiyasono [8] developed a Smart Oven for moringa leaves using DHT22 and Blynk for remote monitoring, but relied on conventional threshold-based control and the Blynk platform rather than an adaptive decision-based algorithm and real-time Firebase web monitoring.

Based on a review of these related studies, most existing IoT-based drying systems still rely on conventional control methods such as simple on-off switching or basic PID control, and relatively few have applied an intelligent decision-making algorithm; in addition, several systems only display temperature and humidity data without an automated analysis that adapts to the drying time and condition. The main distinguishing feature of this study is the application of a Decision Tree algorithm to automatically control the temperature and drying time of rengginang crackers, combined with real-time, Firebase-based web monitoring that allows users to observe the drying process remotely. Based on this background, the research problem addressed in this study is how to design and build an automatic rengginang cracker dryer system based on the Internet of Things that can operate automatically according to a user-defined duration. Accordingly, this study aims to design and build a functional IoT-based automatic rengginang dryer system using an ESP32 microcontroller, a DS18B20 temperature sensor, and a Decision Tree control algorithm, capable of maintaining a stable drying temperature and providing real-time remote monitoring through a website.

2. Research Methods

This research was conducted at two locations. The first location was a home-industry cracker producer on Jl. KS Tubun Gg 7, Samarinda Kota Subdistrict, Samarinda, East Kalimantan, used as the site for observation and interviews with the business owner and workers. The second location was the researcher's residence in the Loa Bakung area of Samarinda, which served as the primary site for further development and comprehensive prototype testing, selected for its ease of access, time and cost efficiency, and security during the development process. The research was carried out over a period of approximately six months, from May to October 2025. The object of this research is the monitoring and design of an automatic rengginang cracker dryer based on the Internet of Things, using an ESP32 microcontroller as the main controller, a heater as the heating element, a DS18B20 sensor for temperature measurement, and fans for air circulation inside the drying oven.

2.1. Research stages

The system was developed using the waterfall development method, consisting of several interrelated stages: data collection, requirement analysis, system design, implementation, testing, and maintenance, as illustrated in Fig. 1. Data collection was carried out through direct observation at the cracker producer's site, interviews with the business owner and workers regarding recurring drying problems such as weather dependency and inconsistent results, and a literature study of relevant theories, prior research, and technical documentation for the hardware and software components used.

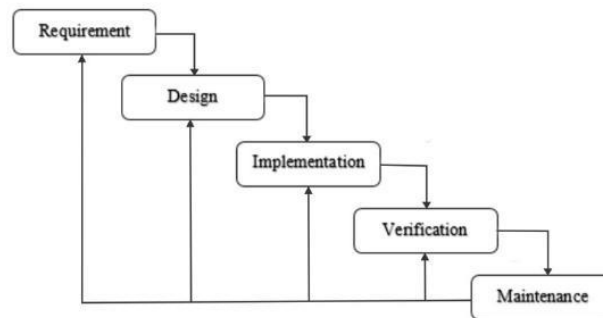


Fig. 1: Research development flow

Based on this data collection, the identified system requirements were grouped into four categories: drying-process requirements (stable, automatically controlled temperature that does not depend on sunlight, with faster and more consistent drying); monitoring requirements (real-time temperature monitoring through a local LCD display and remote monitoring through an IoT website); control requirements (automatic heater and fan control based on temperature, with an alarm for completion or abnormal conditions); and device requirements (a Wi-Fi-enabled microcontroller, an accurate temperature sensor, relays to drive the heater and fan, and a real-time database).

2.2. Tools and materials

The hardware components used in the development and testing of the system are summarized in Table 1.

Table 1: Tools and materials

No.	Component	Function
1	ESP32 Devkit	Acts as the main controller of the system.
2	DS18B20 Temperature Sensor	Measures the drying-chamber temperature as input for the control logic.
3	Fan 12V	Distributes hot air and cools the oven box when the temperature exceeds the target.
4	Heater 50W (x4)	Heats the drying chamber to reach and maintain the target temperature.
5	LCD 16x2 I2C	Displays the real-time temperature and drying time locally on the device.
6	Buzzer	Provides an audible alarm marking the start and completion of the drying process.
7	Relay 2-Channel and 1-Channel	Electronically switches the heater/fan and buzzer components.
8	Step-Down Module (LM2596)	Steps down the supply voltage to the level required by each component.
9	Power Supply	Provides the main current source for the microcontroller and other components.
10	Drying Oven Box	The enclosed chamber in which crackers are placed for automatic, remotely monitored drying.
11	Google Firebase Realtime Database	Cloud backend storing temperature data and device status and powering the web dashboard.

2.3. System architecture and control logic

The overall system architecture, illustrating the interaction between the ESP32 microcontroller, the DS18B20 sensor, the heater and fan actuators, and the Firebase-based web dashboard, is presented in Fig. 2.

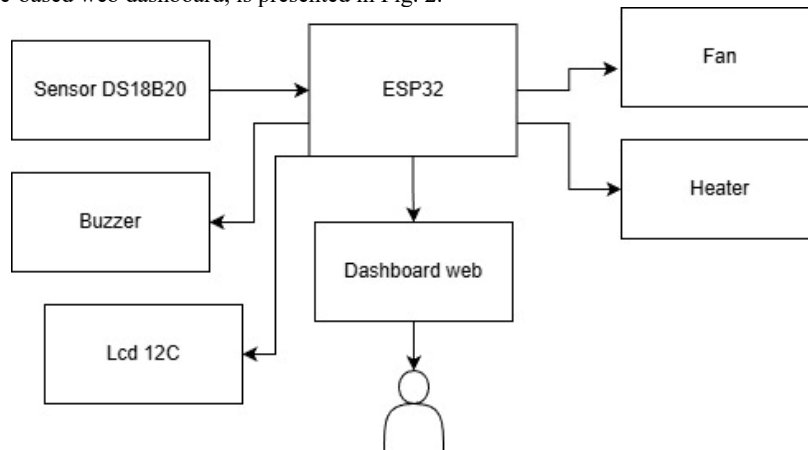


Fig. 2: System block diagram

Temperature control in this system is implemented using a Decision Tree algorithm, a machine-learning method based on a tree-structured decision process that classifies data into branches according to specific conditions until reaching a final decision (leaf node), with each branch representing an if-else rule the system uses to determine the most appropriate action for a given input [9]. In this study, the temperature value read by the DS18B20 sensor is evaluated by the ESP32 firmware, which then decides whether to switch the heater and fan on or off according to three temperature branches relative to a user-defined target temperature: if the reading exceeds the target by more than 5 degrees Celsius (an overheat condition), the heaters are switched off and both the distribution fan and the cooling fan are activated; if the reading exceeds the target by up to 5 degrees Celsius, the heaters are switched off while only the distribution fan remains active; and if the reading is at or below the target, both heaters and the distribution fan are activated to raise the temperature. Because this control logic is executed and stored locally in the ESP32's memory, the heater and fan continue to operate correctly even if the Wi-Fi connection to the web dashboard is temporarily lost.

System evaluation was conducted through several testing scenarios: (1) temperature sensor accuracy testing, comparing the DS18B20 reading against a digital thermometer across a range of target temperatures; (2) automatic control-logic testing, verifying the system's response when the temperature crosses the defined thresholds; (3) fan and buzzer functionality testing across the operating temperature range; and (4) whole-system testing, comparing the drying duration, temperature stability, monitoring capability, and notification behavior of the IoT dryer against the traditional manual drying method.

3. Result and Discussion

3.1. System implementation

The hardware components were assembled into an integrated drying-oven unit consisting of the ESP32 control circuit, the DS18B20 sensor, four 50W heaters, two fans, a buzzer, and the relay-driven switching mechanism, as shown in the final device in Fig. 3 and Fig. 4.



Fig. 3: Final prototype of the automatic rengginang dryer (exterior)



Fig. 4: Final prototype of the automatic rengginang dryer (interior)

The web dashboard provides a real-time temperature display, a device control panel supporting both automatic and manual modes, and a real-time temperature-and-time trend chart, as shown in Fig. 5. In manual mode, the control panel allows the user to switch individual components on or off directly, while in automatic mode the components follow the Decision Tree logic described in Section 2.

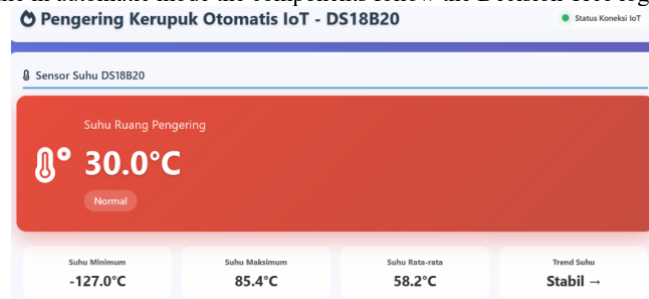


Fig. 5: Real-time web monitoring dashboard

3.2. Sensor accuracy testing results

The DS18B20 temperature sensor was tested by comparing its reading against a digital thermometer across a range of target temperatures from approximately 46 to 80 degrees Celsius. The largest deviation observed was 0.4 degrees Celsius, with an average error of 0.2 degrees Celsius, which remains within the acceptable tolerance for a digital-type temperature sensor. This result indicates that the DS18B20 sensor provides a good level of accuracy and stable readings throughout the testing process, confirming its suitability as the main temperature-sensing component of the system.

3.3. Automatic control logic testing results

The automatic control logic was tested by observing the system's response to several trigger conditions, with the results summarized in Table 2.

Initial Condition	Trigger	System Action	Status
Temperature 28°C	Device powered on	Relay activates the heater elements	Successful
Temperature 28°C	Device powered on	Relay activates the heat-distribution fan	Successful
Temperature 85°C	Overheating	Relay switches off the heater and distribution fan	Successful
Temperature 83°C	Overheating	Relay activates the cooling fan	Successful

As shown in Table 2, the ESP32 processed the sensor data and sent control signals to the relays nearly instantaneously, which is essential for maintaining the temperature within the 50-80 degree Celsius operating range. This fast and accurate control response helps prevent prolonged overheating that could degrade cracker quality, while directly supporting the operating efficiency of the heater and fan.

3.4. Fan and buzzer testing results

Fan and buzzer functionality was tested across the system's operating temperature range in automatic mode, with the results summarized in Table 3.

No.	Temperature (°C)	Heater	Hot Fan	Cooling Fan	Buzzer	Remarks
1	28.0 (below minimum)	ON	OFF	OFF	-	Initial heating; fan follows heater status
2	35.0	ON	OFF	OFF	-	Room-temperature heating
3	45.0	ON	ON	OFF	-	Distribution fan activates
4	55.0	ON	ON	OFF	-	Stable temperature zone
5	85.0	OFF	OFF	ON	-	Cooling fan active
6	Process start	-	-	-	~3 s	Start notification
7	Process end (timer expired)	OFF	OFF	OFF	~10 s	Completion notification

The results in Table 3 show that the hot (distribution) fan activates once the temperature reaches 45 degrees Celsius, following the heater status, while the cooling fan activates when the temperature exceeds the upper threshold and deactivates again once the temperature falls. The buzzer sounds briefly when the process starts and for a longer duration when the drying time ends, and all component responses occurred consistently without significant delay.

3.5. Whole-system testing results

Whole-system testing was carried out to evaluate overall device performance, from heating and temperature stabilization to timer-based process completion, comparing the IoT dryer against the traditional manual drying method. The results are summarized in Table 4.

Table 4: Whole-system testing results compared with the traditional method

Parameter	Traditional Method	IoT Device (Test Result)	Remarks
Drying Duration	1-2 days	~240 minutes (per timer)	Not affected by weather
Temperature Range	Uncontrolled	Maintained within a stable, optimal range	Controlled fluctuation
Consistency	Often uneven	More evenly dried	Fan assists air circulation
Monitoring	Manual	Real-time via dashboard	Updated every ~2-3 seconds
Notification	None	Buzzer at start and completion	Clear to the user

As shown in Table 4, the system maintained the temperature within the defined range throughout testing and completed the process within the configured duration. The dried rengginang crackers showed a more uniform texture compared with the traditional method, indicating that the complete workflow - from sensor reading and heater/fan control logic to IoT communication and the timer mechanism - functioned as designed and supported a faster, more measurable drying process.

3.6. Discussion

Taken together, the testing results confirm that the automatic rengginang dryer prototype operates according to its intended design. The DS18B20 sensor provided accurate and stable temperature readings (average error of 0.2 degrees Celsius), the Decision Tree-based control logic responded to temperature changes almost instantaneously, and the complete system was able to maintain a stable drying temperature between 55 and 80 degrees Celsius while reducing the drying duration to approximately four hours, compared with the one-to-two-day duration typically required by the traditional sun-drying method. With respect to the research problem defined in Section 1, these results confirm that an automatic, IoT-based rengginang dryer capable of operating according to a user-defined duration and independent of weather conditions was successfully designed and implemented.

Compared with the related studies discussed in Section 1, most existing systems rely on simple on-off or PID-based control, or remain dependent on ambient light and weather conditions as in the LDR-based approach of Sunarto et al. [7]. The system developed in this study differs by applying a Decision Tree algorithm for adaptive, three-branch temperature control combined with real-time Firebase-based web monitoring, allowing the system to both make more nuanced control decisions than a simple threshold and to be observed remotely without depending on a third-party platform such as Blynk or Telegram alone.

Despite these positive results, several risks and limitations were identified during implementation. The DS18B20 sensor may be vulnerable to long-term degradation from improper pull-up resistor configuration or excessively long wiring, and although the current prototype's 50W heaters operate with relatively stable power consumption over 4-8 hour cycles, further insulation of the wiring near the dryer's heat source is recommended to reduce the risk of cable damage. A temperature gradient may also occur within the drying chamber, with crackers on lower trays tending to dry faster than those on upper trays if air circulation is not optimized, and unstable Wi-Fi connectivity can interrupt data transmission to the web dashboard, although the local Decision Tree control logic continues to operate independently of the network connection. Future development is recommended to add a humidity sensor to improve drying-process accuracy, incorporate automatic completion notifications through Telegram or the web, develop a more interactive dashboard interface, and integrate a solar power supply for a more energy-efficient and environmentally friendly system.

4. Conclusion

Based on the design, implementation, and testing process described in this study, an Internet of Things-based automatic rengginang cracker dryer was successfully developed using an ESP32 microcontroller, a DS18B20 temperature sensor, DC heaters, DC fans, a buzzer, and relay modules, implemented with the Arduino IDE and Google Firebase using the waterfall development method. Testing results show that the device is able to maintain a stable temperature within a range of 55 to 80 degrees Celsius and dry rengginang crackers in approximately four hours on average, considerably faster than the one-to-two-day duration required by the traditional manual method. Future development is recommended to incorporate humidity sensing, automatic completion notifications, a more interactive dashboard, and solar-based power supply integration.

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