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IMPLEMENTATION OF THE INTERNET OF THINGS (IoT) SYSTEM FOR THE COFFEE BEAN DRYING PROCESS USING A TRAY DRYER

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ABSTRACT

This study aims to implement an Internet of Things (IoT) system in the coffee bean drying process using a tray dryer to improve efficiency and ease of monitoring. The system is designed using a DHT22 sensor to read temperature and humidity, a MAX6675 sensor to monitor the heater temperature, an HX711 load cell sensor to measure the weight of the coffee beans, and a DS1302 RTC to record the drying time. All data is displayed on an LCD and sent to the Blynk IoT platform for remote monitoring. Testing was conducted with five drying temperature variations, namely 30°C, 35°C, 40°C, 45°C, and 50°C, each for 5 hours. The results showed that a temperature of 50°C produced the best results with a final moisture content of 7.21%, which meets the SNI 01-2907-2008 standard for coffee bean storage, which is a maximum of 12.5%. This IoT-based drying system has proven to be capable of automating the drying process with accurate and efficient monitoring, as well as enabling real-time remote monitoring. Thus, this system can be a modern solution in coffee post-harvest processing.

Keywords: Blynk, coffee beans, drying, IoT, moisture content, sensors, tray dryer

1. INTRODUCTION

1.1 Background

Global demand for coffee beans in 2024 will increase by 3.3% according to the International Coffee Organization (ICO, 2024). Indonesia ranks third among global coffee producers after India and Brazil, with exports exceeding domestic consumption. The quality of coffee beans is largely determined by their moisture content, with SNI 01-2907-2008 setting a maximum limit of 12.5%. High moisture content can cause a musty aroma due to prolonged storage, making the drying process an important stage in coffee processing (Syamsiana N, et al., 2024).

Drying is a process of simultaneous heat and mass transfer, in which heat is used to evaporate water from the material, then the vapor transfers to a drying medium such as air (Hasibuan et al., 2023). The initial moisture content of coffee beans is around 48.7% and needs to be reduced to ≤12.5% for safe storage (Namora et al., 2020). The traditional method of sun drying is still widely used, but it depends on the weather, takes a long time, and produces uneven quality.

Tray dryers are a modern alternative that uses hot air from heaters and fans to accelerate drying. This technology is more hygienic, faster, and more uniform than traditional methods (Hasibuan et al., 2023). Drying with a tray dryer can be optimized at a temperature of 30–50 °C with the duration depending on the initial moisture content and environmental conditions (Kurniawan et al., 2024). However, energy use is a challenge, because high temperatures do accelerate drying but risk reducing quality, while low temperatures prolong the process time.

The development of Internet of Things (IoT) technology provides new opportunities in drying automation. IoT is a network of physical objects with sensors, actuators, and communication devices that can collect and exchange data via the internet (Wulandari et al., 2024). The application of IoT in tray dryers enables real-time monitoring of temperature, humidity, and coffee bean weight, as well as more efficient process control.

Based on these issues, this study aims to implement an IoT system in tray dryers for the coffee bean drying process in order to improve efficiency and product quality, while also providing a modern solution for post-harvest coffee processing.

2. RESEARCH METHODS

Research methodology

2.1 Research Place

This research consists of system design carried out at the Chemistry Laboratory of the Chemical Engineering Department at Lhokseumawe State Polytechnic. The research was conducted over a period of four months, starting with a literature study, equipment assembly, system testing, evaluation of adjustments as needed, and writing of the final report.

2.2 Tools and Materials

2.2.1 Tools used

The equipment used in this study consisted of an IoT-based tray dryer prototype measuring 181.5 × 40 × 40 cm, made of aluminum plate and equipped with a heater as a heat source and a fan for air circulation. Stainless steel drying trays were used as containers for the coffee beans. The ESP32 microcontroller acts as the control center for the IoT system, which is integrated with the Blynk platform. The sensors used include DHT22 for reading temperature and humidity, MAX6675 for detecting the temperature of the heater, HX711 load cell for measuring the weight of coffee beans, and RTC DS1302 for recording time. In addition, a 20×4 LCD is used as a data display, an analytical scale is used to verify the drying results, and a laptop or smartphone is used for real-time data monitoring.

2.2.2 Materials used

The research material used was 200 grams of Arabica coffee beans per batch as the main sample. In addition, several supporting materials were used, such as jumper cables to connect the sensors, prototype boxes to house the electronic circuits, double-sided tape as an adhesive, and aluminum foil as a base for the drying tray to keep the coffee beans hygienic during the process.

2.3 Experimental Treatment Design

2.3.1 Fixed Variables

- Initial weight of coffee beans per bacth : 200 gram
- Air flow velocity : 1 m/s

2.3.2 Independent Variables

- Drying temperature : 30, 35, 40, 45, 50°C
- Drying time : 1, 2, 3, 4, 5 jam

2.3.3 Dependent Variable

- Final moisture content of coffee beans (%)
- Drying rate

2.4 Experimental and Testing Procedures

2.3.4 Design and Configuration of the Tray System

The tray dryer system uses a heater as a heat source, a fan for air circulation, and sensors to monitor temperature, humidity, weight, and time in real time. The measurement data is displayed on an LCD and sent to the Blynk application. This system is designed to automate the drying process so that it can be monitored directly via both the LCD device and the IoT application.

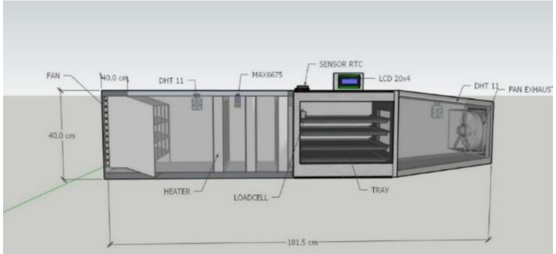

Figure 2.1 Tray Dryer Design

2.3.5 Controller Design

The design of hardware in the coffee bean drying process using an IoT-based tray dryer involves designing a series of tools where each component can be connected to one another so that they can work dynamically. The Control System Block Diagram can be seen below.

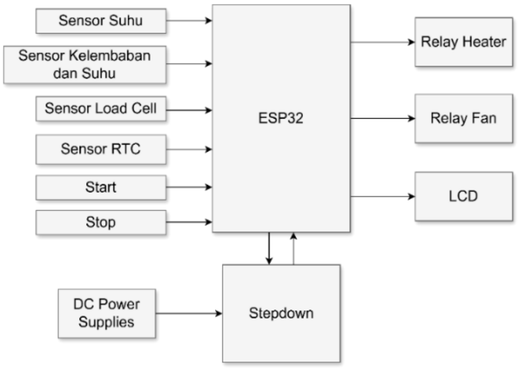

Figure 2.2 Control System Block Diagram

From the image above, the system design can be briefly explained as the working principle of an IoT-based automatic coffee bean drying device.

1. Start will give the command to run the program
2. The power supply is used to convert 220v AC voltage to 12V DC voltage
3. Stepdown is used to convert or reduce 12V DC voltage to 5V DC voltage
4. The DHT sensor will read the temperature and humidity at the air input and output
5. ESP32 is used for I/O control
6. Relay is used as a contact to control the heater and fan
7. LCD is used to display all sensor readings
8. RTC is used to determine the time in real time
9. The load cell is used to determine the weight of the coffee beans
10. The Max 6675 is used to determine the temperature of the heater
11. The heater is used to heat the air
12. The fan is used to circulate hot air to the coffee beans
13. Stop will command the program to stop

Below is an image of an electronic device design, often referred to as a microcontroller design, as a control system intended for input/output from sensor performance in the coffee bean drying process.

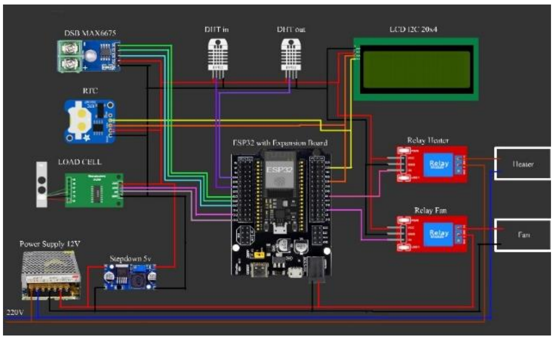

Figure 2.3 Coffee Bean Drying Process Equipment System Series

2.3.6 Perancangan Software

The algorithm to be designed for the tray dryer for drying coffee beans is as follows:

1. Start
2. Detecting program commands
3. Initializing DHT22, Max6675, HX711, RTC, and LCD sensors
4. Displaying initial system information on the LCD
5. The DHT22 sensor detects the temperature and humidity of the

incoming (in) and outgoing (out) air

6. The Max6675 sensor detects the heater temperature
7. The HX711 sensor reads the weight of the coffee beans
8. The RTC sensor reads the current time and date
9. The fan works automatically (active continuously while the system is on)
10. Is the DHT22 temperature value = < lower limit (28°C)?
    - If yes,
    - Heater = On
    - If no, proceed to step 11
    - Heater = Off
11. Is the DHT Out temperature value > upper limit (52°C)?
    - If yes
    - Heater = Off
    - If no,
    - Heater = remains in last status (OK)
12. Display data to the serial monitor and LCD:
    - Time and date from the RTC
    - Temperature and humidity in and out
    - Heater status and heater temperature
    - Coffee bean weight from the load cell
13. Wait 5 seconds
14. Return to step 5 while the system is still running
15. Finish

2.3.7 Research and testing Procedures

1. Prepare the raw materials, namely coffee beans, and weigh them before drying using a tray dryer.
2. Prepare the equipment and its operation
3. Drying process using a tray dryer:
    a. Set the drying temperature to the specified value (°C).
    b. Set the air flow speed to 1 m/s.
    c. Place the coffee beans in the dryer tray and start the drying process for the specified time (hours).
    d. Monitor the temperature, humidity, and drying time via the IoT dashboard.
    e. Record the moisture content of the coffee beans every 30 minutes until it reaches 11-12%.
    f. Save the drying results data for further analysis.
    g. Then put 200 grams of coffee beans in each tray per batch.
    h. Wait until the moisture content of the coffee beans reaches the varied temperature per time.
    i. After the drying time is complete, remove the coffee through the exit door and then weigh the final weight of the coffee after drying using the tray dryer.
    j. Next, turn off the device first.
    k. The testing process on the tray dryer device is complete.
4. Followed by the traditional drying process
5. Compare the automatic drying process with the traditional drying process using a comparison table.

2.3.8 System Testing

Testing stages conducted after the coffee bean drying monitoring system was assembled. The purpose of the testing was to:

1. Ensure that the DHT-22 sensor is capable of providing data in the form of air temperature and humidity values.
2. Ensure that the RTC sensor is capable of tracking time and date.
3. Ensure that the DSB Max6675 sensor is capable of measuring the temperature on the heater.
4. The Load Cell sensor is capable of measuring on the tray.
5. Ensure the effectiveness of the heater as a heating medium for the

automatic drying process of coffee beans.

6. The data displayed on the smartphone is temperature and weight data.

2.3.9 Data Analysis

a. Calculating Moisture Content

$$KA = \frac{Wb - Wk}{Wb} \times 100\%$$

Where:
KA= moisture content (%) wet basis
Wb= weight of wet material before drying
Wk= weight of dry material after drying

b. Calculating Drying Rate

The drying rate method can be calculated using the following equation:

$$Drying\ Rate = \frac{Starting\ Weight - Final\ Weight}{Drying\ Time}$$

3. RESULTS AND DISCUSSION

3.1 Research Results

Table 3.1 Coffee Bean Drying Results Data

Temperature (°C)	Time (hour)	Parameter	
		Moisture Content of Coffee Breans (%)	Drying rate (g/jam)
1	2	3	4
30	0	18,84	0,0
	1	17,11	25,20
	2	16,58	12,05
	3	16,10	7,83
	4	15,45	5,83
	5	14,97	4,40
35	0	18,98	0,0
	1	15,05	22,00
	2	14,22	10,55
	3	13,74	6,87
	4	13,21	4,93
	5	12,55	3,76
40	0	18,62	0,0
	1	11,80	17,30
	2	10,32	8,35
	3	9,85	5,37
	4	9,79	3,83
	5	9,55	2,80
45	0	18,76	0,0
	1	9,38	14,10
	2	8,14	6,70
	3	7,90	4,27
	4	8,02	3,10
	5	8,14	2,38
50	0	18,27	0,0
	1	8,34	10,80
	2	7,39	5,10
	3	7,33	3,13
	4	7,27	2,13
	5	7,21	1,44

3.2 Discussion

Drying data is displayed in graphs to analyze changes in moisture content, moisture ratio, and drying rate. These graphs show the effect of temperature on the effectiveness of the process and help determine the optimal temperature according to quality standards.

3.2.1 The Effect of Drying Time and Temperature on Moisture Content

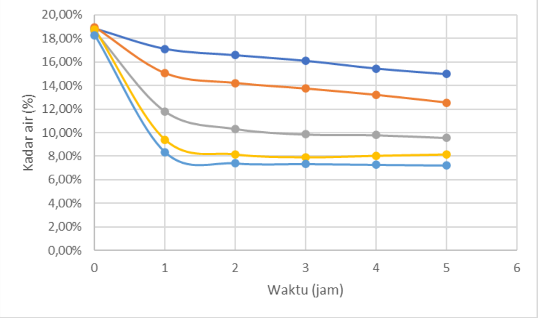

Figure 3.1 Effect of Drying Time on Moisture Content at Various Drying Temperatures

Based on the graph in Figure 3.1, the moisture content of coffee beans decreases as drying time increases at a rate influenced by temperature. At 30°C, the decrease is slow, while at 35°C it begins to stabilize after 2 hours. Temperatures of 40°C and 45°C show a faster decrease, especially in the first two hours, while 50°C produces a significant decrease from the start and reaches stability faster. In general, temperatures of 45–50°C are most effective at reducing moisture content within 5 hours, although they still need to be controlled to maintain coffee bean quality. When compared to the research by Silaban et al. (2020), moisture content decreased by 20.17% at temperatures of 50–75°C within 6 hours.

This study is more efficient because it only uses a temperature of 50°C for 5 hours with a lower moisture content result, namely 7.21%. This confirms that automatic temperature control and temperature stability through the IoT system play a major role in increasing drying efficiency.

3.2.2 The Effect of Drying Time and Temperature on Drying Rate

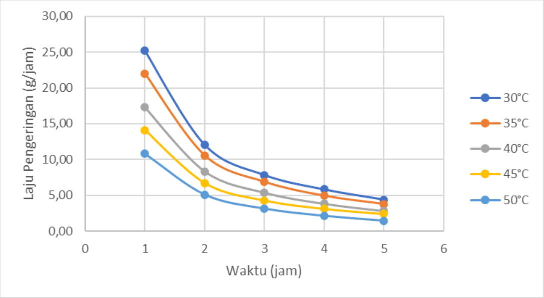

Figure 3.2 Effect of Time on Drying Rate at Various Temperatures

The graph in Figure 3.2 shows that the highest drying rate occurs in the first hour, then decreases sharply until the second hour and stabilizes from the third to the fifth hour. The higher the temperature, the greater the initial drying rate because heat energy accelerates evaporation, while low temperatures result in slower rates. This pattern is consistent with previous research (Sholeha et al., 2022), which states that the drying rate decreases over time and is influenced by temperature and air velocity. Thus, the decrease in the drying rate in this study is in line with the general characteristics of the drying process, which is fast at the beginning and then slows down as the water content decreases.

3.2.3 The Effect of Drying Time and Temperature on Relative Humidity

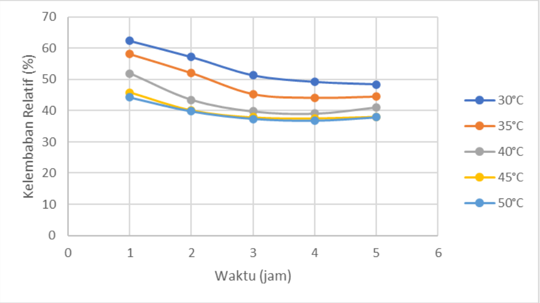

Figure 3.3 Effect of Drying Time on Relative Humidity at Various Drying Temperatures

Figure 3.3 shows the effect of time and temperature on relative humidity during the drying process. At all temperature variations, humidity decreases sharply in the first two hours, then tends to stabilize between the 3rd and 5th hours. The higher the drying temperature, the lower the relative humidity because water evaporation occurs more quickly, making the air in the drying chamber drier. This shows that humidity is not only influenced by the water content of the material, but also by environmental conditions. These results are in line with the research by Sholeha et al. (2022), which explains that an increase in temperature accelerates the release of bound water from the material, causing a significant decrease in relative humidity.

3.2.4 Blynk IoT Results

Testing the Blynk IoT Web Dashboard, because with Blynk IoT, data visualization can be done easily and there are several features that support data visualization from sensors, namely the number of widgets that can be used to create data visualization in the form of charts, numbers, and others, making it easier for users to read sensor data in real time. Testing of the Blynk application that has been programmed includes. The results of the Blynk Web test are shown in Figure 3.4.

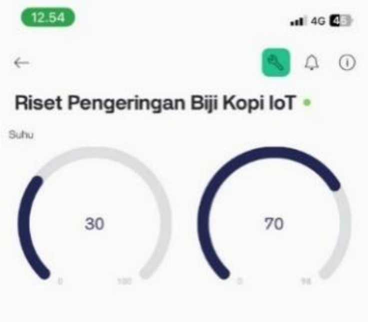

Figure 3.4 Blynk Display on a Smartphone

3.2.5 Perbandingan Proses Pengeringan Menggunakan Matahari

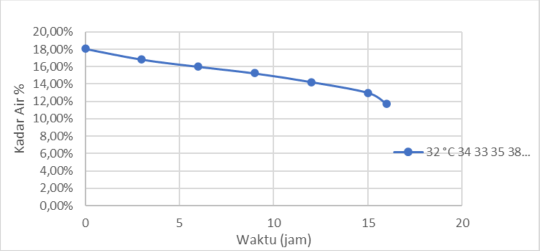

Figure 3.5 Effect of drying time on coffee bean weight

Figure 3.5 shows that the weight of coffee beans gradually decreases during the sun drying process, from 200 grams to 189.2 grams in 16 hours. This decrease occurs because the water in the coffee beans evaporates due to the heat of the sun. The weight reduction process occurs more quickly at the beginning of drying, then begins to slow down as the remaining water content decreases. The final result shows that the moisture content of the coffee beans decreased to around 12.5%, in accordance with the storage standards according to SNI 01-2907-2008.

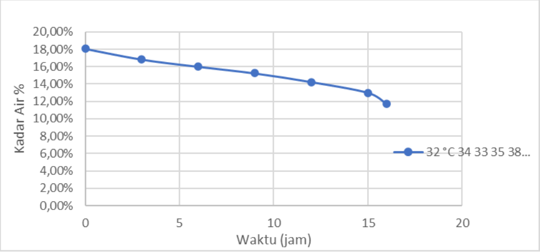

Figure 3.6 Effect of Drying Time on Coffee Bean Moisture Content

Figure 3.6 shows that drying coffee beans in the sun for 2 days (16 effective hours) can reduce the moisture content to around 12% at a temperature of 39°C, in accordance with the SNI 01-2907-2008 standard. Although slower than mechanical drying, this method is still effective for small scales. Compared to the study by Nurbaeti et al. (2021), which required 3 days to achieve 13–14%, this study is more efficient thanks to higher maximum temperatures and favorable weather conditions. In general, sun drying can achieve safe moisture content for storage, although it is highly dependent on the environment.

4. CONCLUSION

4.1 Conclusion

Several conclusions can be drawn from the research results, as follows:

1. The quality of coffee bean drying results using an IoT-based tray dryer has been proven to be better than traditional methods. The tray dryer is capable of producing a final moisture content of 7.21%, which meets the SNI quality standard (<12.5%), while traditional methods take longer and produce less consistent results. The IoT-based system allows real-time monitoring of temperature, humidity, and weight, making the process more efficient and controlled.
2. The drying temperature greatly affects the moisture content and drying rate of coffee beans. The higher the drying temperature, the faster the moisture content will decrease and the drying rate will increase. The optimal temperature is 50°C for 5 hours, which produces the highest drying rate and a moisture content close to the SNI standard.
3. Drying time also affects moisture content and drying rate. Longer drying times can cause the moisture content of coffee beans to decrease further. However, the highest effectiveness is achieved within 5 hours at a temperature of 50°C. Beyond that time, the decrease in moisture content tends to slow down and is not very significant.

4.2 Suggestions

For further research development, it is recommended that a study be conducted on the Implementation of the Internet of Things (IoT) System in the Coffee Bean Drying Process using a Tray Dryer, with the following suggestions:

1. Further research should conduct additional testing with higher temperature variations or the addition of direct humidity sensors on the material to improve accuracy in automatic control.
2. The IoT system can be further developed with full remote control features and automatic notifications via smartphone applications to improve monitoring efficiency for users.
3. Further research is expected so that this IoT-based tray dryer can be applied at the farmer or small industry (IKM) level to improve coffee product quality by reducing dependence on traditional drying methods that are highly dependent on weather conditions.

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