Design of Monitoring and Telecontrol System on Cassava Fermentation as Basic Ingredients of Mocaf Flour (Modified Cassava Flour) Based on Internet of Things (IoT)

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***Abstract*—Mocaf (Modified Cassava Flour) is flour from cassava which is fermented by lactic acid bacteria. The growth temperature for lactic acid bacteria is 30°C-37°C with a fermentation time of 12-24 hours. In previous research, during 24 hours of fermentation at 33°C, mocaf flour produced the highest protein content of 12.87% without using a temperature stabilization system. The success of the fermentation process is indicated by a decrease in the pH value of the fermentation water to 4.5–5.0. In household scale producers, mocaf fermentation is still carried out traditionally at unstable temperatures. Therefore, a system is needed to monitor and control temperature automatically. In this research, the system that has been designed uses an ESP32 microcontroller as the system control center. The pH sensor is used to detect the pH value of water, the gas sensor is used to detect carbon dioxide gas (CO2) and the temperature sensor is used to detect the water temperature value. Peltier elements are used to lower the temperature and heaters are used to increase the temperature of the fermented water. In this research, a successful fermentation process with a pH value of around 5.0 could be achieved within ±12 hours at a temperature of 33°C, ±18 hours at a temperature of 43°C, and ±25 hours at a temperature of 23°C. In this study the mocaf fermentation process was completed in only ± 12 hours at a temperature of 33°C which is the ideal temperature for the growth of lactic acid bacteria.**

***Keywords*— Android application , Carbon dioxide, fermentation, gas, Mocaf (Modified Cassava Flour), pH, Temperature.**

I. INTRODUCTION

Indonesian people are accustomed to consuming wheat-based foods. Based on data from the Indonesian Central Statistics Agency, in 2021 wheat imports in Indonesia reached 11.17 million tons. These import activities have an impact on increasing the price of wheat flour and dependence on food sources from abroad. Therefore, it is very necessary to develop and utilize local resources as a substitute for wheat flour, one of which is using cassava.

Cassava is the basic ingredient for making mocaf. Mocaf (Modified Cassava Flour) is flour made from cassava which is processed using the principle of modifying cassava cells through a fermentation process. Modification is carried out with the help of microbes that produce produce lactic acid and CO_2 [2]. The fermentation process will produce flour with characteristics similar to wheat flour, making it very suitable to replace wheat flour for the food industry [3].

Most of the fermentation process in the mocaf flour making stage still uses manual methods which are left at unstable temperature conditions, resulting in inefficient time and content in the mocaf flour. Therefore, we need a system that can monitor and control temperature automatically.

In previous research, the system created produced the optimum temperature for mocaf fermentation with the highest protein content but did not have a temperature stabilization system. The temperature required for lactic acid bacteria to grow in the fermentation process is 30°C-37°C with a fermentation time of 12-24 hours [5]. During 24 hour fermentation at a temperature of 33°C mocaf flour produces a protein content of 12.87% with a starter concentration of 0.3%, while at a fermentation temperature of 30°C mocaf flour only produces a protein content of 10.745% [5].

The success of the fermentation process in making mocaf is characterized by a decrease in the pH value of the fermentation water [6]. Apart from that, foam appears in the fermented water due to increased production of carbon dioxide gas (CO2). In the mocaf fermentation process, the initial pH of the fermentation water is 7.0 [6]. After 24 hours of fermentation, the pH value of the water drops to 4.5–5.0 [6]. The decrease in pH value is caused by the activity of lactic acid bacteria [6]-[8].

In the mocaf flour fermentation process, regulating the temperature manually is very difficult, therefore a system is needed that can regulate the temperature automatically. For household scale producers, the fermentation process is still carried out traditionally by soaking cassava chips in water, while for factory scale producers it is done by soaking them in a fermentation container equipped with pH value monitoring [9] and temperature controls are very expensive and large in size [10].

Based on these problems, in this study designed and built a household-scale mocaf flour fermentation device using a control system method with temperatures to be used were 23°C [11], 33°C [12] and 43°C [13]. The fermentation process is assisted by peltier and heating elements in the process of changing temperature [14][15]. Data transmission and operation use a telecontrol system with a microcontroller that is connected to the internet network and can be monitored through an Android application.

II. METHOD

A. Block Diagram System

Block diagram system explaining the work system in the research conducted, as shown in Fig. 1.

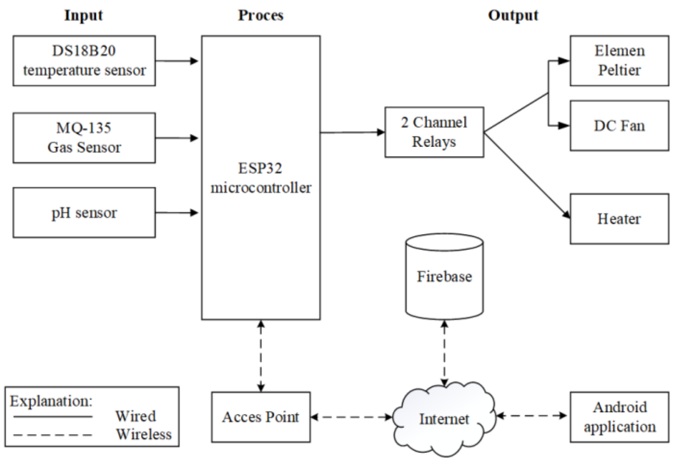

Figure 1. Block Diagram System

Figure 1 is a block diagram system, where temperature, pH, gas values will be monitored and water temperature controlled during the fermentation process. Reading the water temperature value using the DS18B20 temperature sensor, reading the value of carbon dioxide (CO_2) gas using the MQ-135 sensor, reading the pH value using the water pH sensor. Reading the value of each sensor will be processed on the ESP32 microcontroller. The relay is used as an automatic switch which is a command output process from the microcontroller to activate the peltier element and DC fan which functions to lower the water temperature during the fermentation process, as well as a heater which functions to increase the water temperature during the fermentation process. All sensor value data received by the microcontroller will be sent via the internet network and stored in the firebase (database) and displayed on the android application contained on the user's smartphone, so that the user can monitor during the fermentation process.

B. Flowchart System

The following is a flowchart of the planned system, as shown in Fig. 2.

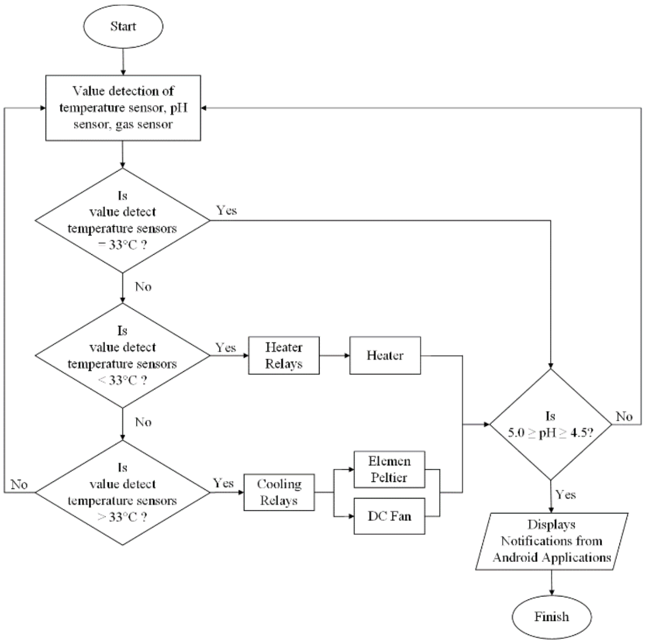

Figure 2. Flowchart of How the Overall System Works

In Fig. 2 is a flowchart of how the system works as a whole which will be explained as follows:

- Once the program is executed, start it.
- First, initialize each sensor.
- User enters the temperature value he wants to use.
- The system will detect the value of each sensor. The gas sensor is used to detect carbon dioxide (CO_2) gas produced, the pH sensor is used to detect the pH value of the water, the temperature sensor is used to detect the temperature of the water during the fermentation process.
- If the temperature detected by the temperature sensor is the same as the temperature input you want to use, it will proceed to the process of monitoring the pH value until it reaches a pH value of 5.0-4.5. If the pH has not reached the pH value = 5.0-4.5, the fermentation process will continue with the sensor detection process and temperature stabilization according to the input value you want to use.
- If the temperature detected by the temperature sensor is less than the input temperature value you want to use, the heating relay will activate the heater to raise the air temperature. Then proceed to the process of monitoring the pH value until it reaches a pH value = 5.0-4.5. If the pH value has not reached the pH value = 5.0-4.5 then the fermentation process will continue with the process of detecting the value of each sensor and stabilizing the temperature according to the temperature value you want to use.
- If the temperature detected by the temperature sensor is more than the input, the cooler will activate the Peltier element and DC fan to lower the air temperature. Then proceed to the process of monitoring the pH value until it reaches a pH value = 5.0-4.5. If the pH value has not reached the pH value = 5.0-4.5 then the fermentation process will continue with the process of detecting the value

of each sensor and stabilizing the temperature according to the temperature value you want to use.

- When the pH value reaches 5.0-4.5, there will be information to smartphone users via the android application that the fermentation process has been completed.
- Finish.

C. Design of Mechanical Device (Hardware)

Design of mechanical device is the design of the physical tool, which is consists of the layout of the components and the dimensions to be made, as shown in Fig. 3, Fig. 4 and Fig. 5.

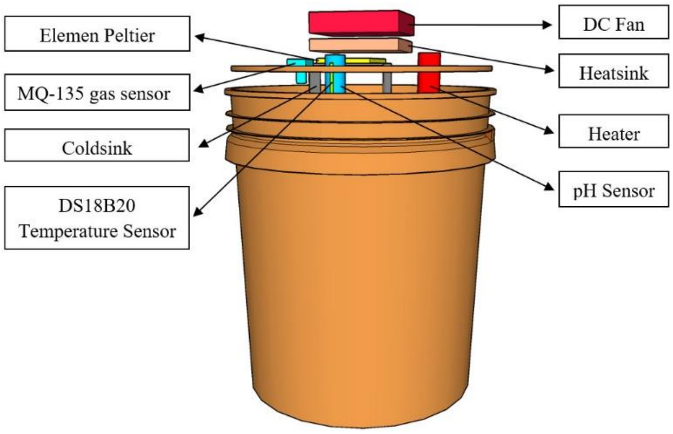

Figure 3. Design of Mechanical Device (Hardware) from Front View

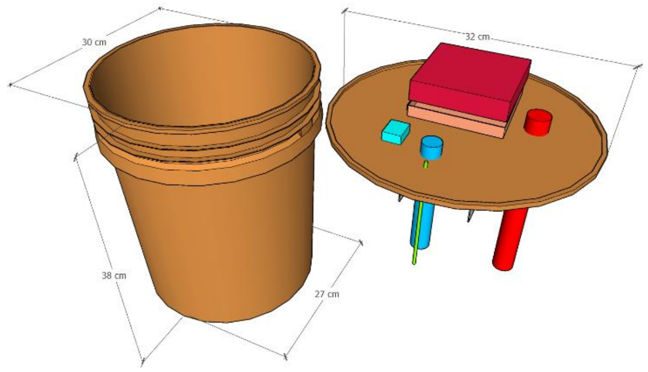

Figure 4. Design of Mechanical Device (Hardware) form Top View

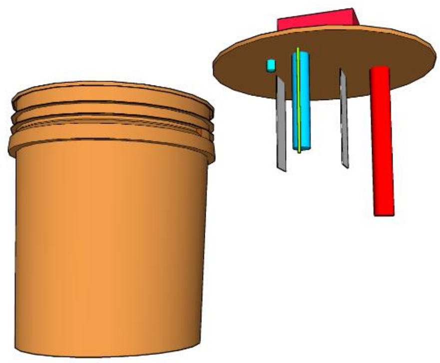

Figure 5. Design of Mechanical Device (Hardware) form Bottom View

The tools in this study used plastic material with a thickness of 2 mm, as shown in Table I.

TABLE I
DIMENSIONAL DESIGN

No	Attribute	Dimension
1.	High	38 cm
2.	Top Bucket Circle Diameter	30 cm
3.	Bottom Bucket Circle Diameter	27 cm
4.	Bucket Lid Diameter	32 cm
5.	Capacity	15 liters of water

D. Design of Electrical Devices (Hardware)

Design of electrical devices is a design regarding design electronic components, as shown in Fig. 6.

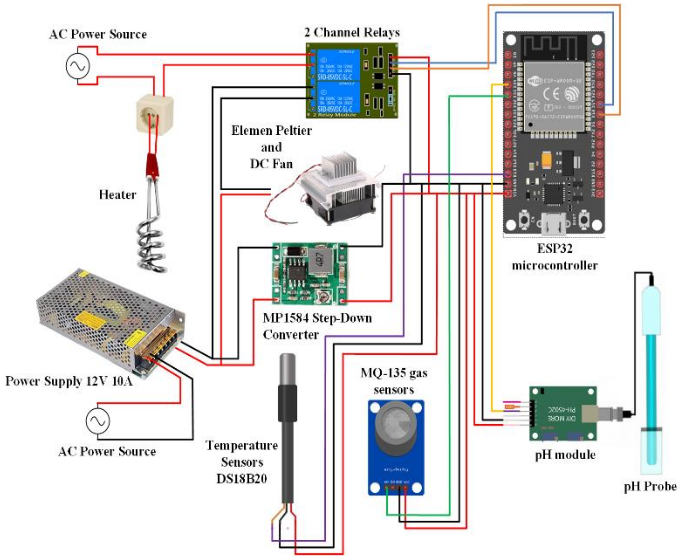

Figure 6. Design of Electrical Device (Hardware)

This circuit consists of all components connected to the ESP32 microcontroller. The overall circuit is shown in Table II.

TABLE II
PIN CONFIGURATION OF ALL SENSORS TO ESP32 MICROCONTROLLER

ESP32 Microcontroller Pins	DS18B20 temperature sensor	pH sensor	MQ-135 gas sensor	Relays
V_{IN}	V_{CC}	V_{+}	V_{CC}	V_{CC}
GND	GND	G	GND	GND
GPIO13	Input Data	-	-	-
GPIO18	-	-	-	IN_1
GPIO19	-	-	-	IN_2
GPIO34	-	P_{OUT}	-	-
GPIO35	-	-	A_{OUT}	-

E. Design of Android Application (Software)

Design of the android application for the login page includes a form for entering the user's email and password. In addition, there is a login button to enter the application, as shown in Fig. 7.

Figure 7. Login Page Design of Android Application

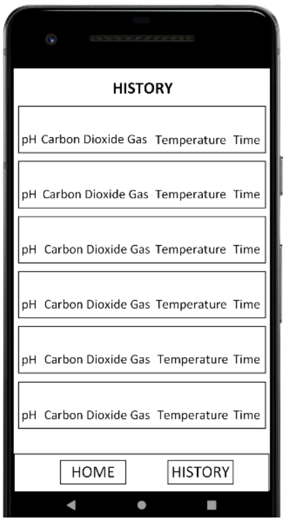

Figure 9. History Page Design of Android Application

Design of the android application for the home page includes a information on the value of water temperature, pH value of the water, carbon dioxide gas (CO_2), control status of heater, control status of the fan cooler and peltier elements, button up and button down to set the temperature value fermentation process, navigation bar button to go to the home page and history page, as shown in Fig. 8.

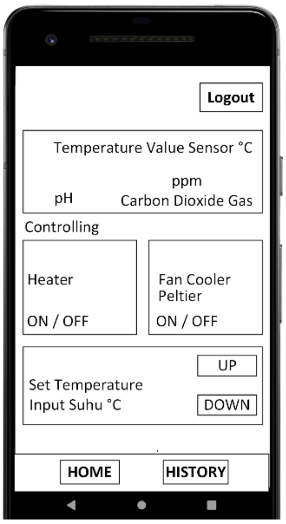

Figure 8. Home Page Design of Android Application

Design of the android application for the history page includes a information on water temperature values, information on water pH values, information on carbon dioxide gas (CO_2) values, time information, and a navigation bar button to go to the home page and history page, as shown in Fig. 9.

III.RESULTS AND DISCUSSION

A. *Design Result of Mechanical Device (Hardware)*

Sensor components, peltier elements, heatsink, coldsink and heater will be placed on the lid of the fermentation container. Power supply will be placed beside the fermentation container. The design result of mechanical device (hardware) are shown in Fig. 10, Fig. 11, and Fig. 12.

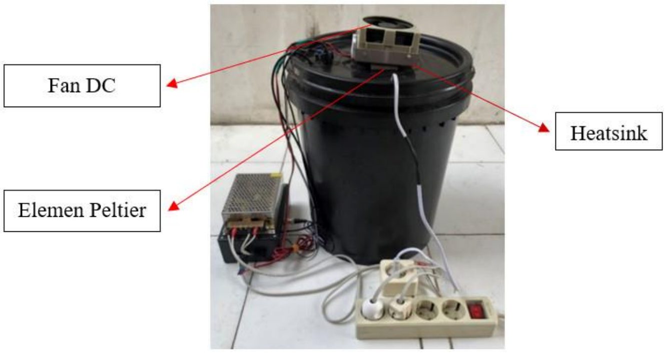

Figure 10. Design Result of Mechanical Device (Hardware) from Front View

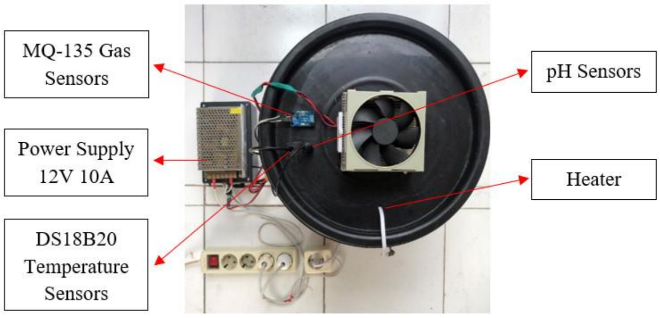

Figure 11. Design Result of Mechanical Device (Hardware) from Top View

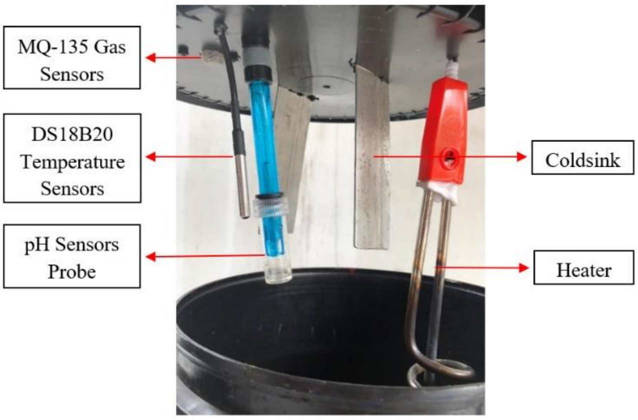

Figure 12. Design Result of Mechanical Device (Hardware) from Bottom *View*

B. *Design Result of Electrical Devices (Hardware)*

The electrical circuit box containing electronic components will be placed beside the fermentation container, as shown in Fig. 13.

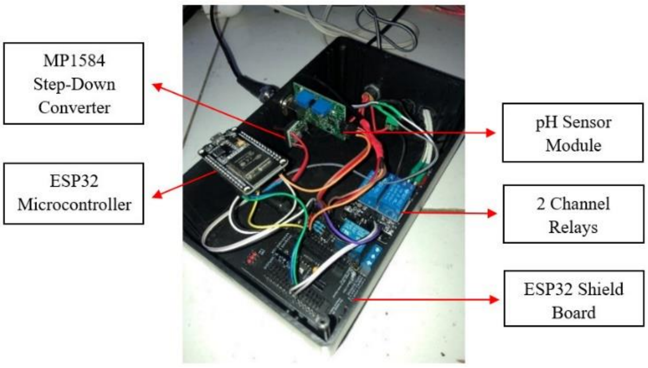

Figure 13. Design Result of Electrical Device (Hardware)

C. *Design Result of Android Application (Software)*

On the user login page, there is an email address and password form to enter the fermentation application software, as shown in Fig. 14.

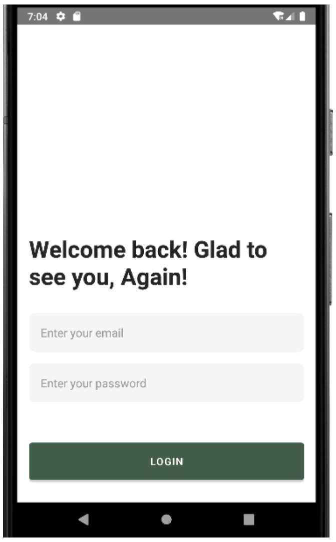

Figure 14. Design Result of Login Page Android Application

On the home page there is a process of monitoring and controlling. The monitoring process shows information about the value of water temperature in units of Celsius, the pH value of water, the value of carbon dioxide gas (CO_2) in units of ppm. The control process shows information about the status of the on/off control on the heater to increase the temperature and the status of the on/off control on the fan cooler to lower the temperature. At the bottom there is a navigation bar button to home page and history page. The fermentation temperature that the user wants to use can be set via button up and button. The display of the home page is shown in Fig. 15.

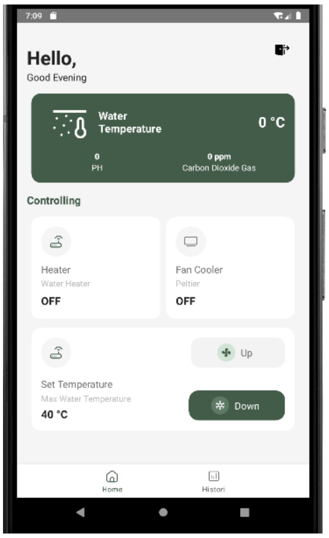

Figure 15. Design Result of Home Page Android Application

On the history page there is information on monitoring data that has been carried out during the fermentation process. There is information regarding the pH value, carbon dioxide gas (CO_2) value in ppm units, temperature values in celsius units and time information. At the bottom there is a navigation bar button to home page and history page. The display of the history page is shown in Fig. 16.

Figure 16. Design Result of History Page Android Application

D. *Sensor Test Result*

Sensor testing is done to ensure that the sensor is there work properly or commonly called sensor accuracy. Sensor testing is done before testing the system as a whole in order to produce accurate data. In addition, sensor testing also serves to calculate the percentage error value and the accuracy percentage of each sensor.

1) DS18B20 Temperature Sensor Accuracy Test Results

Testing the accuracy of this sensor was carried out to determine the accuracy of the DS18B20 temperature sensor by comparing it using a Taffware TP101 measuring instrument (digital temperature thermometer), as shown in Fig. 17 and Table III.

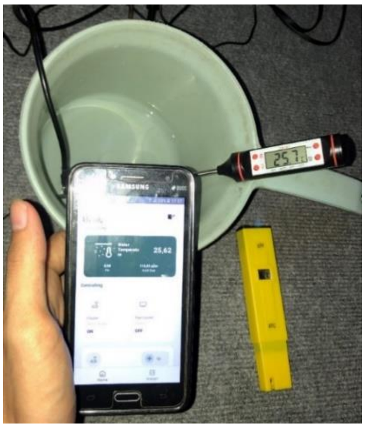

Figure 17. DS18B20 Temperature Sensor Accuracy Testing

TABLE III
DATA ON DS18B20 TEMPERATURE SENSOR ACCURACY TEST RESULTS

No	Thermometer (°C)	Temperature Sensor (°C)	Deviation	Error Percentage (%)
1.	25.7	25.62	0.10	0.00
2.	25.3	25.19	0.20	0.00
3.	41.6	40.75	0.90	0.02
4.	41.8	41.00	0.80	0.02
5.	44.6	43.56	1.10	0.02
6.	45.9	44.94	1.00	0.02
7.	45.4	45.81	0.40	0.01
8.	46.6	46.31	0.30	0.01
9.	46.8	45.94	0.90	0.02
10.	49.5	49.00	0.50	0.01
Average Percentage Error (%)				**0.01**

The value of the temperature sensor reading results is obtained with an average percentage error reading of the water temperature value of 0.01% and the percentage of accuracy reading the water temperature value of 99.99%, then the temperature sensor is feasible to use. The formula used to determine the percentage of error and the percentage of sensor accuracy in each test is expressed in Equations (1) and (2).

$$Percentage\ error = \frac{deviation\ sensor\ with\ measure\ instrument}{measure\ instrument\ value} \quad (1)$$

$$Sensor\ Percentage = 100\% - \text{Average percentage error} \quad (2)$$

$$= 100\% - 0.01\%$$

$$= 99.99\%$$

2) pH E-201C Sensor Accuracy Test Results

Testing the accuracy of this sensor was carried out to determine the accuracy of the E-201-C pH sensor by comparing it with an ATC (digital water pH) meter, as shown in Fig. 18 and Table IV.

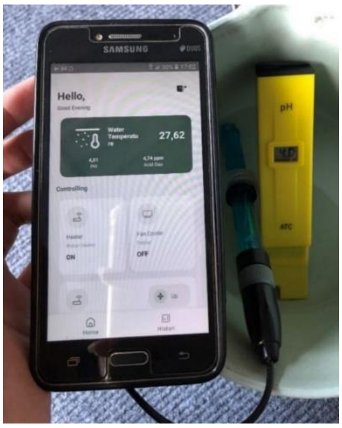

Figure 18. pH Sensor Accuracy Testing

TABLE IV
DATA ON pH E-201C SENSOR ACCURACY TEST RESULTS

No	pH Meter	pH Sensor	Deviation	Error Percentage (%)
1.	4,0	4,01	0,01	0,25
2.	4,3	4,40	0,10	2,33
3.	4,9	5,09	0,14	2,86
4.	5,3	5,41	0,11	2,08
5.	5,5	5,60	0,10	1,82
6.	6,9	6,97	0,07	1,01
7.	6,9	7,05	0,15	2,17
8.	7,0	6,80	0,20	2,86
9.	8,2	8,36	0,16	1,95
10.	9,0	8,90	0,10	1,11
Average Percentage Error (%)				**0.01**

The value of the reading of the pH sensor is obtained with an average percentage of error reading the pH value of water is 1.84% and the percentage of accuracy reading the pH value of water is 98.16%, so the pH sensor is feasible to use . The formula used to determine the percentage of error and the percentage of sensor accuracy in each test is expressed in Equations (3) and (4).

$$Percentage\ error = \frac{deviation\ sensor\ with\ measure\ instrument}{measure\ instrument\ value} \quad (3)$$

$$Sensor\ Percentage = 100\% - \text{Average percentage error} \quad (4)$$

$$= 100\% - 1.84\%$$

$$= 98.16\%$$

3) MQ-135 Sensor Accuracy Test Results

Testing the accuracy of this sensor was carried out to determine the accuracy of the MQ-135 gas sensor (carbon dioxide gas) by comparing it with the JSM-131SC Air Quality Detector (carbon dioxide gas), as shown in Fig. 19 and Table V.

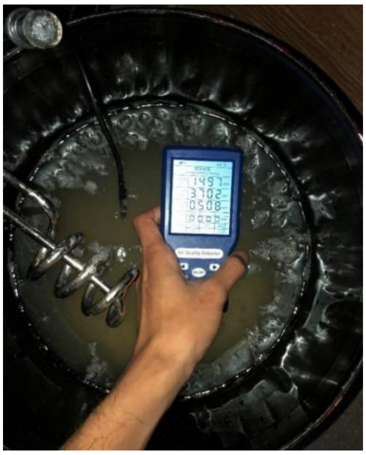

Figure 19. Gas Sensor Accuracy Testing

TABLE V
DATA ON MQ-135 SENSOR ACCURACY TEST RESULTS

No	CO_2 Gas Detector (ppm)	CO_2 Gas Sensor (ppm)	Deviation	Error Percentage (%)
1.	471	468	3	0,64%
2.	524	526	2	0,38%
3.	603	605	2	0,33%
4.	698	701	3	0,43%
5.	739	734	5	0,68%
6.	857	854	3	0,35%
7.	1268	1265	3	0,24%
8.	1379	1378	1	0,07%
9.	1416	1418	2	0,14%
10.	1497	1492	5	0,33%
Average Percentage Error (%)				0,36%

The value of the reading of the gas sensor is obtained with an average percentage of error reading the value of carbon dioxide gas (CO_2) of 0.36% and the percentage of accuracy of reading the value of carbon dioxide gas (CO_2) of 99.64%, then the gas sensor is feasible to use. The formula used to determine the percentage of error and the percentage of sensor data accuracy in each test is expressed in Equations (5) and (6).

$$Percentage\ error = \frac{deviation\ sensor\ with\ measure\ instrument}{measure\ instrument\ value} \quad (5)$$

$$Sensor\ Percentage = 100\% - \text{Average percentage error} \quad (6)$$

$$= 100\% - 0.36\%$$

$$= 99.64\%$$

E. *Manual Testing Results Using Measuring Instruments*

Table VI shows the results of testing fermented cassava as a basic ingredient for mocaf flour (Modified Cassava Flour) which was carried out manually using a measuring instrument with a water medium of 7 liters of tap water with 7 grams of Bimo-CF starter mixture and 7 kg of fresh cassava. Water temperature uses room temperature around 25°C-30°C and is monitored every ± 2 hours. This fermentation process is carried out on Monday, 6 August 2022 at 08.00-09.12 WIB and lasts for ± 25 hours. This fermentation process is complete when the fermented water reaches a pH value = 5.0, as shown in Table VI.

TABLE VI
TEST RESULT DATA MANUALLY USING MEASURING INSTRUMENTS

Data to -	Water Temperature Value (°C)	Water pH value	CO_2 Gas Value (ppm)	Time
1.	25,5 °C	6,7	289	08.00
2.	26,1 °C	6,5	314	10.03
3.	27,3 °C	6,2	458	12.02
4.	30,2 °C	6	672	14.02
5.	28,6 °C	5,7	781	16.04
6.	28,2 °C	5,5	867	18.01
7.	27,9 °C	5,3	925	20.05
8.	27,4 °C	5,4	1028	22.08
9.	25,7 °C	5,3	1144	00.09
10.	25,4 °C	5,2	1271	02.08

F. *Test Results Using The System*

Testing using the system is carried out to find out the system has been running according to plan. In addition, in this test research was carried out on the effect of temperature on the length of time of fermentation with a comparison using the optimum temperature and outside the optimum temperature for the growth of lactic acid bacteria.

1) Testing Using a System with a Temperature of 23°C

Table VII shows the results of monitoring the pH value of water and carbon dioxide gas (CO_2) during testing of cassava fermentation as a basic ingredient for mocaf flour (Modified Cassava Flour) which was carried out using a system that has been made with the tap water temperature set at 23°C and monitored. every ± 1 hour. The volume of water in this test was 7 liters of tap water with 7 grams of Bimo-CF starter mixture and 7 kg of fresh cassava. This fermentation process is carried out on Friday, 12 August 2022 at 07.00-08.06 WIB and lasts for ± 25 hours. The fermentation process is complete when the fermented water reaches a pH value = 4.93, as shown in Table VII.

TABLE VII
TEST RESULT DATA USING A SYSTEM WITH A TEMPERATURE OF 23°C

Data to -	Water pH value	CO_2 Gas Value (ppm)	Time
1.	6,79	239	07.02
2.	6,71	256	08.07
3.	6,63	296	09.10
4.	6,58	317	10.12
5.	6,49	352	11.06
6.	6,42	379	12.04
7.	6,36	412	13.08
8.	6,32	455	14.11
9.	6,28	529	15.07
10.	6,22	545	16.03
11.	6,18	580	17.04
12.	6,14	623	18.08
13.	6,1	668	19.14
14.	6,07	702	20.21
15.	6,04	750	21.13
16.	5,99	871	22.09
17.	5,94	954	23.20
18.	5,86	1096	00.09
19.	5,81	1132	01.14
20.	5,75	1284	02.17
21.	5,61	1331	03.24
22.	5,47	1389	04.12
23.	5,35	1436	05.04
24.	5,28	1494	06.01
25.	5,13	1525	07.09

Data to -	Water pH value	CO_2 Gas Value (ppm)	Time
26.	4,93	1573	08.06

2) Testing Using a System with a Temperature of 33°C

Table VIII shows the results of monitoring the pH value of water and carbon dioxide gas (CO_2) during testing of cassava fermentation as a basic ingredient for mocaf flour (Modified Cassava Flour), which was carried out using a system that has been made with the tap water temperature set at 33°C and monitored. every ± 1 hour. The volume of water in this test was 7 liters of tap water with 7 grams of Bimo-CF starter mixture and 7 kg of fresh cassava. This fermentation process is carried out on Monday, 8 August 2022 at 09.00-21.11 WIB and lasts for ± 12 hours. The fermentation process is complete when the fermented water reaches a pH value = 5.02, as shown in Table VIII.

TABLE VIII
TEST RESULT DATA USING A SYSTEM WITH A TEMPERATURE OF 33°C

Data to -	Water pH value	CO_2 Gas Value (ppm)	Time
1.	6,72	216	09.02
2.	6,64	344	10.04
3.	6,57	496	11.03
4.	6,33	589	12.05
5.	6,21	741	13.04
6.	6,02	901	14.06
7.	5,87	992	15.02
8.	5,63	1098	16.03
9.	5,51	1259	17.02
10.	5,39	1307	18.05
11.	5,23	1398	19.04
12.	5,11	1412	20.04
13.	5,02	1598	21.11

3) Testing Using a System with a Temperature of 43°C

Table IX shows the results of monitoring the pH value of water and carbon dioxide gas (CO2) during testing of cassava fermentation as a basic ingredient for mocaf flour (Modified Cassava Flour), which was carried out using a system that has been made with the tap water temperature set at 43°C and monitored. every ± 1 hour. The volume of water in this test was 7 liters of tap water with 7 grams of Bimo-CF starter mixture and 7 kg of fresh cassava. This fermentation process is carried out on Wednesday, 10 August 2022 at 04.00-22.16 WIB and lasts for ± 18 hours. The fermentation process is complete when the fermented water reaches a pH value = 4.94, as shown in Table IX.

TABLE IX
TEST RESULT DATA USING A SYSTEM WITH A TEMPERATURE OF 43°C

Data to -	Water pH value	CO_2 Gas Value (ppm)	Time
1.	6,68	228	04.05
2.	6,60	294	05.07
3.	6,51	347	06.12
4.	6,44	415	07.08
5.	6,37	519	08.02
6.	6,28	634	09.04
7.	6,17	683	10.06
8.	6,04	712	11.07
9.	5,92	768	12.04
10.	5,85	835	13.03
11.	5,79	903	14.04
12.	5,73	981	15.06
13.	5,69	1067	16.05
14.	5,57	1118	17.08
15.	5,41	1193	18.10
16.	5,34	1287	19.05
17.	5,29	1374	20.04
18.	5,12	1402	21.06
19.	4,94	1493	22.14

G. *Overall System Testing*

All systems that have been designed are then tested, including the accuracy of the DS18B20 temperature sensor, pH sensor and MQ-135 sensor by comparing them with actual measuring instrument. Then testing the data transmission by the sensor is carried out. To know the process of cassava fermentation can seen through the android application, the monitoring information contained in the android application includes the value of water temperature, water pH value, and carbon dioxide gas (CO_2) value, as well as information on the time during fermentation. Meanwhile, the control process shows information about the status of the on/off control on the heater to increase the temperature and the status of the on/off control on the fan cooler to lower the temperature. Based on the results of the tests that have been carried out, the overall results can be obtained. as shown in Table X.

TABLE X
OVERALL SYSTEM TESTING

No.	Testing Process	Succeed	Not Successful
1.	DS18B20 temperature sensor accuracy	✓	-
2.	pH sensor accuracy	✓	-
3.	MQ-135 gas sensor accuracy	✓	-
4.	Data transmission by sensors	✓	-
5.	Data display on android application	✓	-
6.	Reception of data by firebase (database)	✓	-

V. CONCLUSION

The system that has been created is designed using the ESP32 microcontroller as the central control system, processing input and output data and performing wireless data communication. The accuracy value for all sensors reaches a value of ≥ 98%. The data obtained is sent to the firebase (database) so that it can be accessed through an Android application that utilizes Internet of Things (IoT) technology. The android application can receive information on temperature values, pH values, gas values during the fermentation process and can control the temperature according to the temperature value you want to use. With this android application, it can help household-scale mocaf producers to keep the fermentation temperature stable, increase time efficiency and reduce the risk of losses in the cassava fermentation process for making mocaf flour. The temperature of 33°C is the ideal temperature in the cassava fermentation process with a fermentation time of ± 12 hours according to the optimum temperature needed by lactic acid bacteria to grow.

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