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# Modification of a Rice Cooker into Black Garlic Aging Chamber and Performance Analysis

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**Abstract**

*This study aimed to modify a conventional rice cooker into a temperature-controlled aging chamber for black garlic production. The modification involved disabling the automatic switch and replacing the internal sensor with an external DS18B20 sensor, connected to an STC-1000 digital thermostat. The system was designed to maintain consistent heating at three temperature settings: 60 °C, 70 °C, and 80 °C, and enabled real-time temperature monitoring using a thermo recorder. Results showed that the modified rice cooker with only a thermostat had a temperature fluctuation of 10.8 °C. When combined with 4 mm cardboard insulation, the fluctuation decreased significantly to 3.8 °C.*

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## 1. Introduction

The processed food business in the form of black garlic has the potential to continue to grow (Hadi et al., 2021). This is in line with Chan et al. (2022), who stated that black garlic is a functional food currently popular in China and several other regions, including Indonesia. So far, no definitive data have been provided on the number of black garlic consumed in Indonesia or worldwide.

According to Agustina et al. (2020), black garlic is a product of garlic processing, which is heated in the temperature range of 40–90 °C for 5–45 days without adding other ingredients. Najman et al. (2021) explained that black garlic has sensory characteristics, including a chewy and oily texture, a blackish-brown color, and a different taste and aroma from garlic. Black garlic has different sensory characteristics than garlic because of its heating process. According to Purwiyanti et al. (2021), black garlic can be produced using a rice cooker with a temperature range of 70–80 °C without temperature control. This causes the black garlic to be of poor quality.

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Rice cookers, as household electronic appliances for cooking rice (Ali & Yanuar, 2021), perform two functions: cooking and heating. The most important parts of a rice cooker include a micro switch, bimetal sensor, and heating element. The microswitch moves the cook position to a warm position. If the position shift handle is pressed down (cook), the micro switch connects the 220 Volt AC source to the heating element. This heating element heats the metal where the pan sits. When the rice is cooked, the bimetal sensor receives more heat from the pan so that the bimetal sensor loses its magnetic properties, the position shift handle falls to the warm position, and the micro switch connects the 220 Volt AC source to the heating element (warm mode).

A thermostat is a temperature-control component that operates automatically based on the feedback principle. A bimetal thermostat is generally used in rice cookers (Ali & Yanuar, 2021). The bimetal thermostat in the rice cooker is deactivated by changing its phase path. The phase path was then replaced to connect to the external thermostat path.

There are two types of thermostats, namely electronic thermostats and digital thermostats. In this study, a digital thermostat was used to control and detect the system temperature approaching the set temperature. Digital thermostats operate on a digital principle using a relay as a controller. Digital thermostats have a probe that regulates and measures temperature.

According to Utama et al. (2024), temperature is an important factor that influences the physicochemical characteristics of the black garlic produced. Black garlic aged without temperature control produces uneven color, texture, and chemical compound content. Therefore, it is necessary to adjust the temperature of the rice cooker as an aging chamber for black garlic to produce good quality black garlic. According to Aisuwarya and Putra (2018), a rice cooker without temperature control will result in a product that dries out quickly, thereby reducing product quality. The set temperature consisted of three variations 60, 70, and 80 °C. It is necessary to conduct a performance analysis of the thermostat used to determine the actual temperature in real time from a rice cooker whose temperature was set using a thermostat. Performance analysis of the STC-1000 thermostat was performed using an LR8450 thermo recorder. Modifying the rice cooker with a temperature setting using a thermostat as a black garlic fermenter and its performance analysis is expected to produce black garlic products of good quality.

## 2. Material and Methods

### 2.1 Materials

The main equipment used in this study was a rice cooker, model Cosmos CRJ-323s (1.8 L capacity, made in Indonesia), which served as the fermentation chamber. The internal microswitch was deactivated to maintain the device in the warm mode throughout the process. Temperature control was managed using a digital thermostat, model STC-1000 (made in China), which supports a range of

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–50 °C to 99 °C with an accuracy of ±1 °C and a resolution of 0.1 °C. This thermostat utilized an NTC sensor and operated at less than 3 W power consumption.

For temperature sensing, the system employed the DS18B20 digital sensor, known for its precision of ±0.5 °C over a temperature range of –10 °C to 85 °C (Ekayana, 2020). In addition, a type-K thermocouple sensor was used to validate the temperature distribution within the rice cooker. This type converts temperature differences into voltages based on the varying metal densities (Ekayana, 2020).

Temperature performance data were recorded using a thermo recorder, model LR8450 (made in Japan), connected via a 2-meter black stranded cable. The recorder, housed in a black box (18.5 cm × 11.5 cm × 6.5 cm), allowed the real-time monitoring of multiple temperature points. Terminal plugs and connectors from Broco were used to support the wiring and modification process. Schematic diagrams and modification tools are illustrated in Figures 1 and 2, respectively.


**Figure 1.** Thermo recorder LR8450.

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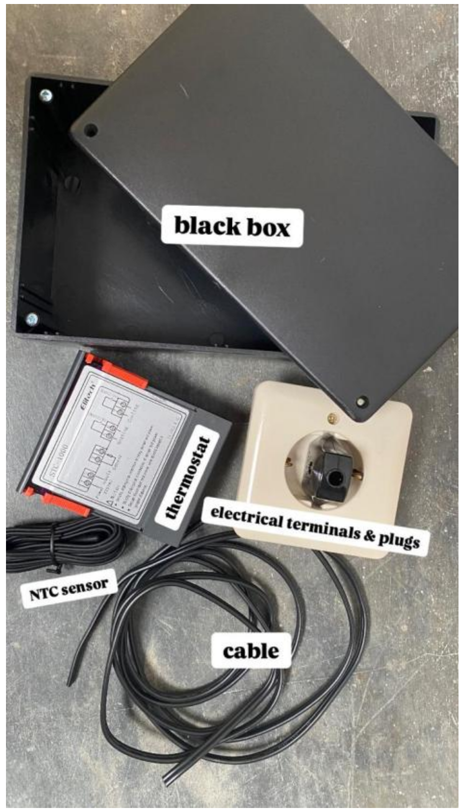


**Figure 2.** Thermostat modification materials.

2.2 Method

The research method consisted of three stages, namely modification of the rice cooker and an external thermostat, setting the rice cooker temperature using a thermostat, and measuring the actual temperature of the rice cooker using a thermo recorder. The research method is illustrated in Figure 3.

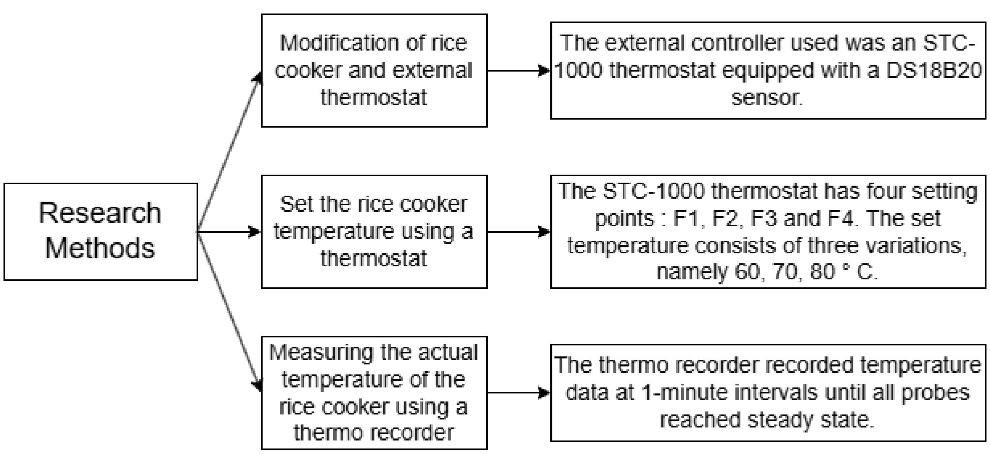


**Figure 3.** Research methods.

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2.3 Modification of Rice Cooker and External Thermostat

The rice cooker (Cosmos CRJ-323s) was modified by deactivating its internal microswitch to maintain the device in the warm mode. Several internal phase lines were rerouted to disable the original bimetal thermostat and to enable control through an external digital thermostat. An STC-1000 thermostat equipped with a DS18B20 sensor was used as the external controller. The installation and wiring modifications are shown in Figures 4 and 5, respectively. In this study, the micro switch was deactivated so that the heating element (cooking mode) was inactive, and the rice cooker was always in warm mode. The modified external thermostat with several cables and electrical lines to the rice cooker was then put together and put into a black box, as shown in Figure 6.

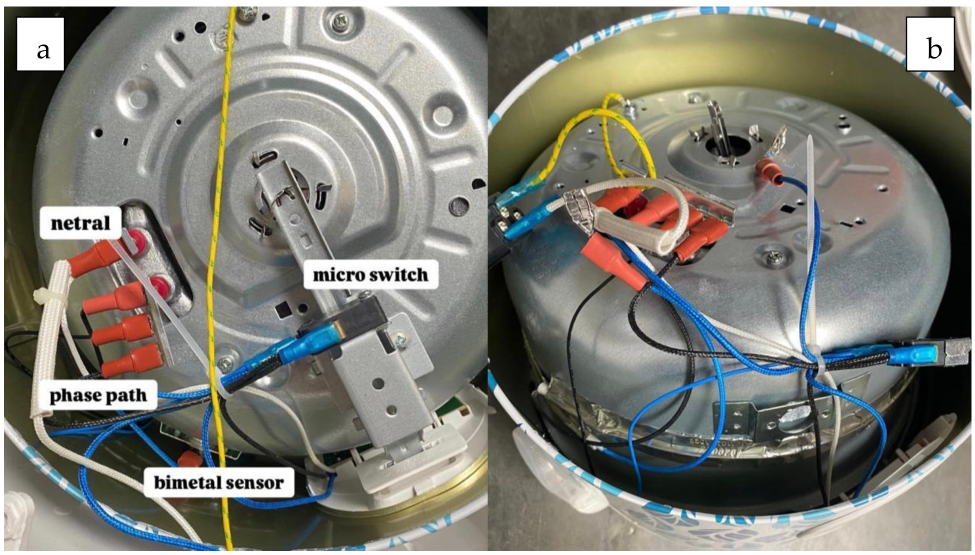


**Figure 4.** Parts of the rice cooker before (a) and after (b) modification.


**Figure 5.** Rice cooker and thermostat.

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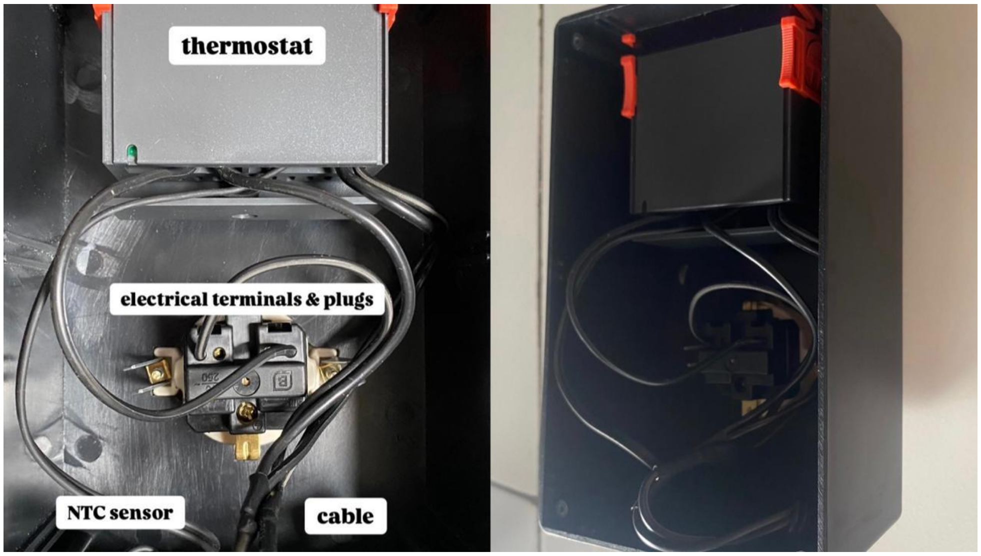


**Figure 6.** Modified thermostat.

2.4 Set The Rice Cooker Temperature Using a Thermostat

The thermostat can maintain the set temperature by cooling or heating the system by turning off and on the elements in the system so that it can reach the set temperature (Simamora et al. 2023). Parts of the thermostat are shown in Figure 7, and the electrical diagram is shown in Figure 8.


**Figure 7.** Parts of the STC-1000 thermostat (Simamora et al. 2023).

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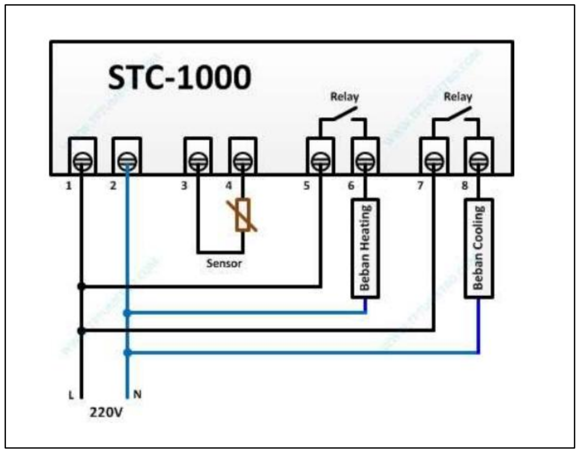


**Figure 8.** Electrical Diagram of STC-1000 Thermostat
(Simamora et al. 2023).

The STC-1000 thermostat has four setting points, F1, F2, F3, and F4, based on their respective functions. The F1 mode was used to set the desired temperature, this study used a temperature setting of 0.1 above the variable. When the temperature of the rice cooker was above the set temperature, it automatically turned off. F2 mode was used to set the differential value. In this study, a differential value of 0.5 was used. This differential value was used to determine the ON/OFF of the rice cooker. When the temperature of the rice cooker is 0.5 below the setting temperature, the rice cooker will start to turn on. In this study, the F3 mode was not used. F4 mode was used to set the correction factor. The use of the F4 mode to set the correction factor aimed to make the temperature read on the thermostat close to the actual temperature. In the present study, a correction factor of 0.8 was used. The correction factor was obtained from the calibration results by using a thermo recorder.

### 2.5 Measuring The Actual Temperature of The Rice Cooker Using a Thermo Recorder

To evaluate the actual temperature consistency, a type-K thermocouple was installed at three locations: the top sample layer (Tc 1-15), the bottom sample layer (Tc 1-14), and near the thermostat sensor (Tc 2-15). Approximately 1 kg of compound garlic was placed in the pot. The thermo recorder recorded the temperature data at 1-minute intervals until all probes reached a steady state.

**Figure 9.** Temperature calibration circuit using a thermo recorder.

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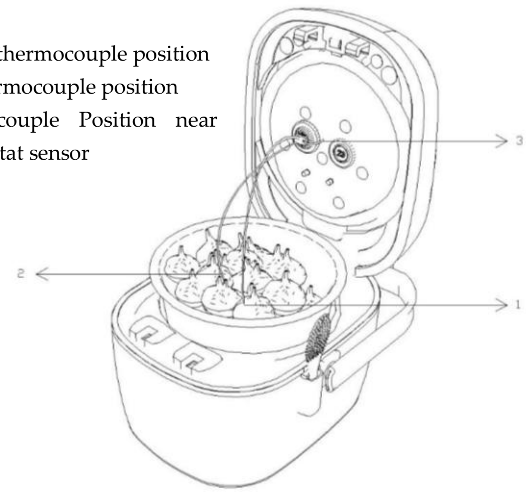


**Figure 10.** Thermocouple position.

Figure 9 illustrates the testing setup and Figure 10 shows the thermocouple placement. Calibration data were used to assess the thermal distribution and effectiveness of the control system during heating (Setiawati et al., 2020).

## 3. Results and Discussion

### 3.1 Rice Cooker Performance with The Addition of A Thermostat

This study modified the ZECC developed by Paluseri et al. (2023) by expanding the storage chamber dimensions to 115 cm × 135 cm × 50 cm (0.776 m³ capacity), which is larger than the previous version (0.32 m³). No-load testing showed that the temperature and RH in the chamber fluctuated more than the small size with a temperature range of 22.7°C-30.5°C and RH of 72.6%-98.8% while the maximum ambient temperature and RH were 33.8°C and 33.8%. The temperature and RH range in the ZECC chamber of Paluseri et al. (2023) was 22.6°C-26.05°C with an RH 93.0%-98.2%. A small ZECC is more effective in maintaining a stable temperature and RH. Factors such as media thickness, water temperature, and chamber size affect the efficiency of ZECCs (Liu et al., Thermostat modification is performed by changing some electrical lines from the rice cooker bimetal thermostat to external thermostat electrical lines. This modification makes the rice cooker contact connected to the modified external thermostat, which is then connected to the electric current from the external thermostat.

A thermocouple is a type of temperature sensor that detects and measures temperature through two different types of conductor metals, thus creating a "Thermo electric" effect. The advantages of thermocouples are their fast response to temperature changes and wide operating temperature range, ranging from -200 °C to 2000 °C; thermocouples are also vibration-resistant. The working principle of a thermocouple is based on two different types of conductor metal wires; subsequently, the ends are

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joined. One type of conductor metal in the thermocouple is a reference with a constant temperature, whereas the other is a conductor metal that detects hot temperatures. The temperature calibration results are shown in Figure 11.

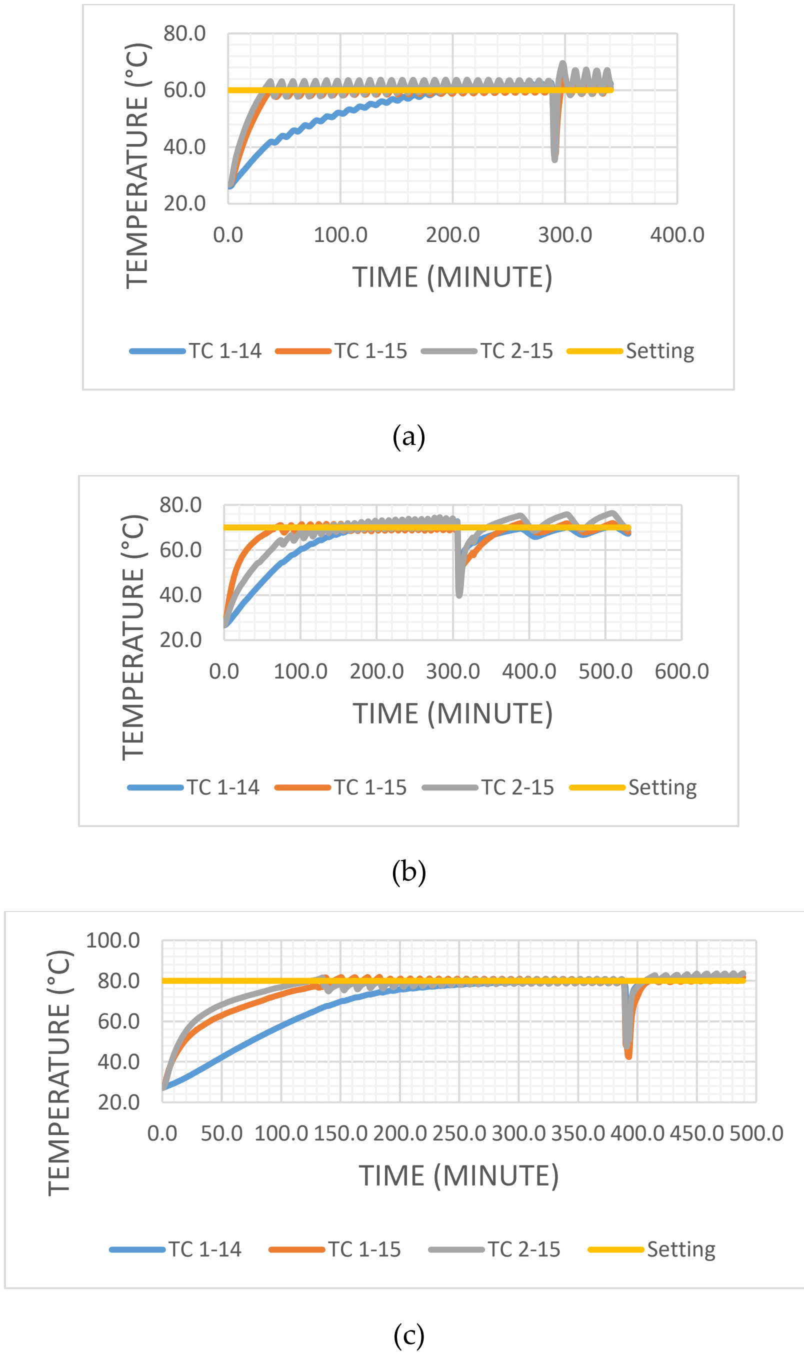


**Figure 11.** Sensor calibration using a thermo recorder (a) temperature 60°C, (b) temperature 70°C, and (c) temperature 80°C.

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The average deviation of temperature measurements between the K-type thermocouple and the thermostat sensor is 0.8 °C with the highest measurement difference of 6 °C. This temperature difference occurs because when the temperature reaches the set point, the heat supply will not be cut off immediately but slowly decreases until it is completely cut off. Temperature control testing is regulated based on a hysteresis of 0.5 °C at each set point. The provision of a hysteresis effect maintains the durability of the relay because without hysteresis, the relay will turn on and off too often to maintain the temperature at the set point (Fadarina et al., 2018). Calibration data show a temperature range from the setting temperature, namely, 3 °C above and 3 °C below the setting temperature. The thermostat can maintain a temperature close to the set point by cooling or heating the system by turning elements in the system off and on so that the temperature reaches the set point (Simamora et al., 2023).

The graph shows a temperature spike that exceeds the upper limit (overshoot temperature) and the lower limit (undershoot temperature) during the measurement process. This is due to the control lag, which means that the controller is late in giving the command to the control element to turn on and heat the material so that the cooler remains on to lower the temperature. A control lag occurred because the temperature transducer was late in measuring the temperature in the rice cooker. This causes the control signal to be sent to the controller late, which affects the command to be given to the final control element (Fadarina et al., 2018).

The results of the thermo-recorded measurements at various temperature variations also show the difference in time required for the three thermocouples to reach the setting temperature. At a temperature of 60 °C, the three thermocouples reached a setting temperature of approximately 280 min, 70 °C for approximately 300 min, and 80 °C for approximately 380 min. Rice cookers whose temperature is regulated using a thermostat take a relatively long time to reach the temperature setting because garlic is also used during calibration, so the heat generated by the rice cooker is first consumed by the garlic. The three thermocouples reach the set temperature, which can be seen from the position of the graph, which is constant and reaches the set temperature. When the three thermocouples reached the set temperature, the rice cooker was opened so that the thermo recorder recorded a decrease in temperature, which was marked by a decrease in the graph. After the graph decreases drastically, there is another increase in the temperature, which is even higher than the previous temperature. The graph on the right shows the treatment of the thermocouples stored around the walls of the rice cooker, and the results show that the temperature around the walls of the rice cooker is higher than the previous thermocouple position. At each temperature, namely, 60, 70, and 80 °C, there is a difference in temperature fluctuations recorded by the thermo recorder with the position of the thermocouple around the walls of the rice cooker, owing to differences in the performance of the thermostat used.

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3.2 Performance of Rice Cooker with The Addition of Thermostat and Cardboard Coating

The time required to reach the setting temperature is relatively long, making this tool less effective for food processing that cannot be exposed to high temperatures for a long time, such as pasteurization. The longer the time, the more constant the temperature in the rice cooker is. This tool is more effective for food processing, such as aging processes that require a long time, for example, making black garlic. In addition to the time required to reach the setting temperature, this tool has another drawback, namely the uneven temperature at which the temperature around the rice cooker wall is higher than that in other positions. This uneven temperature can cause differences in the results for the products produced. These shortcomings can be overcome using a pan with a smaller diameter than that of the rice cooker or a cardboard base around the rice cooker wall. This is done such that the processed material does not stick directly to the rice cooker wall. Figure 12 shows a graph of the calibration results at 60 °C with a cardboard coating around the rice cooker wall. The cardboard used was a single-wall type with a thickness of 4 mm. Table 1. shows a comparison of the highest and lowest fluctuation temperatures of the rice cooker without cardboard coating and with cardboard coating after reaching the setting temperature.

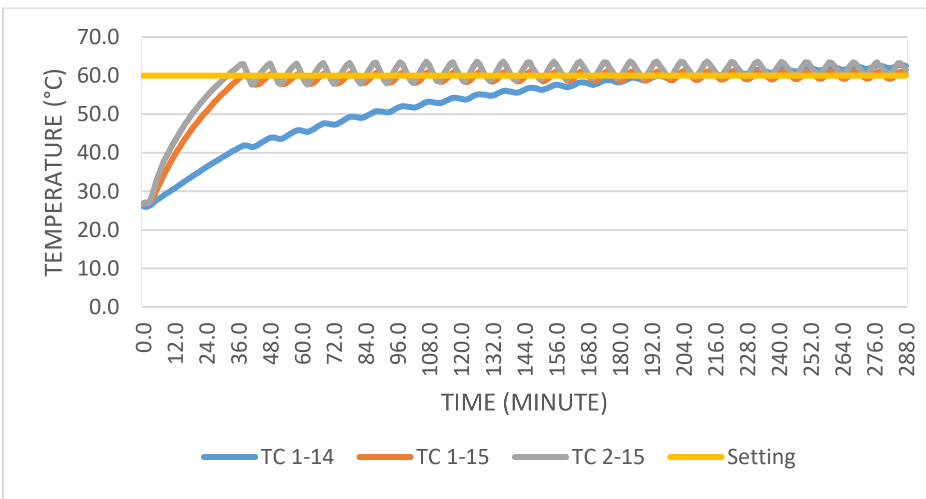


**Figure 12.** Temperature calibration was performed using a thermo recorder with a cardboard coating (temperature setting 60 $^0$C Carton).

**Table 1**. Comparison of rice cooker temperature fluctuations.

| Rice cooker without cardboard lining | Rice cooker with cardboard lining |
|---|---|
| Maximal temperature: 69,1°C | Maximal temperature: 62,9°C |
| Minimal temperature: 58,3°C | Minimal temperature: 59°C |

Table 1 shows that the fluctuation of the modified rice cooker without cardboard coating is 10.8 °C. In comparison, the fluctuation of the modified rice cooker with the addition of cardboard around the inside of the rice cooker pan was 3.9 °C. The maximum and minimum temperatures of the two rice cooker comparisons were obtained from the thermocouple position data near the thermostat sensor, upper sample section, lower sample section, and around the rice cooker wall.

The temperature of the rice cooker before modification with garlic was 70–80 °C in warm mode. By modifying the rice cooker using a thermostat, black garlic can be aged at a lower temperature, for example, 60 °C. The modified rice cooker, also assisted by coating with cardboard, will result in lower temperature fluctuations. The modified rice cooker produced a more consistent temperature, thereby maintaining the quality of the black garlic produced. The temperature deviation of the modified rice cooker was ± 3 °C, whereas before modification, the temperature range reached 10 °C. Rice cookers with thermostat modifications also have the advantage of avoiding overheating owing to the cooling mode system. When the rice cooker reaches a temperature 0.1 °C higher than the set temperature, the thermostat activates the cooling mode so that the temperature returns to the set temperature. This could maintain the quality of the black garlic produced.

## 4. Conclusion

Based on the research findings, modifying a conventional rice cooker with a digital thermostat results in temperature fluctuations of approximately 10.8 °C during black garlic fermentation. By adding a 4 mm cardboard insulation layer to the inner wall of the rice cooker, these fluctuations can be significantly reduced to 3.9 °C. This demonstrates that the cardboard coating effectively stabilized the internal temperature and enhanced fermentation consistency. This approach addresses the challenge of temperature instability in traditional rice cookers and offers the potential for application in small-scale or household-level black garlic production. Future research should explore the use of automated control systems or other insulation materials to further optimize the temperature regulation.

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