Design Of Bread Cooling System with Adaptive Temperature Control in UMKM Rumah Roti Mamita

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***Abstract*—This research aims to design a bread cooling device to assist UMKM Rumah Roti Mamita in overcoming bread cooling challenges during the production process. Proper cooling is essential to ensure bread quality and prevent defects during packaging. By implementing an adaptive temperature control system using a temperature sensor and a microcontroller, the proposed device is able to reduce the bread temperature to approximately 30 degrees Celsius within a relatively short time. This allows the packaging process to proceed efficiently while maintaining consistent product quality and texture. In addition, the system enables users to set and adjust the target temperature according to production needs, providing flexibility and ease of operation for small-scale business owners. The bread cooling device is designed to be simple, cost-effective, and suitable for daily use in MSME environments. Overall, this system is expected to improve production efficiency, reduce cooling time, and minimize potential quality issues. Therefore, the proposed bread cooler serves as an effective and practical solution for UMKM Rumah Roti Mamita in addressing existing production constraints and enhancing overall business performance.**

Keywords*- *Bread, Bread Cooler, MLX90614, Bread Temperature, UMKM Rumah Roti Mamita

I. INTRODUCTION

Bread is one of the food products that has an important role in the consumption patterns of people around the world, including in Indonesia. The manufacturing process involves key ingredients such as wheat flour, baker's yeast (Saccharomyces cerevisiae), salt, and water, which are processed through the stages of kneading, fermentation, and baking to produce a final product with a distinctive texture and flavor. In addition to the main ingredients, the bread industry often adds additional ingredients such as sugar, fat, milk, emulsifiers, and other components to improve the flavor and texture characteristics of bread [1][2].

Bread cooling is an important stage to ensure the product reaches a safe temperature before packaging [3]. The ideal temperature for bread packaging is around 30°C [4]. At this temperature, the bread has the best stability without the risk of condensation that can damage the quality of the product. Condensation that occurs as a result of packing bread in a hot state can cause excess moisture, deterioration in texture, and accelerate mold growth. In addition, inappropriate temperatures can affect consumer satisfaction [5].

Currently, Rumah Roti Mamita uses a manual method with a conventional fan to cool the bread. This process takes more than an hour to reach the optimal temperature. Apart from taking a long time, this method is also less efficient in controlling the temperature precisely. This condition shows the need for technological innovation to improve time efficiency and cooling quality [6]. One solution that can be applied is adaptive cooling technology based on PID (Proportional-Integral-Derivative) control combined with thermoelectric technology. This approach allows precise and adaptive temperature regulation, so that the cooling process can be carried out more quickly and energy-efficiently without sacrificing product quality [7].

To overcome these weaknesses, this study designed an adaptive bread cooling system that uses PID technology and Peltier thermoelectric modules. The system is designed to speed up the cooling process to less than 15 minutes, much faster than the manual method that takes more than an hour. In addition, this research also integrates an Android application-based monitoring feature. This feature allows users to monitor the

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temperature in real-time remotely, providing flexibility and ease of operation [8].

With this adaptive bread cooling system, it is expected that production efficiency and product quality can be significantly improved. The system not only speeds up cooling time but also supports energy efficiency, making it an ideal solution for MSMEs such as Rumah Roti Mamita. The implementation of this technology is expected to answer the needs of modern and efficient bread production, while increasing competitiveness in the domestic market [9].

This study aims to verify the system's performance in achieving the ideal temperature target stably and to test the functionality of the remote monitoring application. Thus, the results of this study are expected to serve as an applied technological reference that contributes to the modernization of production processes in the culinary MSME sector, particularly in post-baking handling.

II. METHOD

The type of research that can be used is the type of tool making research. This research aims to alleviate the problems that hinder the UMKM Rumah Roti Mamita. The making of this bread cooling device in it is divided into several processes such as planning, development, and several other things. The purpose of taking this method is to make a tool that can be a solution to the obstacles that occur in the UMKM Rumah Roti Mamita.

A. System Block Diagram

This automatic bread cooling system is designed to control temperature by using the MLX90614 temperature sensor as input as shown in Fig. 1.

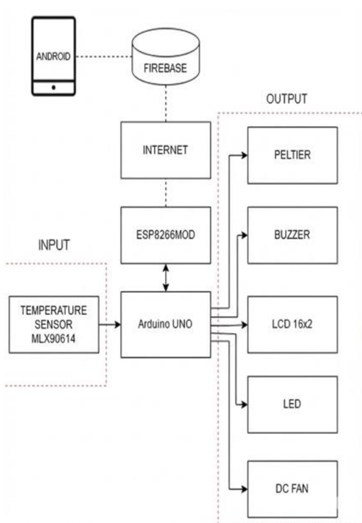


Figure 1. Block Diagram System

This sensor detects the temperature of the bread in real-time and sends the data to the Arduino Uno as the main microcontroller [10]. The Arduino Uno processes the temperature data and controls various outputs based on the needs of the system [11], such as Peltier for cooling, DC fan for air circulation, buzzer as sound indicator, LED as visual indicator, and 16x2 LCD to display temperature information directly.

For connectivity, the Arduino Uno is connected to the ESP8266MOD Wi-Fi module, which serves to connect the system with the internet.[12] Through the internet connection, data can be sent to Firebase, a cloud-based database platform[13]. Firebase allows the system to store and manage temperature data, as well as providing the ability to be accessed through an Android application [14]. With the Android application, users can remotely monitor and control this bread cooling system, providing convenience in temperature management and improving the efficiency of the cooling process [15]. The resulting work can be summarized as follows:

1) *Start:* Starting on the diagram is to describe the beginning and end of a system to start designing the plastic shredding machine. These activities include the background of tool planning, problem formulation, problem limitations, and tool planning objectives.
2) *Literature Study (Automatic Bread Cooler):* The second stage conducts a literature study on reference journals, articles and theses that have been published by various sources regarding automatic bread coolers.
3) *Automatic Bread Cooling System Design:* At this stage, planning for the system design is carried out. At this stage, simulation is carried out first regarding the design of the system being developed and then planning the system so that it can be connected to the system to be developed.
4) *Manufacture of Automatic Bread Cooling Device:* After planning and simulating the automatic bread cooler, the next step is to make this automatic bread cooler.
5) *Testing of Automatic Bread Cooler:* At this stage, testing of hardware, software and connectivity between the two is carried out. The parameters that have been made are used to test the products made, these parameters include: vulnerable temperature, temperature algorithm, tool connectivity with the application. If one of the parameters made is a failure, then the researcher repeats the product design stage.
6) *Data Collection and Analysis:* At this stage, data collection is carried out. Then proceed to analyze the data that has been obtained.
7) *Conclusion:* Furthermore, a conclusion is obtained after the product works as desired
8) *Finish:* In this diagram, the stages have been completed and the automatic bread cooler can be used.

B. Hardware Flow Diagram

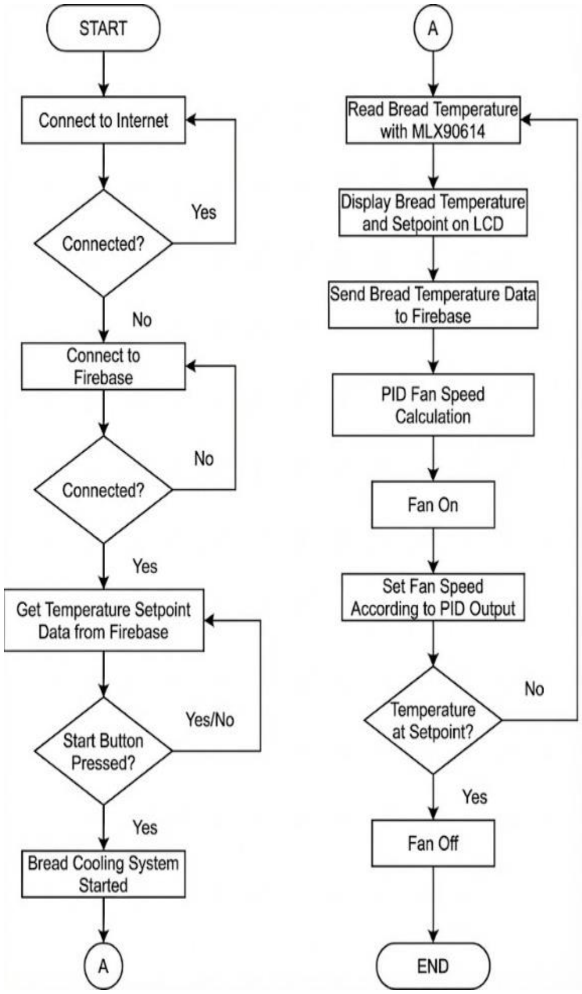


Figure 2. Hardware Flow Diagram

Then the system workflow in Fig. 2 is as follows:

1) The system will connect ESP8266MOD to the internet so that tools and applications can be connected to each other.

2) The system will confirm whether it is connected to the internet or not. If not, go back to the previous step. If it is, then proceed to the next step.

3) ESP8266MOD will connect to firebase.

4) The system will confirm whether ESP8266MOD is connected to firebase or not. If not, then return to the previous step. If it is, then proceed to the next step.

5) When the ESP8266MOD is connected to firebase, it will retrieve the last temperature and set point data.

6) Button to start if pressed then the bread cooling system starts.

7) The temperature sensor MLX 90614 will read the current temperature.

8) The current temperature and set point will be displayed on the LCD.

9) Temperature data will be sent to firebase.

10) The PID will calculate the fan speed according to the distance of the current temperature to the predetermined set point

11) After PID has calculated the distance of the current temperature to the set point, PID will adjust the speed of the DC fan according to the distance of the current temperature and the set point.

12) If the temperature is in accordance with the predetermined set point, the fan will turn off. If not, it will return to the temperature reading by the MLX90614 sensor.

C. Software Flow Diagram

Then the application workflow in Fig. 3 is:

1) On the home page, the login page will be displayed. Users will be directed to log in if they already have an account. If the user does not have an account, then there is an option to create an account.

2) Next, the system checks for account ownership. If the user already has an account, the process continues to point A where the user will be directed to fill in the email and password.

3) If the account has been registered and successfully logged in, the user is directed to the dashboard page. If the account is not registered, the user is directed to the registration page through process B.

4) On the registration page, the user will be asked to enter an email and password, after which the user can press the register button. After the user presses the register button, the user will return to the login page.

5) On the main page, the last temperature recorded on firebase will be displayed and there is a set point that can be set by the user to determine the desired temperature target for the bread cooling system.

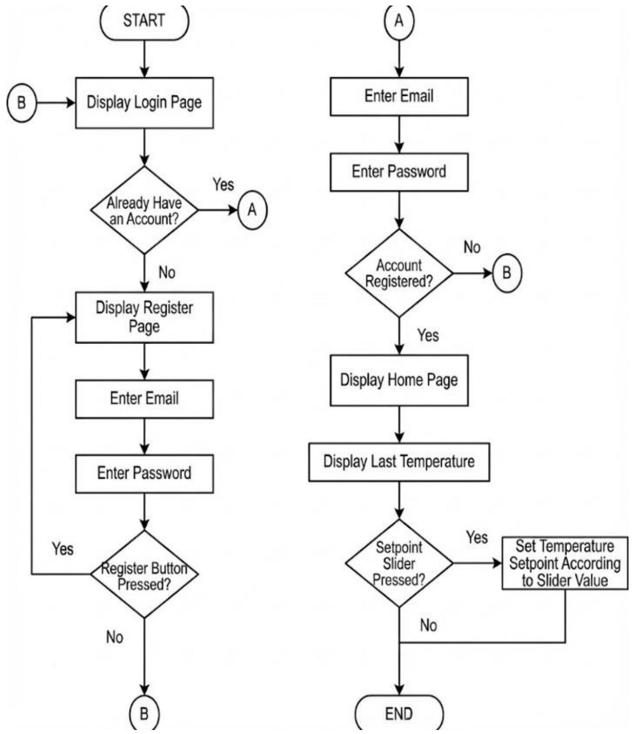


Figure 3. Software Flow Diagram

D. Hardware Desain

Based on the design depicted in Fig. 4, the hardware implementation of the system is constructed using several key components and materials.

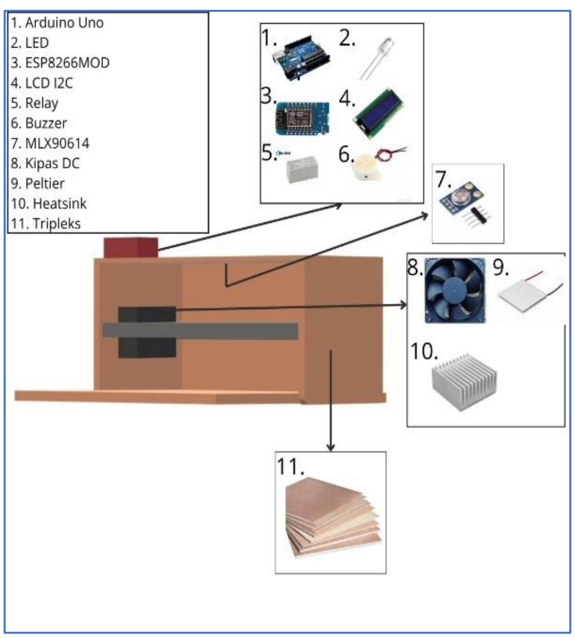


Figure 4. Hardware Desaign

The primary structure consists of a bread cooling chamber made from plywood with dimensions of 50 cm x 25 cm. Attached to this structure is a control box housing the central processing unit and user interface components. The core of the system is the Arduino Uno, which functions as the main microcontroller responsible for managing the entire process, including reading sensor data and controlling peripheral devices. To enable Internet of Things (IoT) capabilities, an ESP8266MOD WiFi module is integrated, allowing for remote monitoring and control.

For user interaction and system status indication, the control box is equipped with an LCD screen, LEDs, and a buzzer. The LCD displays real-time information such as the current temperature inside the box and the preset target temperature. The LED indicators provide visual feedback on the operational status; a red light indicates the cooling process is active, while a green light signals that the bread has reached the desired temperature. Additionally, a buzzer serves as an auditory alarm to notify the user when the cooling cycle is complete. The system also utilizes relays acting as electronic switches to regulate the power supply to high-current components, including the DC fan, the Peltier module, and the buzzer.

Regarding the sensing and cooling mechanism, an MLX90614 temperature sensor is mounted on the ceiling of the chamber to perform non-contact temperature measurements of the bread. The active cooling system is positioned on the left side of the box, utilizing a Peltier thermoelectric module as the primary cooling source. The cold side of the Peltier reduces the temperature within the chamber, while the hot side is managed by a heatsink to absorb and dissipate the generated heat, preventing the system from overheating. A DC fan is paired with this setup to circulate air inside the box, ensuring that the cold air is distributed evenly to accelerate the cooling process.

E. Software Design

The user interaction with the application begins at the login interface ike shown in Fig. 5, which serves as the initial landing page upon launching the app. Users with existing credentials can access the system by entering their registered email and password, followed by selecting the login button. For new users who do not yet possess an account, the application provides a 'create account' option to facilitate registration. On the registration page, users are required to input a personal email address to serve as their username and define a custom password. Once these details are filled in, the account creation is finalized by pressing the register button.

Upon successful authentication, the user is directed to the main menu, which functions as the primary dashboard for monitoring and control. This interface displays essential information, specifically the most recent temperature reading and the adjustable temperature set point. When the bread cooling device is in operation, the temperature display updates dynamically in real-time, reflecting the actual thermal data acquired by the MLX90614 sensor inside the cooling chamber.

Furthermore, the application empowers the user to actively control the system by adjusting the temperature set point directly through the interface. Once the desired target temperature is input and confirmed, the application synchronizes this data with the Firebase Realtime Database, which is then retrieved by the microcontroller to adjust the cooling parameters accordingly. This two-way communication ensures that any changes made in the app are immediately reflected in the device's operation. To conclude the session, a logout feature is provided, allowing users to securely exit the application and return to the initial login screen.

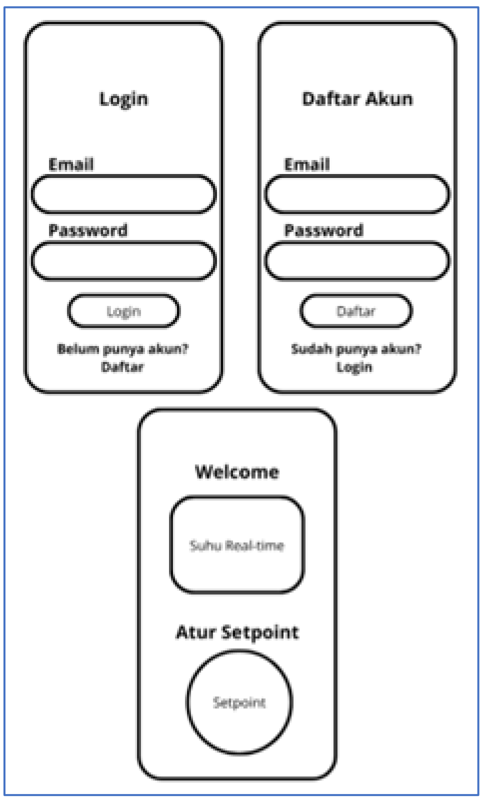


Figure 5. Software Desaign

By integrating these features, the application serves as a robust interface that bridges the gap between manual supervision and automated control. The seamless data transmission via the internet eliminates the need for physical presence near the device, granting the user the flexibility to multitask while the cooling process is underway. Ultimately, this mobile solution enhances operational efficiency by ensuring that critical parameters are constantly monitored and can be adjusted with precision, thereby minimizing the potential for human error during production.

III. RESULT AND DISCUSSION

A. Hardware Implementation

This bread cooler is designed according to a predetermined design, using a plywood box measuring 50 cm x 25 cm covered with styrofoam. This box has a partition made of wire mesh and plywood to accommodate two loaves of bread. Inside the box is an MLX90614 temperature sensor that detects the temperature of the bread. The cooling system consists of a DC fan, peltier, and heatsink. The DC fan inside the box blows cold air from the side of the peltier, while the fan outside the box dissipates heat from the hot side of the peltier. The design is shown in Fig. 6.

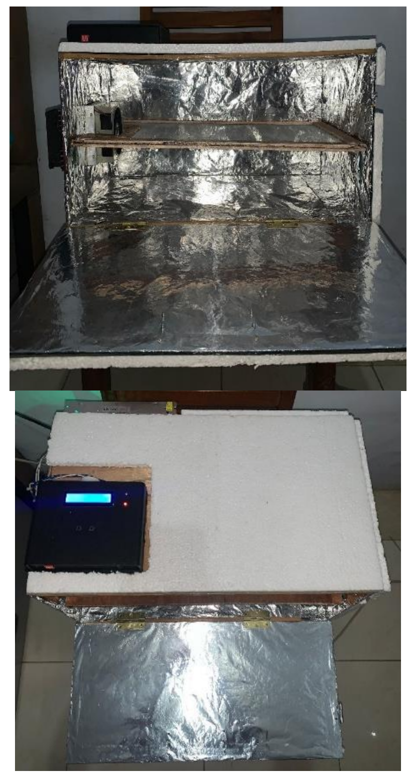
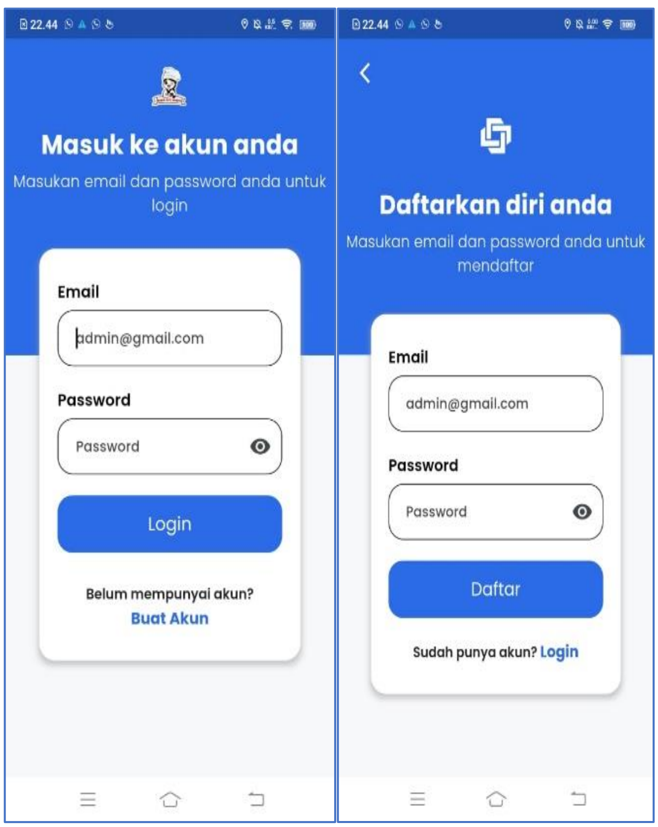


Figure 6. Bread Cooling Hardware

An Arduino Uno microcontroller controls the system, with an ESP8266MOD for Wi-Fi connectivity, relays to control power, buzzers, LEDs, and LCDs for status indicators. The system uses PID control to regulate the temperature, with the MLX90614 temperature sensor detecting the temperature of the bread and sending the data to the Arduino. The PID calculates the temperature difference and regulates the speed of the DC fan to ensure the temperature matches the target, allowing the bread to cool down in less than 15 minutes.

B. Software Implementation (Application)

Based on Fig. 7, there is the first display when the user opens the Smart Temp application. Users will be directed to log in first. Users can fill in the email and password that has been registered. If the user does not have an account, then the user can press the blue "Create Account". After the user presses the "Create Account" button, the user will be directed to the registration page as. On the registration page, users can fill in their email and password to register. After filling in the email and password, the user can press the "Register" button. After that the account will be registered to the database and the user can login using the account that has just been registered. Users will be redirected back to the login page. If successfully logged in the user will enter the main page. On this main page, users will be shown real-time temperatures and setpoint sliders. The real-time temperature will change periodically according to the temperature detected by the MLX90614 sensor. The setpoint slider can be adjusted by the user to set the target temperature of the bread cooling box.



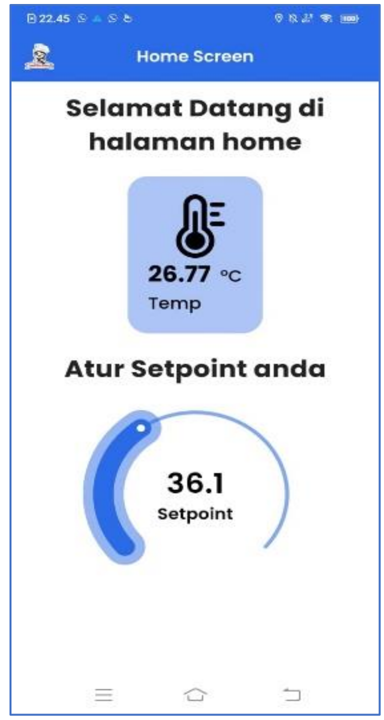


Figure 7. Smart Temp Application

C. Testing Results of Cooling Bread

In this research, 10 times experiments were conducted. The experiment was conducted to obtain the average cooling time of each type of bread, and the result of cooling bread system are shown in Table 1.

TABLE I RESULT OF COOLING BREAD

No	Bread Temperature (Celsius)	Sensor Temperature (Celsius)	Target Temperature (Celsius)	Bread Final Temperature (Celsius)	Sensor Fina Temperature (Celsius)	Cooling Time (minutes)
1	90.70	90.56	30	31.70	30.32	11
2.	92.30	91.55	30	31.90	30.76	11
3.	91.10	88.19	30	30.80	30.52	10
4.	95.40	94.63	30	31.30	30.99	12
5.	91.30	91.19	30	31.00	30.72	11
6.	89.80	88.87	30	30.40	30.22	10
7.	87.60	85.32	30	30.30	30.27	10
8.	89.20	87.37	30	31.10	30.63	10
9.	86.10	85.34	30	30.20	30.18	10

No	Bread Temperature (Celsius)	Sensor Temperature (Celsius)	Target Temperature (Celsius)	Bread Final Temperature (Celsius)	Sensor Final Temperature (Celsius)	Cooling Time (minutes)
10	90.30	89.81	30	31.00	30.39	11
Average Cooling Time						**10.6**

The temperature data in Table 1 was measured when the freshly baked chocolate sweet bread came out of the oven. Then the bread is measured first using a thermometer. After getting the temperature of the bread, the bread is put into the bread cooler to find out how much temperature is detected by the MLX90614 sensor. The next stage is the cooling process. After cooling, the last bread temperature obtained from the thermometer and MLX90614 sensor is recorded. For the type of chocolate sweet bread, the average cooling time is 10.6 minutes.

IV. CONCLUSION

Based on the test results, it can be concluded that this bread cooling device successfully controls the temperature adaptively with high accuracy (0.78% error), increases the production efficiency of UKM Rumah Roti Mamita by accelerating the cooling time to less than 15 minutes, and the Smart Temp application integrated with Firebase facilitates real-time temperature monitoring and allows flexible temperature settings without the need to monitor the device directly. Furthermore, the implementation of this system demonstrates significant potential to modernize traditional operational workflows in MSMEs. By automating the cooling process, business owners can ensure consistent product quality and minimize the risk of spoilage caused by condensation, which is often a critical issue in manual handling. Consequently, this innovation not only solves immediate efficiency problems but also serves as a scalable model for adopting low-cost automation technology in the small-scale food processing industry.

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