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Design And Development Analysis of a Corn Dryer Using the Internet of Things

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Abstract:
Background*: Corn is an important commodity for supporting food security and the livestock feed industry. However, its post-harvest moisture content can reach 20–30%, which may reduce storage stability and quality. Therefore, an effective drying process is required to reduce moisture content and improve corn shelf life.*
Materials and Methods*: This study aimed to design and develop an automatic corn dryer based on the Internet of Things (IoT) to improve drying efficiency and enable real-time monitoring. The system uses an ESP32 microcontroller as the main controller, a DS18B20 sensor for temperature measurement, and relays to control the heater and DC fan. Temperature, drying time, and device status were monitored through Kodular, Firebase, and Spreadsheet.*
Results*: Drying tests were conducted at temperatures ranging from 40–45°C. The results showed that the corn moisture content decreased to 14% within approximately 360 minutes, meeting the specified moisture-content standard.*
Conclusion: *The developed IoT-based automatic corn dryer can automatically control the drying temperature and provide real-time monitoring through a smartphone. The system has the potential to improve post-harvest drying efficiency and support local corn farmers.*
Key Word*: Corn Dryer; Internet of Things (IoT); ESP32; Automatic Drying; Real-Time Monitoring*

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I. Introduction

Corn (Zea mays L.) is one of the most important agricultural commodities because of its contribution to food security, livestock feed, and various agro-industrial applications. However, freshly harvested corn generally contains a relatively high moisture content, which can accelerate deterioration and reduce storage stability if the grain is not properly dried. Therefore, drying is an essential post-harvest process for reducing moisture content to a safe level while maintaining grain quality and storage stability. The drying process involves simultaneous heat and mass transfer and is strongly influenced by drying temperature, airflow, and initial moisture content. Baidhe et al. [1] demonstrated that drying temperature, air velocity, and initial moisture content significantly affect the drying kinetics, moisture diffusion, and energy characteristics of high-moisture corn. Their study also showed that the drying process predominantly occurs during the falling-rate period, indicating the importance of controlling drying conditions to achieve effective moisture removal. Conventional sun drying, although simple and inexpensive, is highly dependent on weather conditions and requires continuous manual supervision. These limitations encourage the development of controlled and automated drying systems capable of maintaining appropriate drying conditions more consistently.

The development of the Internet of Things (IoT) provides new opportunities for improving agricultural drying systems through real-time sensing, remote monitoring, data transmission, and automated control. IoT-based smart drying systems can integrate sensors, embedded controllers, communication networks, and cloud-based platforms to continuously acquire and transmit process information. Bal et al. [2] reported that the integration of IoT and Industry 4.0 technologies into agricultural drying enables modular sensing, embedded-system decision-making, cloud-based monitoring, predictive analytics, and improved process automation, while also supporting energy efficiency and product quality. Hiendro et al. [3] developed a real-time paddy grain drying and monitoring system using long-range IoT technology, integrating sensors, LoRa communication, and an IoT platform to monitor heated-air velocity, temperature, relative humidity, and moisture-related parameters during drying. Similarly, Latif et al. [4] developed a real-time IoT-based grain-drying framework that integrated load, temperature, and energy-performance monitoring. Villa-Medina et al. [5] developed a low-cost IoT-based forced-convection solar dryer that enabled remote supervision, real-time weight-loss measurement, image monitoring, and airflow control through a web interface. These studies demonstrate that IoT technology can transform conventional drying equipment into smart systems capable of continuously monitoring critical process parameters and providing remote access to drying information.

Despite these developments, there remains a need for a relatively simple, low-cost, and practical IoT-based corn dryer that integrates automatic temperature control with real-time monitoring and data storage. Recent smart-drying research indicates that advanced systems increasingly incorporate multiple sensors, cloud platforms, predictive analytics, and sophisticated control technologies, which may increase system complexity and implementation requirements, particularly in small-scale agricultural applications [2]. Therefore, a simpler architecture based on readily available sensors, a low-cost microcontroller, automatic actuator control, and remotely accessible data monitoring may provide a practical alternative for local corn producers. Based on this research gap, this study aims to design, develop, and analyze an automatic corn dryer based on the Internet of Things. The proposed system employs an ESP32 microcontroller as the central control unit and a DS18B20 sensor to monitor the temperature inside the drying chamber. Relay-controlled heating and DC fan systems are used to regulate the drying environment, while temperature, drying time, heater status, and fan status are monitored through a mobile application developed using Kodular and stored using Firebase and Spreadsheet. Experimental tests are conducted at controlled drying temperatures of 40–45 °C to investigate the drying performance and determine the time required to reduce the corn moisture content to approximately 14%. The proposed system is expected to provide a practical and accessible solution for improving the efficiency, consistency, and monitoring capability of corn post-harvest drying.

II. Material And Methods

This research was conducted through several systematic stages, including system architecture design, hardware component selection, physical prototype construction, software design for the program workflow, and functional system testing. Generally, the research method focused on the design and construction of a corn drying device based on automation and wireless connectivity to control and monitor drying parameters in real-time [6-9].

The hardware design utilized an ESP32 microcontroller as the central control unit to manage all data processing and internet connectivity. The temperature parameters inside the drying chamber were detected using a waterproof DS18B20 digital temperature sensor positioned parallel to the object surface. This sensor was stabilized using a 4.7 kΩ pull-up resistor on the data line to prevent floating signals. As actuator elements, the system employed an electric heating element (heater) to supply thermal energy and three 12V DC exhaust fans to regulate air circulation. The entire electronic system was powered by a 12V DC power supply, with the voltage stepped down to 5V DC using two LM2596 step-down converter modules to maintain stable and safe operational voltage for the ESP32 and the 2-channel relay module.

The technological architecture of the drying device was divided into three mutually integrated physical stages through the concept of the Internet of Things (IoT). The input stage consisted of temperature readings from the DS18B20 sensor and drying duration parameters (timer) configured by the user via a smartphone application. The process stage was handled entirely by the ESP32 microcontroller running a program workflow developed in the Arduino IDE. Meanwhile, the output stage involved local monitoring media, including a 20x4 character I2C LCD screen, an active buzzer as a warning alarm, and wireless data transmission. The temperature readings and actuator statuses were transmitted in real-time to the Firebase Cloud database to be forwarded to the smartphone application designed using the Kodular platform, while simultaneously being recorded into a Google Spreadsheet as an automated data logging system. System design is showed in Figure 2.1.

The physical prototype of the drying device was designed with main chamber dimensions of 600 mm × 500 mm × 500 mm, utilizing a structural frame made of hollow iron. The outer enclosure walls were constructed from 0.6 mm thick aluminum sheets lined with a combination of glass wool and aluminum foil on the inside to minimize heat loss and maintain temperature stability. Inside the chamber, a single-tier corn seed holding rack measuring 400 mm × 250 mm made of aluminum wire mesh was installed, capable of carrying a load of up to 2 kg of wet corn. To maximize drying efficiency, three exhaust fans were installed crosswise at the top, right side, and left side to optimize thermal heat distribution while effectively expelling moisture. All electronic control components were housed separately inside a monitoring panel box measuring 150 mm × 200 mm × 300 mm mounted on the left side of the device.

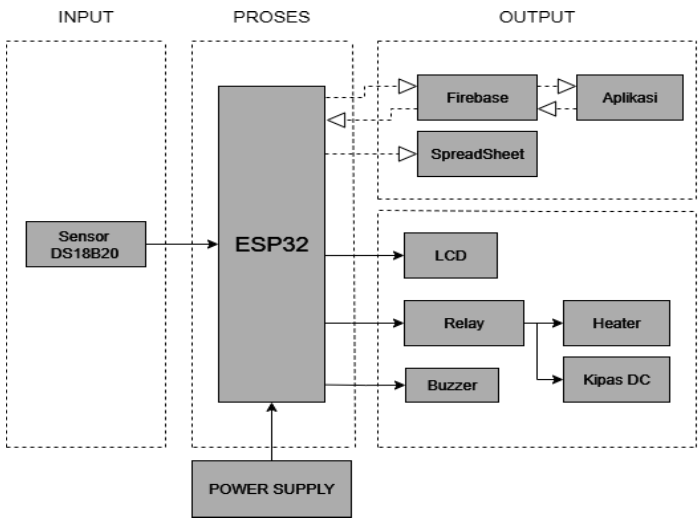

Figure 2.1. Diagram block

The system operation procedure and thermal regulation were automatically controlled using a hysteresis control method within an optimal temperature range of 40°C to 45°C. Once the device successfully connected to the Wi-Fi network, the user inputted the time limit into the application and pressed the start button to activate the timer and initiate heating. If the sensor read a chamber temperature below 40°C, the ESP32 commanded the relay to turn the heater ON and the fans OFF. Conversely, if the chamber temperature was detected to exceed the upper threshold of 45°C, the heater was automatically turned OFF and the exhaust fans were turned ON to vent excess heat. This cycle repeated continuously until the timer duration elapsed, which then triggered the active buzzer to sound for 10 seconds as a process completion indicator. The efficiency evaluation of the device was conducted by calculating the moisture content reduction rate in each test using mathematical formulas, with a final target of reducing the corn moisture content to meet the Indonesian National Standard (SNI) of 14%.

Figure 2.2 shows the component layout design of the corn dryer, where each component is placed according to its position and function: (1) Exhaust fan (top), located at the top of the dryer, this exhaust fan functions to distribute and push the heat generated by the heater evenly throughout the drying chamber. (2) Heater, positioned at the top, this location allows the heat from the heater to spread evenly. (3) Exhaust fan (right side), functions to draw fresh air into the drying chamber, assisting air circulation and effectively distributing heat. (4) DS18B20 sensor, placed inside the drying chamber to measure the chamber's temperature during the drying process. (5) Monitoring box, located on the left side of the dryer, it is used as a housing for the drying system control components. (6) LCD, positioned on the front of the monitoring box to display information during the drying process. (7) Drying tray, a rack or container where the corn kernels are placed during the drying process. (8) Exhaust fan (left side), located on the left side of the device, it is used to help expel hot air from the drying chamber.

Figure 2.2 Component layout design on device

III. Result and Discussion

System and hardware implementation

The implementation of the developed system was conducted to enable the automatic drying of corn kernels. Temperature variations were continuously monitored throughout the drying process, from the beginning to the end of the drying cycle. Temperature measurements were obtained using a DS18B20 sensor and displayed on an I2C LCD. In addition, the drying temperature could be monitored in real time through a smartphone application. Also, the developed hardware consists of a corn-kernel drying system incorporating Internet of Things (IoT) technology, in accordance with the design presented in the preceding section. The implemented drying system is shown as Figure 3.1.

Figure 3.1 Dryer front panel

Hardware testing

Hardware testing was conducted to verify the functionality and performance of the components used in the corn drying system according to the designed specifications. The tested components included the ESP32 microcontroller, DS18B20 temperature sensor, two-channel relay, heater, and exhaust fan. The ESP32 was tested by connecting it to a computer via USB and uploading a simple blink program using the Arduino IDE. The DS18B20 sensor was tested using a simple Arduino IDE program to verify stable temperature readings displayed through the serial monitor. The relay was tested by applying control signals from the ESP32 to verify its ability to switch electrical loads correctly. The heater and exhaust fan were tested through the relay controlled by the ESP32. The heater was evaluated based on its ability to generate heat consistently, with temperature changes monitored using the DS18B20 sensor. Meanwhile, the exhaust fan was tested to verify its ability to operate smoothly and remove hot and humid air from the drying chamber. The hardware components were considered functional when the ESP32 successfully executed the test program, the DS18B20 produced stable temperature readings, the relay switched as commanded, the heater generated a temperature increase, and the exhaust fan operated smoothly without excessive noise or vibration.

Application Testing

Application testing was conducted to verify that all functions operated according to the system design. The application consists of two main interfaces. The first interface serves as the initial control page, providing a logo, drying-time setting, and a button to start the drying process. The second interface displays the corn logo, remaining drying time, heater and fan status, and real-time temperature monitoring. Both interfaces include navigation icons at the bottom to facilitate movement between application pages. The application interfaces are shown in Figure 3.2.

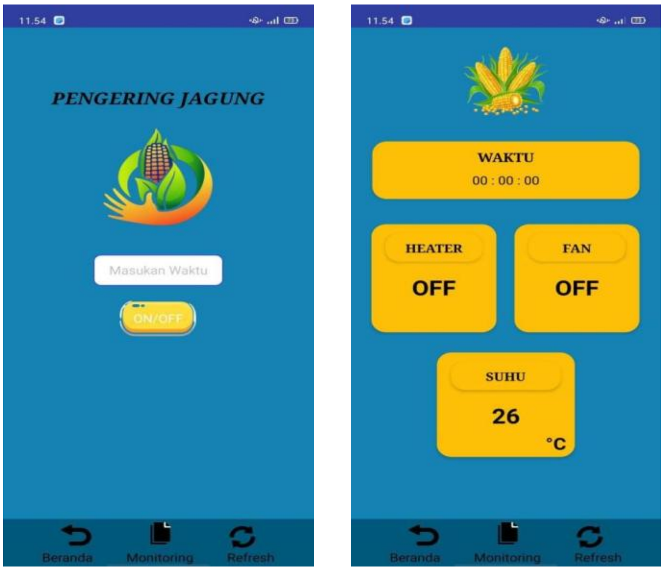

Figure 3.1 Application View

System Testing Analysis

Experimental Data Collection Analysis

In the first experiment, the drying process was conducted for 60 minutes, with an initial corn moisture content of 29.0% and a drying temperature of 45.5 °C, resulting in a final moisture content of 27.0%. In the second experiment, the drying duration was 120 minutes, with an initial moisture content of 29.5% and a temperature of 45.5 °C, resulting in a final moisture content of 25.0%. The third experiment was conducted for 180 minutes at 45.5 °C, with an initial moisture content of 29.5% and a final moisture content of 22.5%. In the fourth experiment, the drying process was conducted for 240 minutes at 45.5 °C, with an initial moisture content of 29.5% and a final moisture content of 19.0%. The fifth experiment was conducted for 300 minutes, with an initial moisture content of 29.0% at 45.5 °C, resulting in a final moisture content of 17.5%. Finally, the sixth experiment was conducted for 360 minutes at 45.5 °C, with an initial moisture content of 29.5% and a final moisture content of 14.5%.

Analysis of the Moisture Content Reduction Rate

The six drying experiments were conducted at 60-minute intervals, with drying durations ranging from 60 to 360 minutes. The experimental results indicate that moisture content decreased with increasing drying duration. The observed reduction in moisture content demonstrates that the drying process proceeded effectively, with a relatively consistent decrease as the drying time increased.

In the first experiment, conducted for 60 minutes, the moisture content decreased from 29.0% to 27.0%, corresponding to an average moisture reduction rate of 0.0333% per minute. In the second experiment, the moisture content decreased from 29.5% to 25.0% over 120 minutes, resulting in an average reduction rate of 0.0333% per minute. In the third experiment, conducted for 180 minutes, the moisture content decreased from 29.5% to 22.5%, corresponding to an average reduction rate of 0.0388% per minute.

In the fourth experiment, the moisture content decreased from 29.5% to 19.0% after 240 minutes, corresponding to an average reduction rate of 0.0437% per minute. The fifth experiment, conducted for 300 minutes, resulted in a decrease in moisture content from 29.0% to 17.5%, with an average reduction rate of 0.0383% per minute. In the sixth experiment, conducted for 360 minutes, the moisture content decreased from 29.5% to 14.5%, corresponding to an average reduction rate of 0.0416% per minute.

Overall, the moisture reduction rates obtained from the six experiments were relatively consistent, ranging from 0.0333% to approximately 0.0438% per minute. The mean moisture reduction rate across the six experiments was 0.0371% per minute. The total of the six calculated reduction rates was 0.2228% per minute, which, when divided by the six experiments, yielded an average moisture reduction rate of 0.0371% per minute.

These results can also be presented graphically to facilitate the interpretation of the moisture reduction pattern as a function of drying time. Based on the measurement results, the total moisture content reduction rate of 0.2228 was divided by the number of trials, which was six times. Thus, the average moisture content reduction rate is 0.0371% per minute. This data can also be displayed in a graphical format in Figure 3.3 to ease the understanding of the moisture content reduction pattern during the drying time.

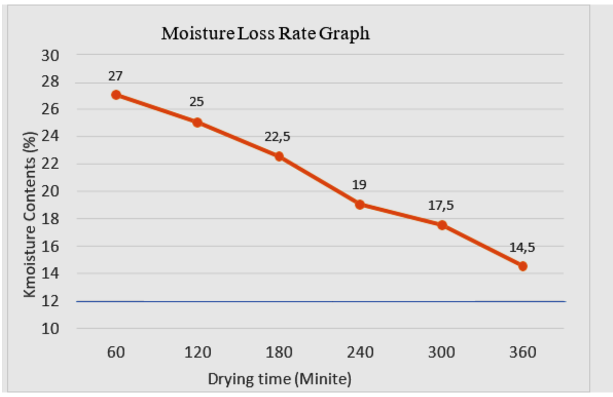

Figure 3.3. Moisture content reduction

III. Conclusion

The Internet of Things (IoT) was implemented in the corn drying system using the Kodular application to enable automatic and real-time control and monitoring of the drying process. The system employs a DS18B20 temperature sensor to continuously measure the temperature inside the drying chamber, thereby supporting more efficient and controlled drying conditions.

Based on the experiments conducted at different drying durations, the sixth experiment, with a drying duration of 360 minutes, reduced the corn moisture content from an initial value of 29.5% to 14.5%. This result indicates that a six-hour drying period was sufficient to achieve a final moisture content appropriate for corn storage. Therefore, a drying duration of 360 minutes (six hours) can be used as a reference for the drying process to achieve the desired moisture content under the tested operating conditions.

The performance of the drying system demonstrated that the heating process could be controlled automatically to maintain the chamber temperature within the specified operating range. The heater was activated when the temperature fell below 45 °C and deactivated when the temperature exceeded 45 °C. When the temperature exceeded 45 °C, the exhaust fan was activated to reduce the chamber temperature until it decreased to approximately 40 °C, after which the heater was activated again. These results indicate that the drying system operated in accordance with the designed control logic and programmed operating conditions.

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