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Research Article

Design and Development of an Automatic *Asem Keping* Drying System Using Infrared Heater Based on Fuzzy Logic

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Abstract: The drying process of Asam Keping (Garcinia atroviridis) is a crucial stage in food processing that significantly affects the final product quality. Conventional drying methods that rely on sunlight have several limitations, such as dependency on weather conditions, extended drying time, and inconsistent results. This study aims to design a drying system for Asam Keping controlled using the fuzzy logic method. The research is expected to improve energy efficiency, accelerate the drying process, and maintain the quality of the dried product. The drying system is designed using an infrared heater as the heat source, temperature and humidity sensors to monitor environmental conditions, and a microcontroller as the main controller. The fuzzy logic method is implemented to adjust the drying temperature and duration adaptively based on environmental parameters and the desired dryness level. The results of this study are expected to reduce drying time by approximately 50% compared to conventional methods. Additionally, the dried Asam Keping is expected to achieve the desired moisture content while preserving its color and texture quality. The analysis of this study concludes that an infrared heater-based drying system utilizing fuzzy logic can be an effective solution for the Asam Keping drying process in terms of time efficiency and product quality.

Keywords: Asam Keping; Drying; Efficiency; Fuzzy logic; Infrared heater

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1. Introduction

Asem keping (asem gelugur) are a natural ingredient widely used in the food, pharmaceutical, and health industries. This product has high economic value because it is rich in active compounds such as hydroxycitric acid, which is useful in food processing. However, one of the problems in processing *asem keping* is the drying process. An inefficient drying process can affect the color, texture, and moisture content of *asem keping*, thereby reducing the product's selling value.

Conventional drying that relies on sunlight is often ineffective due to unpredictable weather conditions. In addition, this method takes a long time and cannot guarantee consistent product quality. In some cases, excessive drying is not good for *asem keping* because it can cause degradation of the active compounds contained in *asem keping*, thereby reducing the benefits that should be obtained from this product.

To overcome this problem, modern and efficient drying technology is needed, one of which is the use of infrared heaters. Infrared heaters have the advantages of energy efficiency, drying time, and maintaining the quality of the dried material, as well as having a high heat transfer rate (80% - 90%).

Infrared heaters have a system in which energy is emitted in the form of electromagnetic waves that can be directly absorbed by the material without the need for preheating the air medium. This allows for a faster drying process than using conventional methods. In addition, the temperature can be better controlled to avoid degradation of heat-sensitive active compounds. Previous research has shown that the use of infrared heaters in drying agricultural products can produce products with better color, texture, and moisture content than conventional methods (Adiandri et al., 2013).

To improve the performance of this system, an adaptive and intelligent control method is required. In this case, fuzzy logic is the right solution because it can handle uncertainties in parameters such as temperature, humidity, and drying time. By using infrared heater technology and the fuzzy logic method, it is hoped that the drying process for *asem keping* will be more effective, efficient, and produce products of optimal quality.

2. Preliminaries or Related Work or Literature Review

This section presents a comprehensive review of relevant prior studies and theoretical foundations related to the development of an infrared drying system for *asam keping* (Garcinia atroviridis), with a focus on food drying principles, infrared heating technology, fuzzy logic control, and the integration of embedded hardware and software components.

Asam Keping (Garcinia atroviridis)

Asam keping, also known as *asam gelugur*, is a tropical plant native to South and Southeast Asia and belongs to the same family as mangosteen and *asam kandis*. It is a dioecious species, with separate male and female trees. Traditionally, *asam keping* is widely used in Malay cuisine as a souring agent, in beverages, traditional medicine, cosmetics, and as an ingredient in preserved snacks such as candied fruit. High-quality dried *asam keping* is characterized by a reddish-brown color, flexible yet firm texture, intact slice shape without excessive shrinkage, and a sharp, fresh sour aroma without mustiness (Adiandri et al., 2013).

Fundamentals of Food Drying

Drying is a natural preservation method that removes moisture from food by applying heat, thereby inhibiting microbial growth, inactivating enzymes, and preventing undesirable biochemical and chemical reactions that degrade food quality. This process extends shelf life while reducing the mass and volume of the product. While traditional sun drying remains common, modern drying technologies now incorporate precise control of temperature, humidity, and airflow to optimize product quality and efficiency (Doymaz, 2005; Adiandri et al., 2013).

Infrared Heating Technology

Infrared (IR) drying utilizes electromagnetic radiation to directly heat the material from the inside out, significantly accelerating moisture evaporation. Compared to conventional convective drying, IR technology offers shorter processing times, higher energy efficiency, and better retention of nutritional and sensory qualities. Halogen-based infrared heaters are particularly effective, as they rapidly agitate water molecules within the food matrix without excessively raising internal temperatures, thus preserving color, texture, and nutrient content while inactivating spoilage microorganisms (Adiandri et al., 2013; Pan et al., 2008).

Fuzzy Logic in Control Systems

Fuzzy logic is an artificial intelligence technique designed to manage uncertainty and nonlinearity in dynamic systems. It is especially suitable for controlling complex processes like drying, where precise mathematical models are difficult to formulate. The method involves four main stages: fuzzification, rule base evaluation, inference, and defuzzification. In this research, fuzzy logic is employed to regulate the intensity of the infrared heater based on real-time inputs of temperature and relative humidity, aiming to enhance energy efficiency and product consistency.

ESP32 Microcontroller

The ESP32-DevKitC-V4 is a versatile, dual-core microcontroller developed by Espressif Systems. It features integrated Wi-Fi (802.11 b/g/n) and Bluetooth 4.2 (including BLE), 520 KiB of SRAM, and a rich set of peripherals—including multiple SPI, I²C, UART, and ADC interfaces—making it ideal for IoT-enabled embedded control applications such as smart drying systems.

DHT22 Sensor

The DHT22 is a digital sensor capable of measuring ambient temperature (±0.5°C accuracy) and relative humidity (±2–5% RH) with high reliability over long cable runs. Its stable digital output protocol ensures robust data transmission to microcontrollers. In prior IoT-based monitoring systems, the DHT22 demonstrated effective real-time performance with the ESP32, achieving data transfer in under 40 ms (Zhang et al., 2020). In this study, it serves as a primary input source for the fuzzy logic controller.

DS18B20 Temperature Sensor

The DS18B20 is a digital thermometer that communicates via the 1-Wire protocol, offering programmable resolution (9–12 bits) and ±0.5°C accuracy in the range of –10°C to +85°C. Its parasitic power mode and multidrop capability allow multiple sensors to operate on a single data line without external power, making it suitable for multi-point temperature monitoring in compact drying chambers. Here, it provides precise internal temperature feedback for fuzzy-based heater control.

Solid State Relay (SSR)

The Solid State Relay (SSR) is an electronic switching device that replaces mechanical relays, using semiconductor components (e.g., triacs or thyristors) for silent, high-speed, and wear-free operation. Its optoisolated design provides electrical isolation between control and load circuits, enhancing system safety and noise immunity. In this system, the SSR modulates power delivery to the infrared heater in response to fuzzy logic commands, ensuring stable thermal regulation.

LCD 16x2 I2C Module

The 16x2 character LCD with I2C interface simplifies display integration by reducing wiring complexity to just two data lines (SDA/SCL). It supports software-controlled backlighting and built-in contrast adjustment. In this prototype, it provides real-time visualization of temperature and humidity readings from the DHT22 and DS18B20 sensors.

MATLAB for System Simulation

MATLAB, developed by MathWorks, is a high-level programming platform widely used for algorithm development, data analysis, and control system modeling. Its Fuzzy Logic Toolbox enables the design, simulation, and tuning of fuzzy inference systems. In this research, MATLAB is used to model and validate the fuzzy controller before implementation on the ESP32, ensuring optimal performance in regulating the drying environment.

Arduino IDE for Embedded Programming

The Arduino Integrated Development Environment (IDE) is an open-source platform that supports C/C++ programming for microcontrollers, including the ESP32. Its extensive library ecosystem—such as the Fuzzy Logic Library—facilitates rapid prototyping of intelligent control systems. Previous studies have successfully used Arduino IDE for environmental control in agricultural applications (e.g., oyster mushroom cultivation). In this work, it is employed to deploy the fuzzy logic algorithm that adaptively adjusts infrared heating intensity based on sensor feedback, aiming to achieve efficient and high-quality drying of *asam keping*.

3. Proposed Method

Research Design and Approach

This study employed an applied experimental approach based on an intelligent control system to design and implement a smart food dryer prototype using an ESP32 microcontroller integrated with the Fuzzy Logic Sugeno method. This approach was selected because of its effectiveness in handling nonlinear systems with dynamic parameters such as temperature and humidity.

The research procedure consists of four main stages: (1) literature study, (2) system design, (3) hardware design, and (4) software design. The overall methodological flow is illustrated in Figure 1.

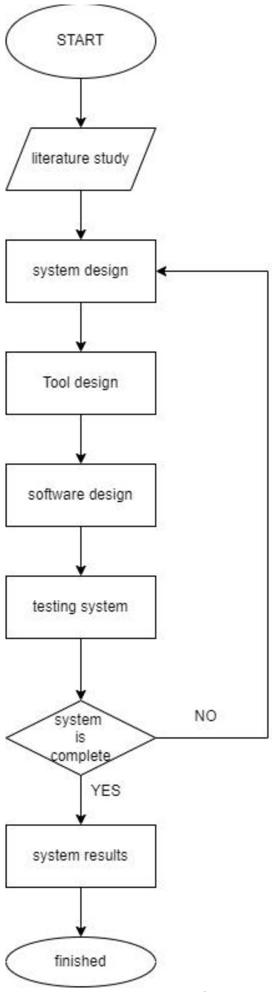

Figure 1. Research Methodology Flowchart

Literature Study

The literature study was conducted to obtain theoretical foundations and technical references related to the system design. Relevant information was collected from scientific journals, textbooks, and reliable online sources. The key references covered topics such as fundamentals of food drying technology, infrared heating systems, fuzzy logic in control systems, and the technical characteristics of the components used — namely ESP32-DevKit-V4, DHT22, DS18B20, Solid State Relay (SSR), LCD I2C, Arduino IDE, and MATLAB.

System Design

The system design stage describes the interaction between the hardware components of the drying system. The overall system consists of input, process, and output components, as shown in Figure 2.

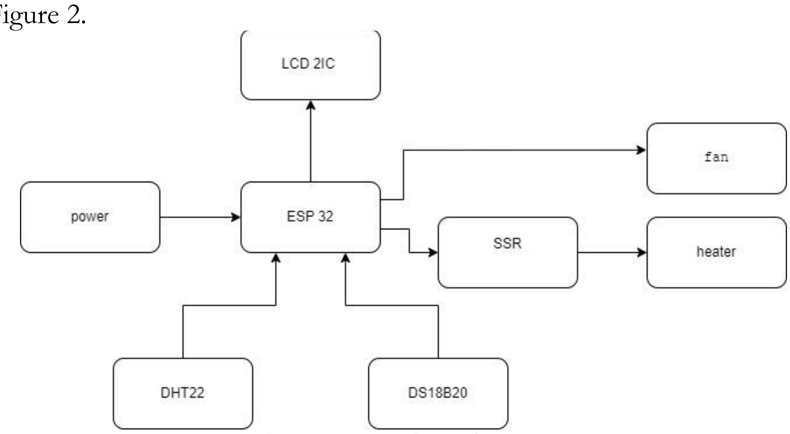

Figure 2. Block Diagram of the Automatic Drying System

The input components include the DHT22 humidity sensor and the DS18B20 temperature sensor, while the output components consist of the SSR, infrared heater, circulation fan, and LCD I2C for real-time display. The ESP32 microcontroller receives digital input from both sensors, processes it using the *Fuzzy Logic* algorithm, and generates control actions based on the temperature and humidity readings. Specifically:

1. If the temperature is low → increase heater intensity (PWM output to SSR).
2. If the humidity is high → activate the fan to reduce moisture.

The ESP32 sends control signals using Pulse Width Modulation (PWM) to regulate heater power, while the fan speed is controlled via an LM2595 module and an NPN **transistor**. Real-time data on temperature, humidity, and actuator status are displayed on the LCD.

Hardware Design

The hardware design stage focuses on the optimal placement and integration of all components to ensure system stability. The ESP32 acts as the central controller, collecting temperature and humidity data and adjusting the drying conditions accordingly. The SSR controls the infrared heater to maintain the temperature range between 50°C and 55°C, while the circulation fan maintains the humidity around 40%.

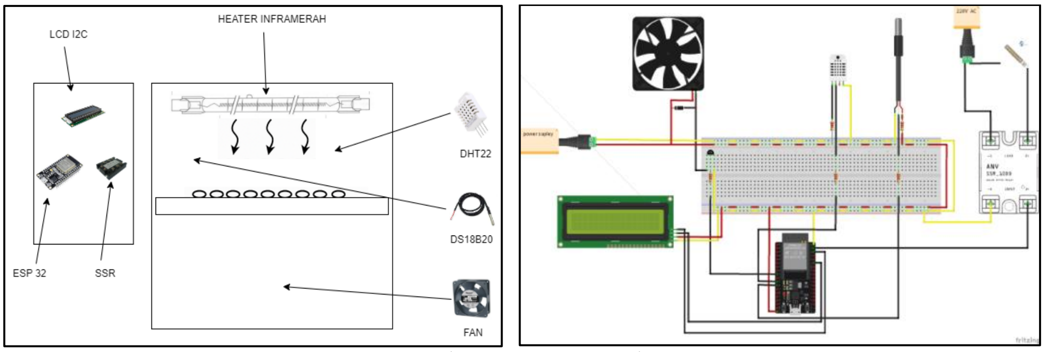

Figure 3. Hardware Layout and Circuit Design

Software Design

The software was developed using Arduino IDE (C++) for system implementation and MATLAB for Fuzzy Logic modeling and analysis. The control logic was built following the flow shown in Figure 4.

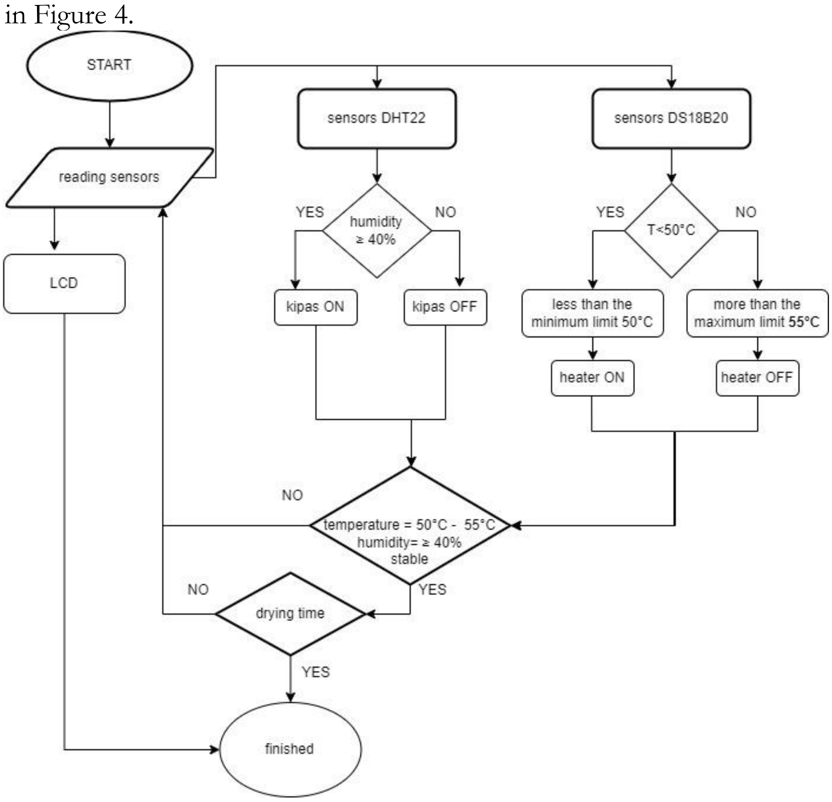

Figure 4. Flowchart of the Drying System with Fuzzy Logic

The main software processes include:

1. Reading temperature and humidity data from DHT22 and DS18B20 sensors.
2. Displaying real-time readings on the LCD.
3. Controlling humidity: the fan turns ON when humidity ≥ 40%, and OFF when < 40%.
4. Controlling temperature:

   a. Temperature < 50°C → heater fully ON.
   b. Temperature 50–55°C → heater partially ON (50% power).
   c. Temperature > 55°C → heater OFF.
5. Continuously monitoring environmental changes until both temperature and humidity reach their setpoints. When drying time is completed, the system automatically stops operation.

Implementation of Fuzzy Logic Sugeno

The Fuzzy Sugeno model was implemented to control the heater and fan outputs based on two input variables: temperature (°C) and humidity (%).

a. Temperature membership functions: *Low* (40–52.5), *Medium* (50–55), *High* (> 55).
b. Humidity membership functions: *Low* (≤ 30%), *Medium* (30–50%), *High* (≥ 50%).

Table 1. Fuzzy Sugeno Rule Base for Heater and Fan Control

Rule	Temperature	Humidity	Heater Output	Fan Output
R1	Low	Low	1	0
R2	Low	Medium	1	0.5
R3	Low	High	1	1
R4	Medium	Low	0.5	0
R5	Medium	Medium	0.5	0.5
R6	Medium	High	0.5	1
R7	High	Low	0	0
R8	High	Medium	0	0.5
R9	High	High	0	1

The inference process applies the min–max method, while the defuzzification process uses the maximum method, producing system output values of 0 (off), 0.5 (medium power), or 1 (on).

System Testing and Analysis

The final stage involves system testing to verify performance stability and accuracy. The test aims to ensure that the temperature remains within 50–55°C and the humidity around 40%. The experimental results are compared against the setpoints to evaluate the control precision, response time, and overall effectiveness of the fuzzy control system.

4. Results and Discussion

System testing

The first test is a power consumption test to determine the total electrical energy consumed during the drying process, which will be displayed in a table. Using the formula:
Total Energy (Wh) = Power (W) × Time (hours) (3.1)

Table 2. Power consumption test

No.	Component	Power (Watt)	Drying Duration	Total Energy (Wh)
1	Infrared Heater	300 Watt	2 hours	600 Wh
2	ESP32	1,2 Watt	2 hours	2,4 Wh
3	Fan	55 Watt	2 hours	110 Wh

SSR and Fan Test (actuator control)

The second test is the SSR and fan test, which ensures that the Solid State Relay (SSR) controls the heater correctly and that the circulation fan operates according to the ESP32 command. This test can be seen in the table.

Table 3. SSR and Fan Test

No.	Signal	Condition
1	High	Heater is ON
2	Low	Heater is OFF
3	High Humidity	Fan is ON
4	Low Humidity	Fan is OFF

Temperature and Humidity Test

For the third test, the temperature and humidity test aims to determine the accuracy of the temperature and humidity sensors by comparing the results with standard measuring instruments, namely a digital thermometer and hygrometer, by filling in the sensor data with measuring instruments, in the form of error presentation with the formula:

$$\textbf{Eror}(\%) = \left(\frac{|\textbf{Sensor Value} - \textbf{Referance Value}|}{\textbf{Referance Value}}\right) \times \mathbf{100\%}$$

Table 4. Temperature Testing

No.	Sensor Reading	Measure Value	Eror
1	32,88°C	33,87°C	2,92%
2	55,06°C	56,05°C	1,77%
3	54,94°C	55,93°C	1,77%

Table 5. Humidity Testing

No.	Sensor Reading	Measure Value	Eror
1	65,30%	66,30%	1,5%
2	40,30%	41,30%	2,42%
3	39,40%	40,40%	2,48%

Dryer Performance Test

This fourth test aims to determine the time and quality of the dried slices required. The weight test is conducted manually by weighing the samples using a digital scale. The results of this test are shown in the table.

Table 6. Conventional dryer performance testing

Time	Temperature (°C)	Humidity (%)	Initial Weight (gram)	Final Weight (gram)	Weight Reduction (%)	QUA
0 (Initial)	30,4°C	66%	350	350	0%	GOOD
1 hours	28,1°C	70%	350	332	5,14%	GOOD
2 hours	31,2°C	67%	350	309	11,71%	GOOD
3 hours	32,7°C	66%	350	267	23,71%	GOOD
4 hours	34,1°C	65%	350	244	30,29%	GOOD
5 hours	35,6°C	65%	350	228	34,86%	GOOD

Table 7. Dryer performance testing integrated with fuzzy logic

Time	Temperature (°C)	Humidity (%)	Initial Weight (gram)	Final Weight (gram)	Weight Reduction (%)	Heater Status	Fan Status	Quality
0 (awal)	32,8°C	65,30%	350	350	0%	ON	ON	BAIK
1 jam	55,06°C	40,30%	350	269	23,14%	OFF	OFF	BAIK
2 jam	54,94°C	39,40%	350	223	36,29%	ON	OFF	BAIK

Initial and final data for drying efficiency

The fifth test was used to determine the drying efficiency and drying rate calculations to be used, as shown in the table.

Table 8. Dryer performance testing integrated with fuzzy logic

No	Parameter	Kondisi Yang Dicatat	Satuan
1	Initial Weight of *Asem Keping*	Before Drying	1000 g
2	Final Weight of *Asem Keping*	After Drying	637 g
3	Drying Duration	Total Drying Time	2 Hours

Discussion

Based on the test results, the fuzzy logic method can adaptively adjust the heater power and fan speed in response to changes in temperature and humidity within the drying chamber. For example:

1. When temperature < 50°C → Heater is turned ON at full power.
2. When temperature is 50–55°C → Heater operates at half power (50%) to maintain stability.
3. When temperature > 55°C → Heater is turned OFF.
4. When humidity > 40% → Fan is activated to accelerate evaporation.
5. When humidity < 40% → Fan is turned OFF to prevent overdrying.

This control strategy results in a stable and energy-efficient system, as actuators operate only when necessary, rather than continuously.

Regarding time and energy efficiency, as shown in Table 3.8, the drying process using this system requires 2 hours with an energy consumption of 0.91 kWh. In contrast, conventional sun-drying methods require approximately 5 hours under direct sunlight without guaranteed temperature control; this duration can be significantly longer during rainy weather. This demonstrates that the designed system achieves approximately 60% time efficiency and about 40% energy efficiency compared to conventional methods.

The Analyze stage aims to identify the main root causes of the high defect rate in woven sarongs at PT Ibrahim Bin Manrapi. Based on the Pareto analysis results, it was found that the most dominant types of defects were stitching defects at 46.38% and color defects at 24.96% of the total defects. These two types of defects were the main focus of the analysis because they contributed to more than 70% of the total product defects.

These results were reinforced by the Production Manager's statement, "The most frequent errors are indeed in the stitching. Because the process is manual using ATBM, sometimes the weaving is uneven or the threads come loose. Sometimes the colors are also not consistent because the dyeing is unstable." This shows that the skills of the workers and the condition of the manual machines greatly affect the quality of the weaving.

Through fishbone (Ishikawa) analysis, the root causes of stitching and color defects were grouped into five main factors: human, machine, method, material, and environment. In stitching defects, the human factor was the dominant cause due to the lack of operator skills and training. Non-standardized and poorly maintained manual machines (ATBM) also increased the risk of defects. In addition, the absence of standard operating procedures (SOPs), inconsistent thread quality, and poor lighting in the work area further worsened the weaving results.

Meanwhile, the main cause of color defects was the dyeing process, which was still done manually without standard time, temperature, or automatic dipping tools. Workers often dye based on personal experience without proper measuring tools. Material factors such as yarn with uneven color absorption and humid environmental conditions also worsen inconsistent color results.

Figure 5. Results of the P-Chart control chart for product defects from April to June 2025 after 5W+1H.

5. Comparison

This study makes a significant contribution to the application of the Six Sigma method in the traditional textile industry, particularly in the production of woven sarongs that still rely on non-machine looms (ATBM). The results of the study show that before the improvement, the average defect rate reached 4.21% with a DPMO value of 13,191 and a sigma level of 3.73. After implementing the DMAIC approach and 5W+1H-based interventions, there was a significant decrease to an average DPMO of 6,398 and a sigma level of 3.99, equivalent to a defect rate reduction to 2.56%.

A comparison with recent studies shows the relevance and superiority of the approach used in this study:

- Puji (2024) at UD. Berkah Fajar reported a decrease in DPMO from 89,711 to 20,486 (an increase in sigma from 2.84 to 3.54). Although the absolute reduction in DPMO is larger, this study achieved a higher final sigma level (3.99) despite operating in a more complex production environment (manual weaving with high dependence on human skills).
- Putri (2022) in the combination batik industry noted a very high initial DPMO (250,708) with a sigma level of only 2.18, indicating that traditional textile industries generally have process quality far below Six Sigma standards. This study successfully maintained a sigma level above 3.7 even before improvement and reached nearly 4.0 after intervention—indicating better process maturity than the industry average.
- Fajar (2025) in the MSME shoe industry successfully reduced the defect rate from 5.5–7.1% to around 3% through operator training and machine maintenance. This study achieved similar results (from 4.21% to 2.56%) despite the main challenges being technological limitations (ATBM) and the variability of natural raw materials—factors that were rarely addressed in previous Six Sigma studies.

Additionally, this study expands the application of Six Sigma by integrating FMEA analysis and the 5W+1H approach in the Improve stage, which is not always found in previous studies. This integration enables more systematic identification of improvement priorities and more structured implementation of solutions, especially in the context of limited resources such as traditional textile SMEs.

Thus, this study not only confirms the effectiveness of Six Sigma in reducing production defects but also demonstrates relevant methodological adaptations for skill-based craft industries—an important contribution that enriches the Six Sigma literature in the non-automated manufacturing sector.

6. Conclusions

Based on the design, implementation, and testing of the automatic *asem keping* drying system using an infrared heater based on fuzzy logic, several conclusions can be drawn. The system primarily consists of an ESP32 microcontroller, a DS18B20 sensor for temperature measurement, a DHT22 sensor for humidity measurement, an infrared heater as the heat source, and an SSR (Solid State Relay) along with a fan as actuators. All components functioned properly. With three membership levels Low, Medium, and High for both temperature and humidity, the system can automatically adjust the operation of the heater and fan.

According to the test results, the fuzzy logic-based system required only 2 hours to reduce the weight of *asem keping* by approximately 36%, whereas the conventional drying method required 5 hours. This indicates that the developed system achieves approximately 60% time savings and 40% energy savings compared to conventional methods.

References

Adiandri, R. S., Rahayu, E., & Rachmat, R. (2013). Efek pengeringan inframerah terhadap perubahan mikrostruktur, sifat fisik, dan kapasitas rehidrasi bahan pangan. *Buletin Teknologi Pertanian, 9*(1), 33–46.

Arthawani, G. (2021). *Karakteristik rebung petung pengeringan foam-mat menggunakan* [Skripsi, Universitas Jember]. *Digital Repository Universitas Jember.*

Asiah, N., & Djaeni, M. (2021). *Konsep dasar proses pengeringan pangan.* AE Publishing.

Ferdi, A., Syelly, R., & Studi Teknik Komputer Sekolah Tinggi Teknologi Payakumbuh. (2022). Rancang bangun sistem pengatur suhu dan kelembapan pada kumbung jamur tiram menggunakan sensor DHT11 dan Arduino. *Jurnal SIMTIKA, 4*(1), 14–20.

Guide, A. (n.d.). *Solid-state relays.* Rockwell Automation.

Handson Technology. (2021). *I2C serial interface 1602 LCD module user guide* (pp. 1–8).

Imaroh, U., & Asriningsih. (2021). *Self-efficacy sedang tidak dapat melakukan pengecekan ulang jawaban secara efektif sehingga kesalahan dalam proses penerapan rencananya tidak dapat terdeteksi* [Penelitian].

Ma'ruf, A., et al. (2023). Efektivitas pengeringan chip singkong menggunakan inframerah dan *hot air dryer* dalam pembuatan *modified cassava flour (MOCAF). JRST (Jurnal Riset Sains dan Teknologi), 7*(1), 77. https://doi.org/10.30595/jrst.v7i1.16133

Maulana, R. F., Ramadhan, M. A., Maharani, W., & Maulana, M. I. (2023). Rancang bangun sistem monitoring suhu dan kelembapan berbasis IoT: Studi kasus ruang server ITTelkom Surabaya. *Indonesian Journal of Multidisciplinary Social Technology, 1*(3), 224–231. https://doi.org/10.31004/ijmst.v1i3.169

Maxim Integrated. (2019). *DS18B20 programmable resolution 1-wire digital thermometer* (Vol. 92, pp. 1–20).

Permata Tiar, A. E. (2024). *Rancang bangun purwarupa alat pengering sepatu berbasis IoT menggunakan ESP32* (pp. 1–23).

Rahmawati, L., Hariadi, H., Saputra, D., Sahim, K., & Priyanto, G. (2022). Studi pendahuluan pengeringan kulit buah duku segar dengan mengekspos di bawah pemancar radiasi inframerah. *Agrointek: Jurnal Teknologi Industri Pertanian, 16*(1), 18–27. https://doi.org/10.21107/agrointek.v16i1.11857

Rumiati. (2024). *Peserta didik dengan tingkat self-efficacy rendah sering kali mengalami kesulitan signifikan dalam merencanakan penyelesaian masalah matematika yang tepat dan efektif* [Penelitian].

Sci, W. J., & Thammarat, N. S. (2006). Drying characteristics of [Original article]. *Journal of Food Engineering, 3*(1), 13–32.

Wahab, F., Sumardiono, A., Al Tahtawi, A. R., & Mulayari, A. F. A. (2017). Desain dan purwarupa *fuzzy logic control* untuk pengendalian suhu ruangan. *Jurnal Teknologi Rekayasa, 2*(1), 1–8. https://doi.org/10.31544/jtera.v2.i1.2017.1-8

Wijayanti, Surahmat, & Nursit. (2021). *Peserta didik dengan self-efficacy tinggi mampu memeriksa kembali penyelesaian dengan cara menuliskan kesimpulan dengan tepat* [Penelitian].

Yunitasari, & Zaenuri. (2020). *Peserta didik dengan self-efficacy sedang cenderung dapat mencapai indikator memahami masalah dengan baik pada semua tes yang dikerjakan* [Penelitian].