



Embedded System

Design and Implementation of an Automatic Rotating Paddy Drying System based on Microcontroller using Fuzzy Logic

Fadhil Ramdani ¹, Nefy Puteri Novani ^{*2}

^{1,2} Department of Computer Engineering, Faculty of Information Technology, Universitas Andalas, Padang, West Sumatra, 25163, Indonesia

ARTICLE INFORMATION

Received: October 30, 2025
Revised: January 27, 2026
Available online: April 30, 2026

KEYWORDS

Fuzzy Logic, Paddy Drying, Automatic Control, ESP32, IoT

CORRESPONDENCE

E-mail: nefyputeri@it.unand.ac.id

ABSTRACT

Rice production faces major challenges, notably unpredictable weather and pest attacks. The duration of sun drying depends on the climate and weather: if the weather is clear and the sun shines fully throughout the day, drying only lasts about 2–3 days. However, when the weather is occasionally cloudy or drizzly and sometimes hot, the drying time can extend to approximately one week. Pests such as birds cause significant physical damage to the paddy from pecking, which frequently occurs in conventional drying methods. The system design in this Final Project aims to design and build an automatic rotating paddy drying system that can control temperature and humidity using fuzzy logic. Fuzzy logic was chosen to adjust the drying temperature so that the resulting temperature is appropriate for the current paddy moisture, thereby maintaining paddy quality, operating independently of weather, and protecting against pests. The system utilizes an ESP32 microcontroller as the main processing unit. Input is obtained from a Capacitive Soil Moisture Sensor for paddy moisture and a DHT22 sensor for the drying chamber temperature. Fuzzy logic with 9 rules is implemented to control the Fan & Heater actuator based on the inputs from moisture and temperature. An AC motor with a gearbox is used to rotate the drying drum. The system is also integrated with a Telegram Bot for real-time monitoring and control. Testing was conducted in five weight scenarios ranging from 10 kg to 30 kg. The system successfully lowered the paddy moisture from the initial level to the drying target of 13%. The optimal capacity was identified at 10–20 kg, where the system was capable of maintaining the ideal temperature at 40°C–60°C. The system successfully controlled the drying process automatically, maintained temperature and humidity, and protected the paddy from contamination, resulting in a quality drying process.

INTRODUCTION

Rice production is a vital activity that processes paddy into rice. One of the main challenges in this process is drying. Post-harvest paddy has a high moisture content, ranging from 20-27%. This high moisture level makes the paddy vulnerable to fungus, decay, and enzymatic browning reactions, which reduce quality and cause the rice to turn yellow.

The most common drying method is conventional sun drying. This method has significant weaknesses: it is highly dependent on unpredictable weather. The process can take 2-3 days in clear weather, but it can extend up to one week during cloudy or rainy weather. Furthermore, drying in open areas is highly susceptible to pests like birds and rats, which can physically damage the paddy and reduce rice quality.

Mechanical drying machines (dryers) exist as a solution, but many of them still have shortcomings. Often, these machines lack automatic control for heat and moisture levels, thus requiring regular manual checking. This creates a gap analysis need for a system that is not only weather-independent and safe from pests, but also fully automated in monitoring and controlling drying parameters.

Previous studies have explored various aspects of drying. Al Faris et al. [10] designed a paddy dryer prototype using ATmega328, but focused on static chamber temperature control. Fatkhurrozi & Hery [18] showed the successful application of fuzzy logic to control temperature and moisture in coffee bean drying, proving the method's feasibility for agricultural products. Research by Ulfa [9] and Millati et al. [4] also emphasized the importance of achieving the correct moisture content and temperature to maintain rice quality. Although mechanical drying technology exists [5], the integration of an automatic rotating system for heat distribution, smart control using fuzzy logic, and real-time Internet of Things (IoT) monitoring specifically for paddy is still an area that needs development.

The objective of this research is to design and build an automatic rotating paddy drying system using an ESP32 microcontroller with the fuzzy logic method. This system is designed to monitor paddy moisture and chamber temperature in real-time, automatically control the heater to achieve the ideal moisture content (13-14%), and protect the paddy from pests.

METHOD

This research methodology covers hardware design, software design (fuzzy logic), and experimental testing procedures. The proposed solution is an automatic rotating drying system designed for portability and real-time monitoring. As illustrated in Figure 1, the system consists of a rotating drying drum unit that holds the paddy, powered by a motor, and heated by a fan heater unit. A control box houses the microcontroller and electronic circuits. The system is equipped with a mobile application (Telegram Bot) for data visualization and logging

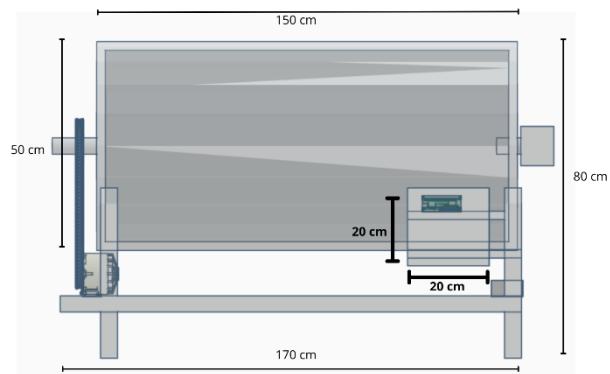


Figure 1. General System Design

Figure 2 shows the 3D design of the overall system. The system is designed with a rotating drying drum (hopper) connected to a DC motor (which was changed to AC during implementation) for rotation, ensuring even drying. A control casing houses the ESP32 and LCD 20x4

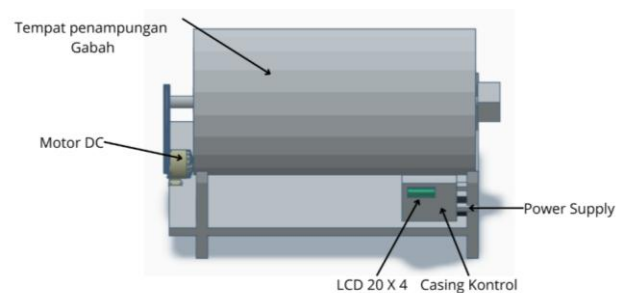


Figure 2. 3D Design of Overall System

Figure 3 illustrates the 3D design of the internal drying drum. The Paddy Drying Drum is the rotating section, made of iron, with mesh on both the left and right sides to facilitate air flow. Inside, the Capacitive Moisture Sensor and DHT22 temperature sensor are placed to directly monitor the paddy. The Fan Heater unit is positioned at both ends to circulate hot air.

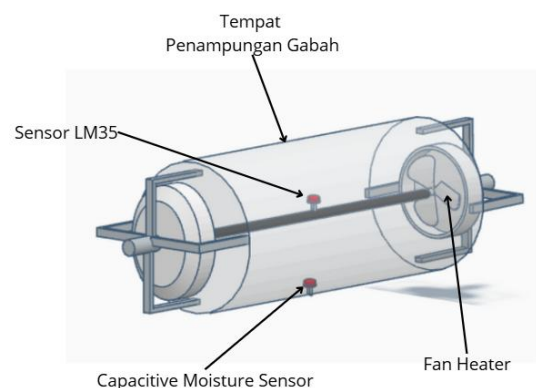


Figure 3. 3D Design of Drying Drum

The main input components are the Capacitive Soil Moisture Sensor v2.0 for detecting paddy moisture and the DHT22 temperature-humidity sensor. The DHT22 sensor was chosen to replace the LM35, which showed unstable readings during the initial implementation. A Real-Time Clock (RTC) module DS3231 is used for time tracking and duration logging. The actuator components consist of two Fan & Heater units. Each unit

is a combination of a Welhome WH-1061 fan (28W) and a PTC Heater (300W). To rotate the drum, an AC motor Wasser PW131E (125W) is used, connected to a 60:1 gearbox and a pulley system. As an interface, the system is equipped with an LCD 20x4 for local data display and a Telegram Bot for remote monitoring and control.

Figure 4 shows the final hardware scheme after implementation modifications. The system is centered on the ESP32. Inputs are sourced from the Capacitive Soil Moisture Sensor and the DHT22 sensor. An RTC DS3231 tracks the duration. The ESP32 controls three relays: two for the Fan & Heater unit and one for the AC Motor. An LCD 20x4 (I2C) displays the status, and the ESP32's WiFi module connects to the Telegram Bot for notifications.

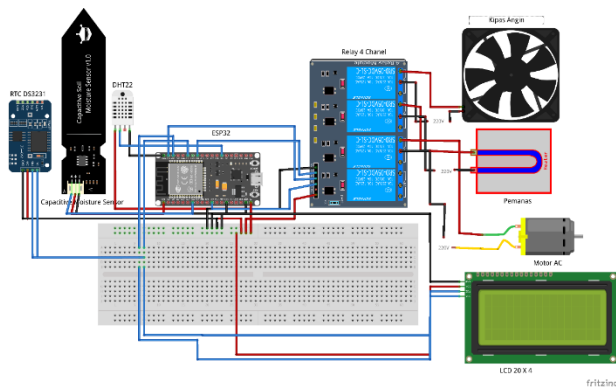


Figure 4. Hardware Schematic

Figure 5 illustrates the general system workflow. Following initialization, the system checks the internet connection for the Telegram Bot. Subsequently, it reads the moisture, temperature, and RTC time. This data is then fed into the controlling subprocess (fuzzy logic), which, in turn, operates the Fan Heater and the Motor. The data is simultaneously displayed on the LCD and sent to Telegram for remote monitoring.

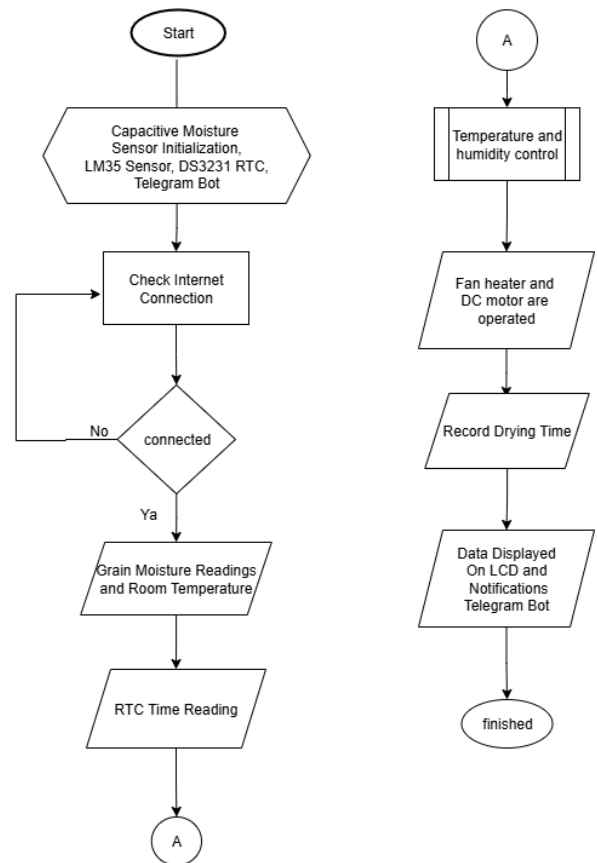


Figure 5. General Flowchart System

Figure 6 illustrates the fuzzy logic workflow. This process takes the Moisture and Temperature sensor data and passes it through the Fuzzification stage, which converts crisp values into fuzzy values. Next is the Rule Evaluation, which uses the 9 rule base, and finally the Defuzzification stage, which converts the fuzzy result back into a crisp value to control the actuator.

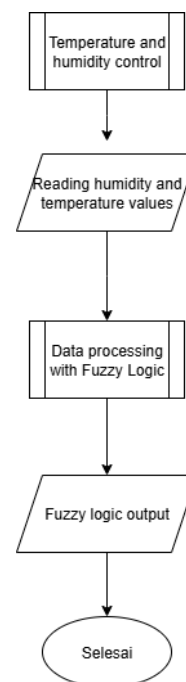


Figure 6. Sub Flowchart of the nRF52840 Process

Fuzzy logic was designed with 2 inputs and 1 output after the motor was removed from fuzzy control. The final membership function uses a trapezoidal curve (trapmf) for better stability compared to the triangular design (trimf). The Moisture Input is divided into 'Dry', 'Medium', and 'Wet' (Table 1). The Temperature Input is divided into 'Below Standard', 'Standard', and 'Above Standard' (Table 2)

Table 1. Membership Function – Moisture

Moisture Variable	Range(%)
Dry	13 -14
Medium	13– 22
Wet	21 - 30

Table 2. Membership Function – Temperature

Moisture Variable	Range(°C)
Below Standar	< 42°C
Standard	40 ≤ °C ≤ 60
Above Standard	>58°C

The Fan & Heater Output has three statuses: 'Off', 'Half', and 'Full' (Table 3).

Table 3. Membership Function – Fan & Heater

Moisture Variable	Range(°C)
Off	0
Half	1
Full	2

The nine rules (Table 4) determine the output based on the input combination. Example: IF Moisture is 'Wet' AND Temperature is 'Below Standard', THEN Fan&Heater is 'Full'.

Table 2. Hyperparameter Tuning Configuration

Moisture	Temperature	Fan & Heater
Dry	Below Standar	Off
Dry	Standard	Off
Dry	Above Standard	Off
Medium	Above Standard	Off
Medium	Standard	Half
Wet	Above Standard	Half
Medium	Below Standar	Full
Wet	Below Standar	Full
Wet	Standard	Full

The system is also designed to send notifications to the Telegram application, as seen in Figure 7, which shows various notification scenarios: process complete, process running, high temperature warning, and final reminder.

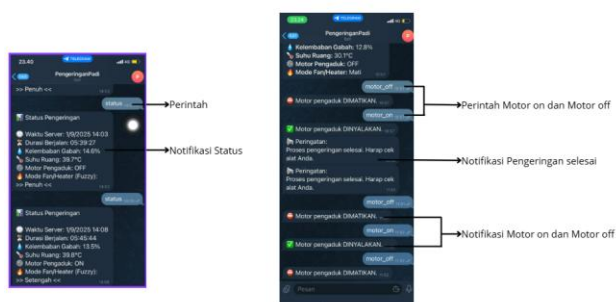


Figure 7. Telegram Bot Interface Design

RESULTS AND DISCUSSION

Hardware Implementation

Figure 8 shows the final hardware implementation of the paddy drying system. This closed design is crucial for protecting the paddy from pests during the drying process. Figure 9 details the control box which houses the ESP32, three relay modules, and an LCD 20x4 for local monitoring.



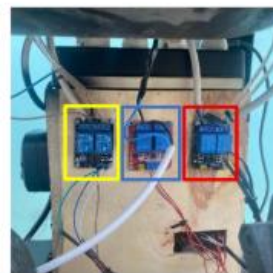
Figure 8. Hardware Implementation



a. Depan



b. Samping



c. Belakang



d. Dalam

Figure 9. Hardware Implementation of Device 1

During implementation, several important modifications were made from the initial design. The LM35 temperature sensor was replaced with the DHT22 because the readings of the LM35 on the ESP32 were very unstable and jumping.

The most significant modification was to the driving system. The planned DC motor MY1016 proved to lack sufficient torque to rotate the drum filled with paddy. Therefore, the system was changed to use a Wasser PW131E, 125W AC motor combined with a 60:1 gearbox and a pulley system.

Torque Calculation

$$T_{\text{motor}} = (P \times 9.549) / N = (250 \text{ W} \times 9.549) / 2850 \text{ RPM} = 0.84 \text{ Nm}$$

$$T_{\{akhir\}} = T_{\{motor\}} \times R_{\{pulley1\}} \times R_{\{gearbox\}} \times R_{\{pulley2\}}$$

$$T_{\{akhir\}} = 0.84 \times 2.5 \times 60 \times 2.4 = 302.4 \text{ Nm}$$

The final torque of 302.4 Nm significantly exceeds the requirement, ensuring the motor does not overheat and has a longer lifespan.

Software Implementation

Software implementation focused on fuzzy logic and Telegram Bot integration. The Telegram Bot named "Pengeringan Padi" was successfully implemented (Figure 11). This bot allows users to request real-time "status" and provides emergency manual control ("motor_off", "motor_on").

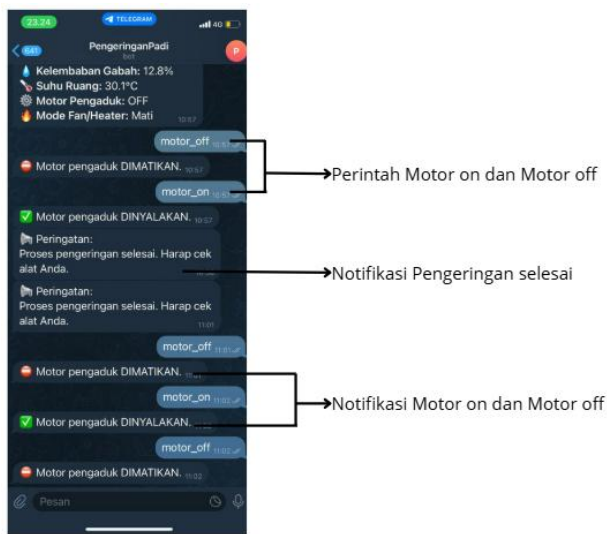


Figure 10. Telegram Bot Implementation

Testing and Analysis

This system testing phase includes testing of hardware, testing of software, and testing of the entire system.

ESP32 Performance

Compilation testing showed the program uses 80% of flash memory and 14% of RAM, leaving sufficient space. The execution speed testing (Table 5) indicated that the fuzzy logic process is very fast, executing in less than 0.1 milliseconds, proving the system's computational efficiency

Table 3. ESP32 Execution Time Profile

Procces	Time(ms)
Detection System Time (Sensor)	505.982
Computation Method (Fuzzy)	0.086
Information & Notification (LCD/Bot)	1.686

Sensor Testing

Sensor accuracy testing is crucial. The moisture sensor (Table 6) was tested using a comparison method against a grain moisture meter and showed an average accuracy of 98.27% for dry paddy and 97.7% for wet paddy

Table 4. Dry Moisture Testing Result

Sensor Value	True Value	Difference
13.7%	13.8%	0.7%
13.5%	13.8%	2.2%
13.8%	13.8%	0.0%
13.7%	13.8%	0.7%
13.2%	13.8%	4.3%
13.9%	13.9%	0.0%
13.9%	13.9%	0.0%
14.4%	13.9%	3.6%
13.2%	13.9%	5.0%
13.7%	13.8%	0.7%

$$\text{Error} = \frac{\text{Selisih Pengukuran}}{\text{Pengukuran alat ukur}} \times 100$$

$$\text{Rata rata error} = \frac{\sum \text{Nilai Error}}{\text{Banyak data pengukuran}}$$

$$\text{Akurasi} = 100\% - \text{Rata rata error}$$

From the measurement results on dry paddy, it was found that the average error value of the sensor reading using the comparison method is a low value, specifically 1.73%, with an accuracy achieved above 98.3%. It can be concluded that the soil sensor is capable of accurately detecting the moisture content of dry paddy.

Table 5. Wet Moisture Testing Result

Sensor Value	True Value	Difference
18.8%	19.0%	1.1%
18.4%	18.4%	0.0%
17.6%	18.3%	3.8%
18.1%	18.3%	1.1%
18.0%	17.7%	1.7%
18.2%	18.4%	1.1%
17.6%	17.9%	1.7%
17.3%	17.7%	2.3%
18.2%	19.0%	4.2%
17.2%	18.3%	6.0%

$$\text{Error} = \frac{\text{Selisih Pengukuran}}{\text{Pengukuran alat ukur}} \times 100$$

$$\text{Rata rata error} = \frac{\sum \text{Nilai Error}}{\text{Banyak data pengukuran}}$$

$$\text{Akurasi} = 100\% - \text{Rata rata error}$$

From the measurement results on wet paddy, it was found that the average error value of the sensor reading using the comparison method is 2.3%, which is a low value. The resulting accuracy is 97.7%, indicating that the sensor has good performance in detecting the moisture of wet paddy.

The DHT22 temperature sensor (Table 7) was tested using a comparison method against a digital thermometer and also showed an accuracy of 97.88%.

Table 6. DHT22 Sensor Accuracy Test

Sensor Value(°C)	True Value(°C)	Difference
32.7	33.2	1.51%
36.2	36.9	1.90%
39.9	39.9	0.00%
42.2	42.1	0.24%
48	46.7	2.78%
56.2	52.8	6.44%
61.7	59.3	4.05%
64.1	63.5	0.94%
68.7	67.5	1.78%
71.2	70.1	1.57%

$$\text{Error} = \frac{\text{Selisih Pengukuran}}{\text{Pengukuran alat ukur}} \times 100$$

$$\text{Rata rata error} = \sum \frac{\text{Nilai Error}}{\text{Banyak data pengukuran}}$$

$$\text{Akurasi} = 100\% \text{ Rata rata error}$$

From the temperature measurement results using the DHT22 sensor, it was found that the average error value of the sensor reading using the comparison method is a low value, specifically 2.12%, with an accuracy of 97.88%. It can be concluded that the DHT22 sensor can accurately detect temperature. This proves the sensor's feasibility for use in the paddy drying system to ensure the drying process runs effectively and avoids paddy damage due to excessive heat

Fuzzy Logic Validation

The fuzzy logic output on the ESP32 was tested and compared with the MATLAB rule viewer simulation using the same inputs (Table 8). The results showed that the implementation on the microcontroller consistently produced the correct output (Off=0, Half=1, Full=2) in accordance with the designed rule base.

Table 7 Fuzzy Logic Validation (ESP32 vs. MATLAB)

Input (Moisture, Temperature)	Output ESP32	Output MATLAB	Matches Rule
(19.1%, 39.1°C)	2 (Full)	2 (Full)	Image after the table
(18.4%, 42°C)	1 (Half)	1 (Half)	Image after the table
(12.8%, 49.2°C)	0 (Off)	0 (Off)	Image after the table

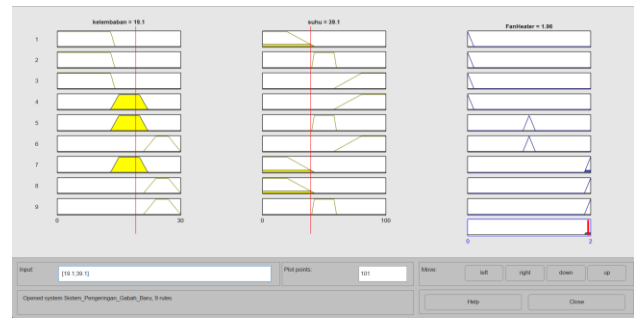


Figure 11. Fuzzy Testing 1



Figure 12. Fuzzy Testing 2

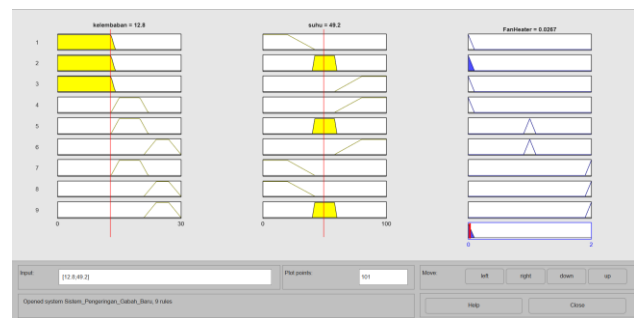


Figure 13. Fuzzy Testing 2

Connectivity Telegram Testing

The delay of the Telegram Bot notification was measured (Table 9). The average delay for all commands "status", "motor_on", "motor_off" was below 1 second under 962 ms, confirming the system's real-time capability

Table 6. Telegram Bot Delay Test

Category	No	Message		
		Send	Accept	Delay (ms)
status	1	11:17:21:3	11:17:22:263	926 ms
	37			
	2	11:17:33:3	1:17:34:244	927 ms
	17			
status	3	11:17:41:7	11:17:42:616	823 ms
	93			
	4	11:17:48:0	11:17:49:990	927 ms
	63			

	5	11:18:45:99	11:18:46:822	823 ms
	6	11:18:04:23	11:18:05:349	926 ms
	1	11:19:11:08	11:19:12:624	616 ms
	2	11:19:19:89	11:19:19:303	614 ms
	3	11:19:34:34	11:19:35:356	922 ms
motor_on	4	11:19:42:21	11:19:43:344	923 ms
	5	11:20:15:94	11:20:15:215	821 ms
	6	11:20:22:79	11:20:23:202	923 ms
	1	11:20:38:46	11:20:39:908	962 ms
	2	11:21:07:31	11:21:08:054	923 ms
	3	11:21:15:20	11:21:16:040	820 ms
motor_off	4	11:21:40:88	11:21:40:277	889 ms
	5	11:21:55:54	11:21:56:007	953 ms
	6	11:22:36:07	11:22:37:528	821 ms

Based on Table 4.17, it can be seen that the communication system tested has good performance. For all control commands, namely status, motor_on, and motor_off, the recorded delay ranges between 614 ms and 962 ms. This delay indicates that notifications and control commands are sent and received in less than 1 second, suggesting that communication occurs in real-time or very close to real-time. Overall, the data shows that the system operates in real-time and is responsive for control tasks.

System Functionality Testing (5 Scenarios)

This is the main functional testing of the system as a whole (Table 10). The system was tested with five different paddy loads. The drying test used 5 different weight scenarios, namely 10 kg, 15 kg, 20 kg, 25 kg, and 30 kg, to evaluate the system's performance. The objective of these scenarios was to test the system's ability to adapt to variations in paddy moisture and weight, and to analyze the time required to complete the drying process in each scenario.

Table 7. Summary of 5 Drying Scenarios

Skenario	Berat	Kelem baban Awal	Kelem baban Akhir	Dura si (jam)	Penuru nan kelem baban	Rata Rata Penuru nan
1	10Kg	18.9%	13.1%	8:36	5.8	0.70
2	15Kg	16,2%	12.9%	7:34	3.3	0.45
3	20Kg	16.4%	13.3%	6:43	3.1	0.46
4	25Kg	15.6%	12.8%	5:29	2.8	0.51
5	30Kg	15.4%	12.8%	6:14	2.6	0.42

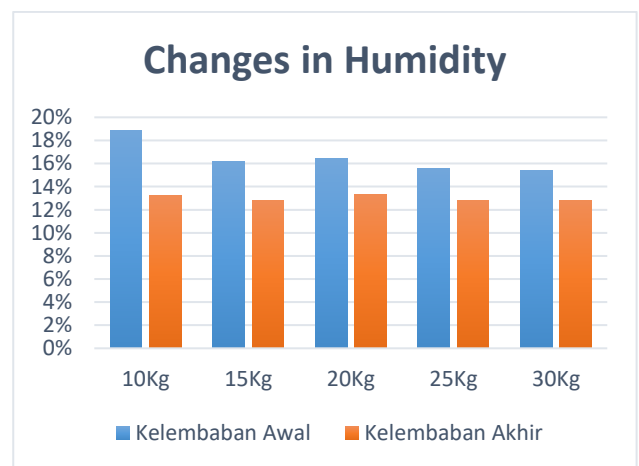


Figure 13. Changes in Humidity

The drying system showed the most efficient performance in scenario 1 (10 kg load), with the highest moisture reduction rate of 0.70% per hour due to stable operational temperatures in the optimal range of 42–44°C. Conversely, scenario 5 (30 kg load) showed the lowest efficiency with a rate of only 0.42% per hour. At this heaviest load, the temperature failed to reach 40°C, indicating that the system was approaching its capacity limit and the process was slow.

Performance at medium loads (15–25 kg) showed varied results. Scenario 2 (15 kg) ran slowly at 0.45% per hour because the temperature failed to reach optimal levels, staying only at 39.8°C, likely due to paddy husks obstructing the heat flow. Scenario 3 (20 kg) performed better at 0.46% per hour because the temperature successfully reached the optimal level of 41–43°C. Surprisingly, scenario 4 (25 kg) was faster at 0.51% per hour, but this was influenced by a lower initial moisture content and a sensor error that caused a temperature spike up to 49°C.

Overall, the system's efficiency is highly dependent on its ability to reach and maintain the optimal temperature in the range of 40–60°C. The light load of 10 kg proved to be the most ideal, while efficiency dropped drastically at the heaviest load of 30 kg and also at the 15 kg load where air flow issues occurred. Despite various operational constraints, the fuzzy control system was reported to function well in all scenarios.

As a comparative method, a 20 kg batch of grain was dried conventionally (sun drying), starting at 15.7% initial humidity.

The results showed the superiority of the automatic drying machine, which started with an initial humidity of 16.4%. The machine proved to be 34 minutes faster and more effective, achieving a total humidity reduction of 3.1 points compared to the 2.9 points from the conventional method, as seen in Table 8.

Table 8. System vs. Conventional Drying (20kg)

Metode	Durasi	Kelem	Kelem	Perubah	Suhu
Pengeri	(Jam:	baban	baban	an	Pengeri
ngan	Menit)	Awal	Akhir	Kelemb	ngan
				aban	
Conves	7 :17	15.7%	12.8%	2.9	33.3°C
ional					-38.2°C
Mesin	6:43	16.4%	13.3%	3.1	22.9°C-
					42.7°C

The primary difference in performance lies in temperature control. The conventional method is entirely dependent on the weather and only reached suboptimal temperatures (33.3–38.2°C), which is below the ideal range of 40–60°C. In contrast, the machine, using fuzzy logic control, successfully maintained a stable temperature within the optimal range of 41–43°C, resulting in far more efficient heat transfer.

Furthermore, the machine offers the advantage of automation. The drying drum rotates automatically, ensuring the grain dries evenly without the need for manual turning, which is required by the conventional sun-drying method.

CONCLUSIONS

The automatic rotating paddy drying system based on fuzzy logic has been successfully designed, implemented, and tested. This system proved capable of monitoring and detecting paddy moisture and the drying chamber temperature in real-time and accurately. The moisture sensor showed an accuracy of 98.27% (dry) and 97.7% (wet), while the DHT22 temperature sensor had an accuracy of 97.88%. The implemented fuzzy logic successfully controlled the Fan & Heater actuator to maintain the temperature within the ideal range (40°C-60°C) during drying at optimal loads (10–20 kg)

REFERENCES

- [1] N. Dzuchroidah and A. Mus'if, "Kebiasaan Penyimpanan Gabah Oleh Petani Pasca Panen dalam Perspektif Hukum Islam," Rizquna: Jurnal Hukum dan Ekonomi Syariah, vol. X, no. X, pp. 1–19, 20XX.
- [2] Dinas Pertanian Kabupaten Ngawi, "Prosedur Penanganan Pasca Panen pada Tanaman Padi," Dinas Pertanian Kabupaten Ngawi, Dec. 23, 2022. [Online]. Available: <https://pertanian.ngawikab.go.id/2022/12/23/prosedur-penanganan-pasca-panen-pada-tanaman-padi/> [Accessed: 19-Jan-2025].
- [3] Dinas Pertanian Kabupaten Buleleng, "Pengeringan Gabah," Dinas Pertanian Kabupaten Buleleng, [Online]. Available: https://distan.bulelengkab.go.id/informasi/detail/artikel/81_pengeringan-gabah [Accessed: 19-Jan-2025].
- [4] S. A. Susilawati, "Kesiapan Teknologi Panen dan Pascapanen Padi dalam Menekan Kehilangan Hasil dan Menjaga Mutu Beras," Jurnal Teknologi Pertanian, vol. X, no. X, pp. 1–10, 20XX.
- [5] T. Millati, Y. Pranoto, N. Bintoro, dan T. Utami, "Pengaruh Suhu Penyimpanan pada Gabah Basah yang Baru Dipanen terhadap Perubahan Mutu Fisik Beras Giling," Agritech, vol. 37, no. 4, pp. 477–485, Nov. 2017. DOI: 10.22146/agritech.12015.
- [6] Raja Pengering, "Mesin Pengering Pertanian Model Bed," Raja Pengering, [Online]. Available: <https://www.rajapengering.com/page/Mesin-Pengering-Pertanian-Model-Bed> [Accessed: 19-Jan-2025].
- [7] Badan Penelitian dan Pengembangan Pertanian, "Teknologi Penanganan Pascapanen Padi untuk Mengurangi Kehilangan Hasil," Kementerian Pertanian Republik Indonesia, 20XX. Available: <https://repository.pertanian.go.id/server/api/core/bitstreams/a68c7b47-d180-4490-a3a7-3939241620dd/content> [Accessed: 19-Jan-2025].
- [8] Cohen, Quality Fuction Deployment: How to Make QFD Work for You, Massachusetts: Addison Wesley Publishing Co., 1995.
- [9] T. Wijaya, Manajemen Kualitas Jasa (Desain Servqual, QFD, dan Kano), Edisi 2, Jakarta: Indeks, 2018.
- [10] Ulfa, R. (2022). Efek Lama Pengeringan Terhadap Kadar Air Gabah Dan Mutu. *Jurnal Teknologi Pangan dan Ilmu Pertanian (JIPANG)*, Vol. 4 No. 1.
- [11] M. Al Faris, S. Purwiyanti, and Herlinawati, "Rancang Bangun Prototype Pengering Gabah Otomatis Dengan Pengendali Sensor Kelembaban Dan Suhu Berdasarkan Suhu Ruang Berbasis Mikrokontroler ATmega 328," Electrician - Jurnal Rekayasa dan Teknologi Elektro, vol. 14, no. 1, pp. 22–25, Feb. 2020.
- [12] Biomaker, "Soil Moisture Sensor Aaideepen V1.2," Biomaker, Dec. 17, 2021. [Online]. Available: <https://www.biomaker.org/block-catalogue/2021/12/17/soil-moisture-sensor-aaideepen-v12>. [Accessed: 19-Jan-2025].
- [13] DFRobot, "Capacitive Soil Moisture Sensor SKU: SEN0193," DFRobot Technical Journal, vol. X, no. X, pp. 1–5, 2017.

- [14] ElectronicWings, "LM35 Sensor Interfacing with ESP32," Electronic Wings, [Online]. Available: <https://www.electronicwings.com/esp32/lm35-sensor-interfacing-with-esp32> [Accessed: 10 November 2024].
- [15]. Maxim Integrated, "DS3231: Extremely Accurate I2C-Integrated RTC/TCXO/Crystal," Maxim Integrated Technical Document, vol. X, no. X, pp. 1–19, 2005.
- [16]. "ESP32WROOM32 Datasheet," 2019. [Daring]. Tersedia pada : <https://www.alldatasheet.com/datasheet-pdf/pdf/1179101/ESPRESSIF/ESP-WROOM-32.html> [Accessed: 10 November 2024].
- [17]. E.A.Prastyo, "Mengenal Pin GPIO ESP-WROOM-32", arduino.bi.id, Agustus 2022 [online] Available : <https://www.arduino.biz.id/2022/08/mengenal-pin-gpio-esp-wroom-32.html> [Accessed: 10 November 2024].
- [18]. Setia, B., & Agus Ramadan. (2019). Penerapan Logika Fuzzy pada Sistem Cerdas. *Jurnal Sistem Cerdas*, Volume 02 No 01 IS SN : 2622-8254 Hal 61 -66.
- [19]. Fatkhurrozi, B., & Hery, T. S. (2024). Implementation Of Fuzzy Logic In A Microcontroller-Based Air Temperature And Humidity Control System For Coffee Bean Drying Room. *Journal Of Telecommunication, Electronics, And Control Engineering (Jtece)* , Vol. 06, No. 01, Pp. 50-59.
- [20]. "Penghangat Ruangan Untuk Kamar," shopee.co.id.
- [21]. Probots, "MY1016 24V 250W 2650RPM Brushed DC Motor DIY eBike," Probots, [Online]. Available: <https://probot.co.in/my1016-24v-250w-2650rpm-brushed-dc-motor-diy-ebike.html> [Accessed: 19-Jan-2025].
- [22]. HandsOn Tech, "I2C LCD 2004 Datasheet," *HandsOn Tech*, [Online]. Available: https://www.handsontec.com/dataspecs/I2C_2004_LCD.pdf. [Accessed: 10 November 2024].
- [23]. Traco Power, AC/DC Industrial Power Supply TXN 100 Series, 100 Watt. Datasheet, November 11, 2024. [Online]. Available: <https://www.tracopower.com/overview/txn100> [Accessed: Dec. 28, 2024].
- [24]. Digikey, "4 channel 5V Relay Module" Accessed: Nov. 19, 2024. [Online]. Available: <https://mm.digikey.com/Volume0/opasdata/d220001/medias/documents/5773/TS0011%20DATASHEET.pdf>
- [25] Qwords, "Cara Menggunakan Telegram," Qwords Blog, [Online]. Available: <https://qwords.com/blog/cara-menggunakan-telegram/>. [Accessed: 10 November 2024].
- [26]. HashMicro, "Mengenal Cost of Product dan Cara Mudah Menghitungnya," HashMicro Blog, [Online]. Available: <https://www.hashmicro.com/id/blog/mengenal-cost-of-product-dan-cara-mudah-menghitungnya/>
- [dan-cara-mudah-menghitungnya/](https://www.hashmicro.com/id/blog/mengenal-cost-of-product-dan-cara-mudah-menghitungnya/) [Accessed: 10 November 2024]
- [27]. UpCounsel, "Development Cost Definition," UpCounsel, [Online]. Available: <https://www.upcounsel.com/development-cost-definition>. [Accessed: 10 November 2024]
- [28]. Welhome, "Kipas Angin Welhome WH-1061M/Kipas Angin Meja". [Online]. Available: <https://welhome.co.id/kipas-angin-welhome-wh-1061m-kipas-angin-meja/>. [Accessed: 4 Oktober 2025]
- [29]. Diskonlapak, "Heater 300W Elemen Pemanas Udara Mesin Tetas Telur Inkubator 220V AC 300W". [Online]. Available: <https://shopee.co.id/Heater-300W-Elemen-Pemanas-Udara-Mesin-Tetas-Telur-Inkubator-220V-AC-300W-i.77405886.1540743490>. [Accessed: 4 Oktober 2025]
- [30]. Wasser, "Wasser Shallow Well Pump (Pompa Air) PW-131 E 1pc". [Online]. Available: <https://www.monotaro.id/s003477434.html>. [Accessed: 4 Oktober 2025]
- [31]. Aosong Electronics Co.,Ltd. *DHT22 (DHT22 also named as AM2302) Capacitive-type humidity and temperature module/sensor*, Aosong Electronics Co.,Ltd.

AUTHOR(S) BIOGRAPHY



Fadhil Ramdani

Born in Saruaso on August 29, 2002, he attended SMAN 3 Batusangkar and is currently studying Computer Engineering at the Faculty of Information Technology, Andalas University. His interest is data analysis.