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MULTIPURPOSE INCUBATOR BASED ON MICROCONTROLLER SYSTEM WITH DISTANCE MONITORING FEATURE CASE STUDY FOR CRACKERS DRYING

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ABSTRACT
Most available commercial incubators are considered not appropriate for certain food processing such as for crackers drying and also considerably expensive. Besides, they do not have distance monitoring and control features. The objective of this article is to present the development process of an incubator prototype which has distance monitoring and control feature built based on the components commercially available in the market involving traditional stove-based oven, electric heater, DHT22 temperature sensor, ESP8266 microcontroller, buzzer, and LCD OLED display. The incubator was equipped with the Blynk platform of a smartphone for distance control and monitoring. The functional test results showed that the developed incubator works well as expected. The calibration testing results suggested that temperature measurement by using the developed system has inaccuracy of 0.34% when compared to measurement by using a commercial thermometer. To validate its function in actual condition, the incubator was used for drying rice crackers. The rice crackers were dried at the temperature of 70 ℃ with a duration of 5 hours. It can be observed that the drying result by using the developed incubator was comparable to that of drying by direct sunlight on a sunny day with a duration of 16 hours.
Keywords : *Incubator, Drying Equipment, Temperature Control, Distance Monitoring, Microcontroller*

1. Introduction

In general, an incubator is an equipment used for drying or heating objects such as food, drinks, materials or perhaps a baby. Based on the heat source, there are two types of incubators used in the society. There are manuals namely fire-based incubator and electric based incubator. Traditional fire-based incubators used to be placed on top of the stove in the operational environment. It usually does not have any feature which can be used for setting temperature level or heating period. The user can only control the temperature inside the incubator cabin by visually detecting the heated object inside the incubator cabin and then manipulate the fire.

Drying process could be done by using high temperature or low temperature in accordance with whether the materials are sensitive to high temperature or not such as research results reported in (Hubbard et al., 2021; Silva et al., 2019). Controlling temperature properly could be a crucial step and has an economic impact in food not only in processing but also during its transportation (Skawi'nska & Zalewski, 2022). Drying method could affect mechanical and thermal characteristics of certain materials (Sozcu et al., 2024). In food processing, drying method should be chosen properly because it could affect certain substance content of a food such as Selenium (Wang et al., 2023), antioxidants (Nawawi et al., 2023), microorganism and color (Maoloni et al., 2023). Besides, the drying method also could affect the flavor of food (Wei et al., 2024). Especially for crackers, research results showed that the drying method affects its chemical properties (Kusumaningrum et al., 2020).

Crackers are a type of food that has long been known and liked by Indonesian people. Apart from being a snack, crackers are often used as a side dish for everyday meals. One of the stages in making crackers is the pre-cooked drying process. The successful production and quality of crackers depends on the drying process. If the water content in the crackers is still high and then fried immediately, the crackers will be hard and not crunchy. The drying process for crackers usually uses heat from direct sunlight, which can take approximately 2 to 3 days depending on the weather and heat of the sun. Small scale entrepreneurs usually find it very difficult to produce crackers when entering the rainy season, because there are still many small crackers entrepreneurs who still rely on direct sunlight for the drying process of crackers. Sunlight heat is the most widely used option for drying crackers because it does not require costs but requires a large space and lacks hygiene for the crackers. Crackers drying using an incubator or oven has potential advantages such as the crackers becoming more hygienic and independent of weather conditions. Drying method affected crackers characteristics including its protein content, appearance, and taste (Anshori et al., 2023). Compared to using direct sunlight, drying crackers by using an incubator or oven provide better drying characteristics (Abdullah et al., 2019).

Development of incubators for various purposes has attract interest of researchers for example a model of incubator for human baby (Aryanto et al., 2023), incubator for poultry hatching (Peprah et al., 2022; Cheepati & Balal, 2024; Mohlalisi et al., 2024), and other similar research results. It can be noted that the incubator development for crackers processing is still rare proposed by researchers. Besides for commercial use, incubator also being used for laboratory work or experiment in the school or university.

There are many commercial electric incubators or ovens or microwaves for food available in the market today. However, they are mainly used for heating food or drinks, not for drying crackers. Besides, they may be arguably too expensive for crackers drying in the household or experimental in the school or university laboratories. Moreover, most commercial conventional electric incubators usually have offline operational features for example manual on/off button, and heating setting for both temperature level and heating period onsite only. Internet of things technology is able to facilitate operating the incubator from a distance. The problem of this article can be formulated as how to develop a low cost general incubator built based on the stove-based oven for crackers drying which has distance temperature level setting and heating time as well as continuous monitoring. The main objective of this article is to present the development process and its testing results of an incubator prototype which has distance monitoring and control features built based on the components commercially available in the market. The main contribution of the article is in the hardware design, namely conversion of the traditional stove-based oven into an electric-based incubator equipped with distance monitoring feature by using commercially available components in the market which arguably can be considered as a low cost. The developed incubator can be used for general drying purposes of food production especially for crackers drying.

2. Literature Review

2.1. NodeMCU ESP 8266 Microcontroller

NodeMCU ESP8266 is a multipurpose microcontroller which is developed based on microprocessor with clock speed of 80-160 MHz. It has 64 KB Random Access Memory (RAM) and 4 MB flash memory. It is equipped with 16 General Purpose Input/Output (GPIO) pins and a 10-bit Analog to Digital Converter (ADC). Among its advantages are that it has Pulse Width Modulation (PWM) output in all GPIO pins and it has wireless data communication feature which uses IEEE 802.11 b/g/n standard with frequency of 2.4 GHz. This data communication feature enables the ESP8266 microcontroller to be connected to the internet via available wifi directly without any additional component. With this specification, ESP8266 microcontroller is applied in the system development in broad areas for example in home automation (Windesi et al., 2022), remote monitoring (Naimuddin et al., 2025), environment monitoring (Mitu et al., 2021), and distance robot control (Deshmukh et al., 2024).

2.2. Comparison of the Developed System to Previous Works

Research gap which was filled by this article can be seen from the comparison of the developed system to other incubators published previously is summarized in Table 1. It can be noted that the main contribution of the article is on the system design involving using different hardware components and its features. The main features of this article which are different from other publications are including the use of Blynk platform for distance monitoring and control as well multi temperature and heating period setting where users are able to choose any available value.

Table 1 - Comparison between developed system and other similar research results

Previous works	Hardware and Software	User Interface	Distance Monitoring Feature	Multi Temperature Setting	Heating Period Setting
Developed system	DHT22 sensor, NodeMCU 8266 microcontroller, 2 500W electric heater, buzzer	Push button, Blynk platform of smartphone: temperature set point and drying duration, LCD OLED local display.	Wireless internet+Blynk platform of smartphone	Yes, by using Blynk platform	Yes, by using Blynk platform
System 1 (Cheepati & Balal, 2024)	Peltier module heating source, fans, thermocouple temperature sensor, solar panel	Up and down button.	None	NA	NA
System 2 (Shoewu et al., 2020)	ATMega16L microcontroller, LM35 temperature sensor, 300 W 220 V heater	Manual button, 7-segment local display	None	NA	NA
System 3 (Derisma et al., 2020)	DS18B20 temperature sensor, soil moisture sensor, electric heater, Arduino Uno microcontroller	Manual button, LCD 2 x 16 local display	None	NA	NA
System 4 (Purwanti et al., 2021)	DHT11 temperature sensor, Raspberry pi processor, camera, electric heater	Manual button, local display	None	NA	NA
System 5 (Suleiman & Abdulhamid, 2024)	Programmable Logic Controler (PLC), electric heater, RTD and thermocouple temperature sensors,	Push button, local display	None	NA	NA
System 6 (Jusman et al., 2024)	Arduino Uno microcontroller, DHT11 temperature sensor, ligths	Manual button, LCD local display	None	NA	NA

2.3. DHT22 Temperature Sensor

DHT22 is a digital temperature sensor which has a considerably wide temperature range between - 40 ℃ and 80 ℃ and humidity range between 0% and 99.9%. It has measurement inaccuracy of ± 0.5 ℃ and ± 2% RH and also it has low power consumption. With these features, DHT22 sensor is popularly used in many applications of temperature monitoring (Azhari et al., 2023), (Adhiwibowo et al., 2020; Desnanjaya et al., 2022). Research results published by Rurono

& Sunardi (2023) showed that DHT22 temperature sensor has better performance than other temperature sensors when applied for temperature monitoring.

2.4. Blynk IoT Platform

Blynk application is a mobile platform for developing internet of things (IoT) applications. This application can receive data from embedded systems and display it in the smartphone as well as be able to send the command signal to the embedded system. It has an interactive user interface and is easily configured. Blynk platform has been applied for broad application areas for example in smart home (Lakshmi et al., 2022), air quality monitoring (Suhaidi & Yunus, 2021; Zain et al., 2024), irrigation monitoring and control (Saputri et al., 2025), and smart agriculture (Mohapatra et al., 2022).

3. Research Methods

3.1. General Architecture of the Developed System

The development of the incubator in the present study was partly following the general design procedure proposed by Oberloier & Pearce, (2017). The main functional requirements of the developed system include being able to heat in the changeable temperature value and duration time, as well as distance controlling and monitoring features. Different from research results reported in (Leman et al., 2017), in which the drying equipment was used for fried crackers, the developed system was intended for pre-cooked crackers. The developed incubator was built based on a traditional stove-based oven made of aluminum commercially available in the market shown in Figure 1. It has a dimension of 35 centimeters in length x 29 centimeters in width x 34 centimeters in height which is bigger than the average of commercial electric based ovens. Initially, the heat source of the oven was the stove fire. In the developed system, the stove fire was replaced by using an electric heater as the heat source. The electronics circuits were then installed in it for controlling and monitoring its temperature cabin. The general architecture of the hardware circuit of the developed system is represented in the block diagram of Figure 2. The developed system used components commercially available in the market. The bill of hardware components materials is presented in Table 2. It can be seen in Table 2 that the component cost for developing the incubator system was IDR 478.000 which was considerably much cheaper compared to commercial ovens or incubators.

Fig. 1. The traditional stove-based oven commercially available in the market which was used as a basis of the developed incubator system

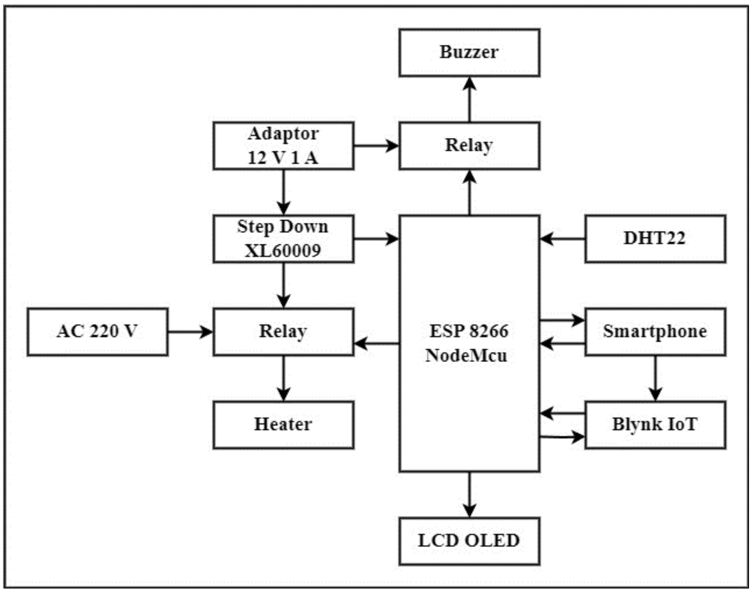


Fig. 2. Block diagram representing the general hardware circuit of the developed incubator system

Table 2 - Bill of hardware component materials of the developed incubator

No.	Component	Number	Cost per unit (IDR)	Total cost (IDR)
1	Stove-based aluminum oven	1	126.000,-	126.000,-
1	DHT 22 temperature sensor	1	22.500,-	22.500,-
2	ESP8266 microcontroller	1	50.000,-	50.000,-
3	LCD OLED display	1	26.500,-	26.500,-
4	500 W electric heater	2	75.000,-	150.000,-
5	DC to DC Step down module	1	8500,-	8.500,-
6	Relay	2	6.500,-	13.000,-
7	Buzzer notification	1	6.500,-	6.500,-
8	Adaptor as the power supply for the electronic hardware circuit. Specification: 12 V, 1 A	1	75.000,-	75.000,-
	Total cost (IDR)			478.000,-

The developed system employed a NodeMCU ESP8266 microcontroller as the main controller, a DHT22 temperature sensor, two electric heaters as a heating source, a buzzer for sound-based notification, an LCD OLED display, an adapter used to reduce the voltage from 12 V to 5 V, and a Blynk platform installed in a smartphone for distance control and monitoring features. There were two relays, namely a relay which was connected to the heater and connected to the buzzer. Microcontroller ESP series is a popular microcontroller which is used in various areas such as for health application (Dinulloh & Kusban, 2022) because it can be connected to the wireless internet network directly without any additional component. Electric heater was used in the developed system because it was simpler and widely available compared to when using other heating sources such as biomass-based open fire used by Muhammad et al., (2021) or infrared used by Kuhn et al. (2024). The DHT22 sensor was chosen because it is able to measure temperature between -40 ^{0}C and 80 ^{0}C which is enough for the developed system. The temperature read by the DHT22 sensor was displayed on the OLED LCD and also in the Blynk application of the smartphone. In order to be able to send the data from ESP8266 microcontroller to the Blynk platform, wifi connection which uses IEEE 802.11b/g/n data communication standard is needed. In the article, wifi was provided by smartphone tethering. The buzzer was turned on when the specified time was up. The temperature set point value is set using the Blynk application on a smartphone. Using the Blynk platform for distance control and monitoring features is simpler compared to other architectures, for example using LoRaWAN used by Chavanne & Frangi (2024). In general, the work of the developed system performs closed control which is presented in the block diagram of Figure 3.

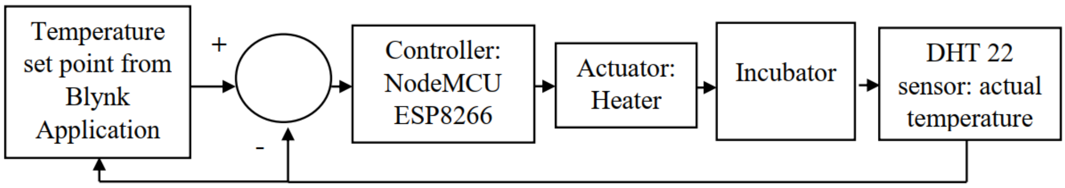


Fig. 3. Closed loop control of the developed system

3.2. Hardware Design Implementation

Block diagram in Figure 2 was then implemented by using off the shelf electrical components whose hardware connection is outlined in Figure 4. The NodeMCU ESP8266 microcontroller as the main processor requires power with a voltage of 5 V so that the voltage coming from the 12 V adapter must be lowered using the XL6009 step down module to 5 V. The DHT22 temperature sensor requires a minimum voltage of 3-5 V. The DHT22 temperature sensor data pin was connected to pin D5 NodeMCU ESP8266 microcontroller. In the first relay, a single channel relay was connected to a buzzer. The buzzer can be supplied by a using power supply in the range of between 3 and 24 V. The relay has a working voltage of 5 V. The data pin of this relay was connected to pin D4 of the NodeMCU ESP8266 microcontroller. Buzzer was a very common notification feature used in broad areas for example in notification for blind people (Chandra et al., 2022). The second relay was connected to two 500 W heaters. The data pin of the second relay was connected to the Pin D0 of the NodeMCU ESP8266 microcontroller.

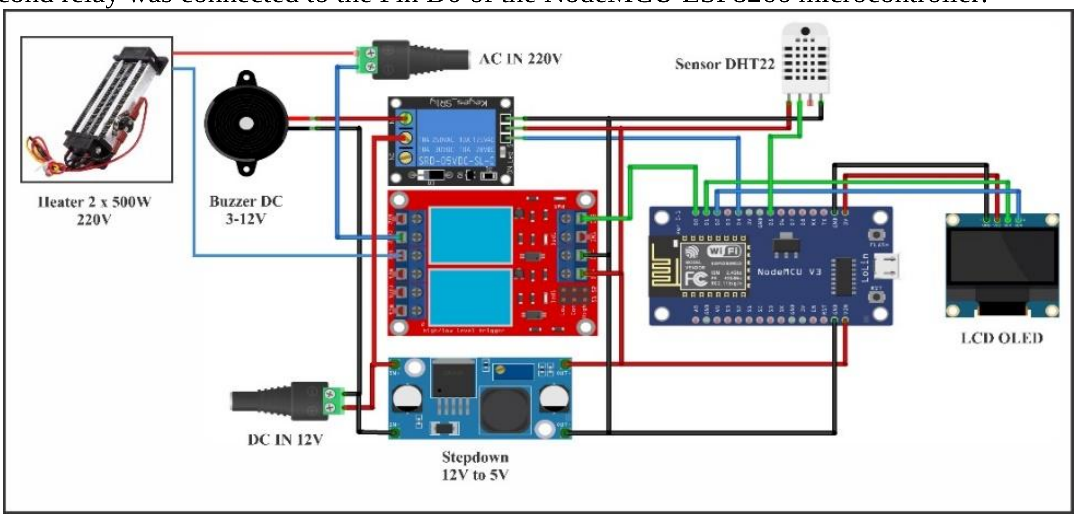


Fig. 4. Schematic diagram showing connections between hardware components

3.3. Software Design Implementation

The NodeMCU ESP8266 microcontroller was programmed by using Arduino Integrated Development Environment (IDE) software. The general computation step of the program coded in the NodeMCU ESP8266 microcontroller is represented in the flowchart depicted in Figure 5. Firstly, after the developed system was turned on, the NodeMCU ESP8266 microcontroller reads the data from the DHT22 temperature sensor. After that, the microcontroller will be able to connect itself to a predetermined available wireless network so that it can be connected to the Blynk application of the smartphone. The NodeMCU ESP8266 microcontroller always checks the set point inputted from the Blynk application, namely its intended temperature value and time setting. The NodeMCU ESP8266 microcontroller compares the actual temperature value measured from the DHT22 sensor to the set point value inputted from Blynk application, if the actual temperature below the set point then the NodeMCU ESP8266 microcontroller continue to connect the relay otherwise the relay will be disconnected. The NodeMCU ESP8266 microcontroller counts down the time set up from the Blynk application, if the time has not finished it continues the loop otherwise it turns on the buzzer. Finally, the NodeMCU microcontroller checks whether the on/off button was pressed, if the on/off button is pressed then the developed system will be turned off otherwise it will start the program from the beginning.

Figure 6 showed the part of its program for connecting the electronics hardware via ESP8266 microcontroller to Blynk application of smartphone. The Blynk application name is “IoT Oven”.

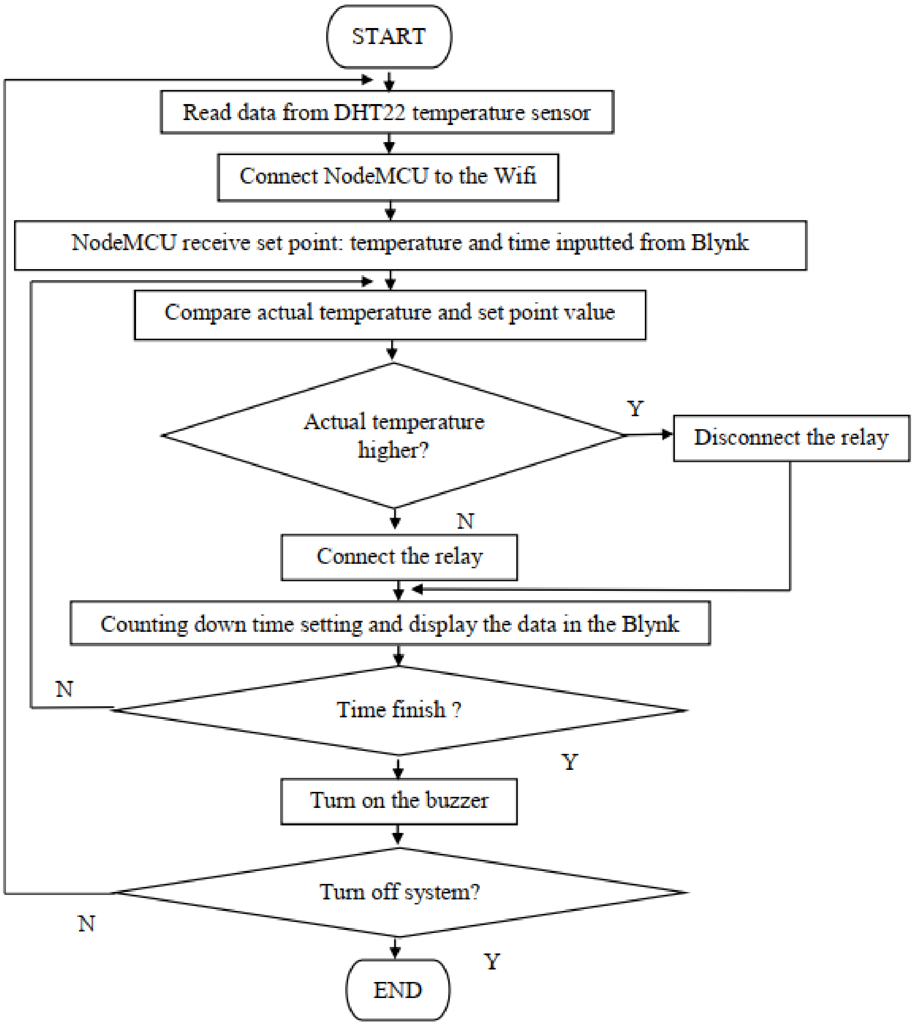


Fig. 5. Flowchart of the developed system

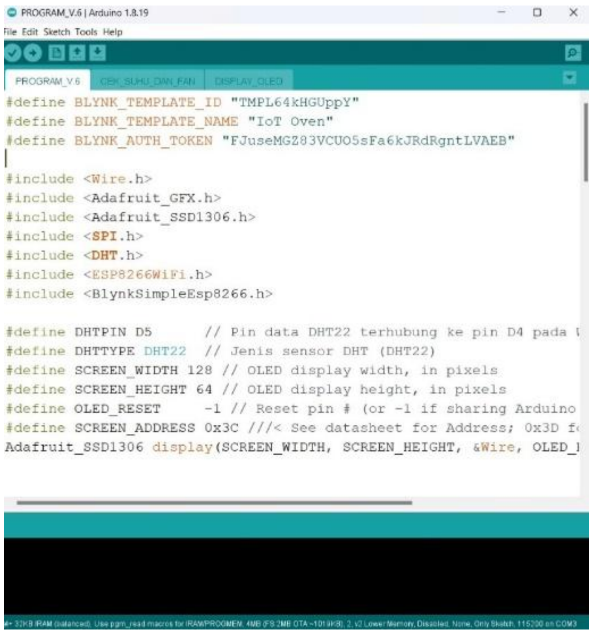


Fig. 6. Example part of program in Arduino IDE for connecting Blynk application to ESP8266 microcontroller

4. Results and Discussions

4.1. Acquired System

As a prototype, the interior of the incubator was coated with an aluminum sheet to prevent heat absorbed by the box so that the temperature inside the incubator can be maintained stably. The interior of the incubator can be seen in Figure 7. Two 500 W heaters were installed in the upper part of the incubator roof while the DHT22 sensor was placed below the heater. The electronic hardware was placed in the plastic box in order to protect it from external potential hazard as can be seen in Figure 8. The LCD OLED and the buzzer are placed on top of the box. The developed incubator system was equipped with the Blynk platform of the smartphone which can be seen in Figure 8(a) while the electronic hardware configuration inside the box is depicted in Figure 8(b). The Blynk platform is used for operating the developed incubator system including for turning on/off, setting the temperature value, setting the duration of the drying process, and displaying the actual temperature. By using the Blynk platform, users can control and monitor the temperature of the developed incubator from a distance. This is the main benefit compared to direct manual operation and monitoring. There were three tests conducted in order to evaluate the developed incubator system involving functional testing, calibration testing and testing in the actual environment.

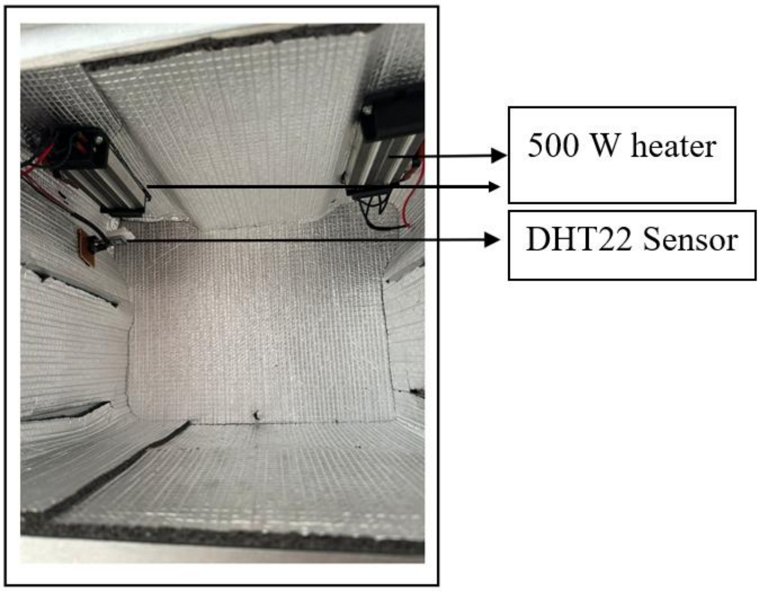
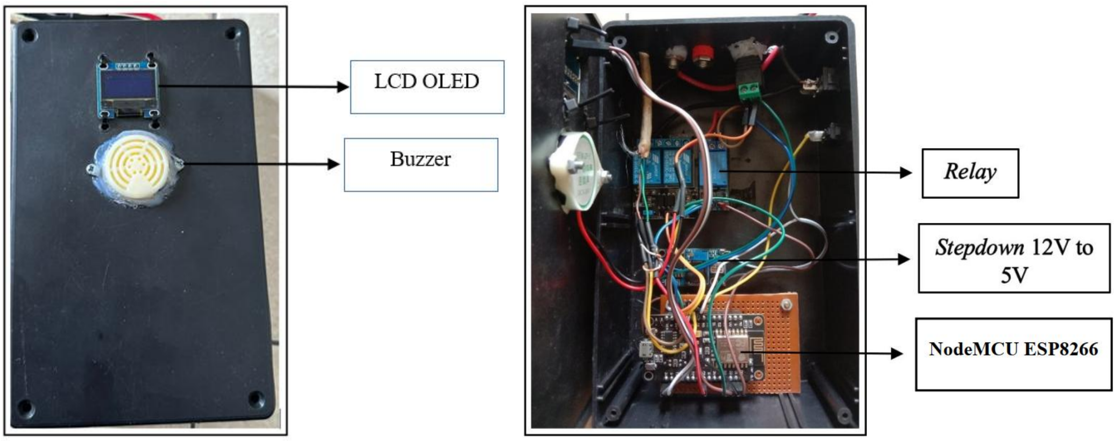


Fig. 7. Interior condition of the developed incubator



a. b.

Fig. 8. (a). Upper side view box containing electronic hard circuit, (b). configuration of electronic hardware circuit inside the box.

4.2. Functional Testing

The functional test was conducted to check whether all features of the developed incubator system were working as expected. The test was conducted by using following steps:

a. For every feature of the developed incubator system, certain test action was conducted
b. The actual working characteristics of the developed incubator system was then recorded
c. The actual working characteristics was then compared to its expected working characteristics
d. Conclusion was then determined: valid or not valid

The functional testing results summarized in Table 3 suggested that the developed incubator system works well as expected.

Table 3 - Functional test results

No.	Feature	Test Action	Expected Results	Actual Results	Conclusion
1.	On/off push button	The on/off button was pressed	The developed incubator was turned on/off in accordance with the button position	The developed incubator successfully was turned on/off in accordance with the button position	Valid
2.	Blynk application namely IoT Oven	Open/close the application	The Blynk application namely IoT Oven open/close in accordance with button position	The Blynk application namely IoT Oven successfully open/close in accordance with button position	Valid
3.	Temperature setting using Blynk platform	Certain value of temperature and heating period was set by using Blynk application	The incubator started to work, the electric heater was turned on, the temperature was increased and its actual value was displayed in both Blynk application and local LCD LED display, when the heating period was finished then the electric heater was turned off and the buzzer notification was turned on.	The incubator started to work, the electric heater was successfully turned on, the temperature was increased and its actual value was displayed in both Blynk application and local LCD LED display, when the heating period was finished then the electric heater was turned off and the buzzer notification was turned on.	Valid
4.	Display features of Blynk application	The developed incubator was operated and observe the Blynk application display.	The actual temperature was displayed in the Blynk application in real time.	The actual temperature was successfully displayed in the Blynk application in real time.	Valid

4.3. Calibration Testing

The calibration testing was performed in order to measure the difference of the measurement result by using the developed incubator system compared to a commercial instrument widely used daily in the society which is shown in Figure 9. The main variable tested in the calibration testing was temperature level. The calibration testing was conducted by using the following steps:

a. The developed incubator system was turned on.
b. Certain target temperature value and heating period was chosen. There were three temperature values used in the calibration testing which were chosen according to

research results reported by Kusumaningrum et al. (2019) that incubator or oven used for drying crackers usually apply 50, 60 or 70 °C of temperature.

c. The actual temperature value of the cabin of the developed incubator system shown in the LCD OLED display and Blynk platform of the smartphone (shown in Figure 9a) was compared to those of commercial measuring instruments. The commercial measuring instrument used in the testing was a thermo gun type thermometer broadly used in the society which can be seen in Figure 9b.

d. The measurement difference (Δ) between the measurement using the developed incubator system (T_D) and commercial measuring instrument (T_C) was then calculated by using Equation (1) and (2).

$$\Delta(^\circ\mathrm{C}) = |T\_C - T\_D\,| \quad (1)$$
$$\Delta(\%) = \Delta / T\_C \times 100\% \quad (2)$$

a.

b.

Fig. 9. The calibration testing process: (a). Display of the Blynk platform, (b). Temperature measurement using commercial measuring instrument

In the test, for every designated targeted temperature value there were three heating periods chosen and the temperature was measured and compared for every chosen heating period. The calibration test was performed in two days and their results are summarized in Table 4 and 5 for day one and day two respectively. It can be noted from the test results that the temperature measurement by using the developed incubator system was stable without any sudden change for any given temperature level and heating period. Moreover, the measurement difference average was 0.34%. These test results suggested that the developed incubator system is working well.

Table 4 - Calibration testing in day one: T_S is set point temperature, is t heating time, T_D is temperature read by developed system, T_C is temperature read by a commercial instrument

T_S (°C)	t (Minutes)	T_D (°C)	T_C (°C)	Δ (°C)	Δ (%)

	30	50	50	0	0
50	45	50	49.8	0.2	0,4
	60	50	50	0	0
	30	60	60	0	0
60	45	60	59.8	0.2	0.33
	60	70	60	0	0
	30	70	69.8	0.2	0.29
70	45	70	70	0	0
	60	70	70	0	0
	Average			0.067	0.34

Table 5 - Calibration testing in day two: T_S is set point temperature, is t heating time, T_D is temperature read by developed system, T_C is temperature read by a commercial instrument

T_S (°C)	t (Minute)	T_D (°C)	T_C (°C)	Δ (°C)	Δ (%)
	30	50	50	0	0
50	45	50	49.8	0.2	0.4
	60	50	50	0	0
	30	60	60	0	0
60	45	60	60	0	0
	60	60	59.8	0.2	0.33
	30	70	70	0	0
70	45	70	70	0	0
	60	70	69.8	0.2	0.29
	Average			0.067	0.34

4.4. Testing on the Actual Crackers

The developed system is a multipurpose incubator which means it could be used for drying or heating processes of various foods. However, for functional validity testing purposes, the developed incubator system was tested for drying actual rice crackers as a case study. The test was carried out using the following steps:

a. The fresh rice crackers (crackers which are just cooked and sliced) were placed inside the developed incubator systems. As an experimental case study, there were 18 pieces of rice crackers chosen as samples.
b. The rice crackers were dried by using the developed incubator with a temperature of 70 ^{0}C for 5 hours which was operated by using Blynk application. After 5 hours operating, the developed incubator was turned off automatically.
c. The rice crackers dried up using the developed system was then compared to it dried up with sun shine previously. The comparison was made based on its physical appearance, especially its dryness level.

Figure 10.a-c. showing the drying process of the rice crackers in the developed incubator system in the testing. After 5 hours drying, the rice crackers was dried enough (its appearance can be seen in Figure 10d) comparable to the rice crackers which has been dried by using direct sunlight for two days from 07.00 am to 16.00 pm or totally for 18 hours (its appearance can be seen in Figure 11) in average sunny day in greater Surakarta area. It can be noted that the use of

the developed incubator system was able to shorten the drying process with comparable results. This because it can provide the constant heat at predetermined. The energy consumption of the developed incubator for the 5 hour drying operation process is around 5 KWH.


a.


b.


c.


d.

Fig. 10. (a). The fresh rice crackers before being dried, (b)-(c). Position of rice crackers inside the developed incubator in the drying process, (d). The rice crackers appearance after a 5-hour drying process.

Fig. 11. The appearance of rice crackers dried by using direct sunlight

4.5. Discussion

The test results showed that the temperature in the developed incubator system was stable as expected. This stable temperature was provided by ESP8266 microcontroller which implements the closed control system presented in Figure 2. The DHT22 reads the actual temperature of the incubator and then ESP8266 microcontroller compares it with the targeted temperature. The comparison was then calculated by using Equation 3, where $e(t)$ is the error or difference between the targeted temperature and actual temperature, $r(t)$ is the reference or targeted temperature inputted by using Blynk temperature and $c(t)$ is the actual temperature value measured by using DHT22 temperature sensor. Based on the error value, the ESP8266 microcontroller was then produced a control signal to turn on/off the electric heater by using Equation (4) where $u(t)$ is the control signal, the ESP8266 output pin to relay connected to the electric heater. By this mechanism, it is able to make the temperature inside the incubator cabin stable around the designated value.

$$e(t) = r(t) - c(t) \quad (3)$$

$$u(t) = OFF \text{ if } e(t) < 0 \quad (4)$$

OR

$$u(t) = ON \text{ if } e(t) > 0$$

By using the stable temperature, based on the experiment, the developed incubator system was able to dry the rice crackers in 5 hours, faster than by using sunshine which was totally needed 18 hours with the comparably the same drying results. It was because by using the developed incubator, the rice crackers received stable temperature of 70 ℃ without any intervention compared to by using sunshine which its heat level was varying according to time and weather condition so that the rice crackers received less heat. The power consumed by the developed incubator system is a combination of the power consumed for the electronics hardware circuit and two 500 W heaters. Because the power consumption of the electronic hardware was considered very low in comparison to the power consumed by the electric heaters, it can be ignored. The power consumption of the developed incubator system can be calculated by using Equation 5, where E is the total power consumption in KiloWatt Hour (KWH), P is the power consumption in Watt and t is the operational time in hour. Based on the experiment results, for case study of rice crackers drying, it needs 5 hours of operation of developed incubator systems so that the total power consumption is equal to 5 KWH.

$$E = P \times t \quad (5)$$

From the experiment, it can be noted that the unique features namely set point interface and distance control and monitoring which was performed by using the Blynk platform of the smartphone worked well. The Blynk platform was able to be used for inputting temperature set point and the drying duration as well as to display the actual temperature of the incubator. The Blynk connection capability and stability was dependent on the wifi signal strength provided for the ESP8266 microcontroller. In the experiment, the wifi was provided by using a mobile phone tethering facility where the internet was provided by one of the national mobile internet providers in Indonesia. In the experiment, the wifi signal is in full scale (5/5) so that the Blynk application works well in receiving and displaying data as well as sending control commands from and to ESP8266 microcontroller instantly without any necessary delay.

In the future, the developed system could be enhanced by adding more features, for example a temperature recommendation such as proposed by Khan (2020). Also, the use of more advanced sensors and advanced controllers such as closed loop with cascaded control algorithms proposed by Zhang et al. (2024) could be employed to increase its performance. Moreover, besides its temperature performance, an incubator or oven should be safe being in use.

5. Conclusion

The general incubator for drying purpose has been successfully developed based on a manual stove-based incubator and off the shelf electronics components. The developed incubator system was equipped with the Blynk platform of a smartphone for distance control and monitor. The functional testing results showed that all features of the developed incubator system were working well. The test results showed that the temperature in the developed incubator system was stable as expected. The calibration testing results suggested that temperature measurement by using the developed system has inaccuracy of 0.34% when compared to measurement by using a commercial thermometer. To validate its function in actual condition, the incubator was used for drying rice crackers. The rice crackers were dried on the temperature of 70 ℃ with a duration of 5 hours. It can be noted that the drying result by using the developed incubator was comparable to that of drying by direct sunlight on a sunny day with a duration of two days from 7 am to 16.00 pm, totally for 18 hours. These results suggested that the developed incubator has considerably good performance. Further research could be carried out in several areas for example by implementing intelligent controllers, artificial intelligence and its construction regarding insulation for energy efficiency.

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