Innovative IoT-Based Fuzzy Logic Kitchen Model for Palembang's Traditional Crackers Production MSMEs

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Abstract. This research discusses the development of a smart kitchen system for MSMEs in the production of Palembang crackers based on the Internet of Things (IoT) which aims to improve the efficiency of workers in the production kitchen through automatic control of exhaust fans. The system utilizes DHT11, MQ135, and MQ7 sensors to detect temperature, smoke, and CO gas. The sensor readings are controlled by the NodeMCU ESP8266 microcontroller which is connected to IoT Blynk as a control and monitoring platform. Tsukamoto fuzzy logic model is integrated to automatically adjust the fan's rotational speed based on the sensor inputs. Automating the exhaust fan control based on smoke, temperature, and gas detection helps maintain good air circulation and creates a safer working environment so that workers can focus more on the production process without having to constantly monitor the condition of the kitchen environment. The system allows users to manage the exhaust fan manually or automatically via the Blynk application which is equipped with real-time monitoring of kitchen conditions and a notification system related to dangerous smoke or gas levels in the kitchen environment that allows workers to take precautions faster. The test results show that this system is able to operate with an accuracy of 99.93%, and provides an effective solution in monitoring and controlling air quality in the cracker production kitchen.

Keywords: Exhaust Fan, Fuzzy Tsukamoto, Internet of Things.

1 Introduction

Air pollution is one of the many environmental pollutants. Air is essential for the sustainability of living things as it provides the oxygen needed for metabolic processes in the body [1]. Carbon monoxide, a harmful type of air pollution, is produced from smoke due to combustion in the kitchen [2].

During cracker production, frying is the primary activity carried out in the kitchen. This process results in an increase in kitchen temperature and smoke, leading to a hot and stuffy environment with poor air quality. This poses health risks as smoke can

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cause coughing, reddened eyes, and aggravate respiratory and heart problems [3]. Long-term exposure to indoor CO gas pollution can be harmful and pose health risks if inhaled [4].

To address this issue, we require an exhaust fan to manage air circulation in the kitchen while cooking, enhancing air quality [5]. Currently, the kitchen exhaust fan is operated manually, with the user adjusting the fan speed as needed. This manual control is ineffective, emphasizing the essential requirement for an automated control system to regulate the exhaust fan automatically [6].

Previous research has conducted an automatic control system for exhaust fans using an Arduino microcontroller, which will turn the fan on if the temperature exceeds 29 ° C. When the temperature is below 28 ° C, the fan turns off. Exhaust fans are designed to switch on when the humidity level is higher than 64% and to turn off when it falls below 63% [6]. Research [7] regulates the exhaust fan speed using VSD and PLC as the central controller in controlling CO2 concentration to stabilize at 300-980 ppm based on the number of occupants in the room and save electricity usage 62.36-98.38%. Research [8] on reducing smoke in mini-utopia production was done by implementing an exhaust fan equipped with a smoke sensor to read the smoke concentration and control the exhaust fan rotation. The exhaust fan rotates at a low speed when the sensor detects less smoke and at a higher speed when it detects more smoke.

These studies have not yet been integrated with an Internet of Things (IoT)-based control and monitoring system. IoT provides an intelligent solution for controlling exhaust fans without manual intervention [9]. It allows for control and monitoring via smartphones and the internet [10]. For instance, research [11] focuses on using IoT to monitor and control the temperature in the travo substation room based on a set point. Another study [12] implements an Android-based IoT system for easier control and monitoring of household objects. Additionally, research [13] monitors the condition of IoT-based public toilets, detecting changes in temperature, CO levels, and oxygen. When these measurements exceed the set points, the exhaust fan is activated to circulate the air. In another study [14] IoT is used to monitor the server room temperature and prevent interference with data reception via WhatsApp. Furthermore, research [15] involves IoT-based benzene gas monitoring with notifications sent to Android smartphones through the Blynk application. When the set point value is reached, the system notifies the user and activates the buzzer and exhaust fan.

This research aims to address the issues identified in previous studies by automatically controlling the exhaust fan in the production kitchen of Palembang specialty crackers. The system utilizes Blynk IoT to monitor and manage smoke, CO, and temperature levels generated during cracker frying. It incorporates an MQ7 sensor as input and a DHT11 to adjust the rotating speed of the exhaust fan using fuzzy logic. With the Blynk application, the system can be controlled and monitored in real-time. Additionally, the system will send notifications when it is first activated, when switching modes, and when input values reach specified limits.

This research's contribution is the implementation of Tsukomoto fuzzy logic to regulate the speed of the exhaust fan motor and the use of the Blynk application as an information notification medium that can monitor the smart exhaust fan system in the kitchen of an MSME that produces typical Palembang crackers. Recent advances in Internet of Things (IoT) technology and fuzzy logic have enabled real-time intelligent control over systems that are usually managed manually. IoT provides connectivity and automation for various devices, which significantly improves productivity and operational efficiency, especially in industrial and production environments.

2 Methods

This study aims to develop an automatic speed control system for exhaust fans using the Blynk application to control and monitor sensor readings. In this system, the rotating speed of the exhaust fan is controlled using the Tsukamoto fuzzy logic model with the input of the DHT11 sensor reading value in temperature detection, MQ135 sensor in kitchen smoke detection, and MQ7 sensor in CO gas detection. The results of sensor readings can be monitored directly using the Blynk IoT application. The research progress is outlined in a series of steps, illustrated in Figure 1.

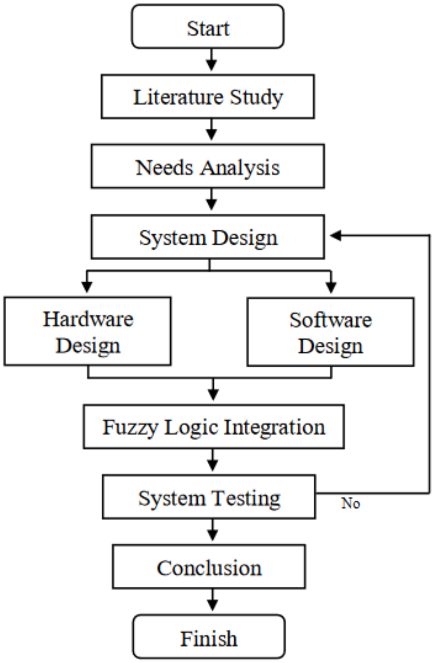

Fig. 1. Research Flow Chart.

The first step in this research is a literature study by reviewing relevant literature to understand and collect information about technology, methods, and concepts in the application of IoT and fuzzy logic in automation systems, especially for automatic control of exhaust fans in MSME kitchens. Furthermore, the needs analysis stage includes identifying and understanding the needs of the system being built, both hardware and software. In this case, some of the components needed for the system include sensor types (smoke, temperature, and CO gas), NodeMCU as the main controller, AC dimmer to control the exhaust fan speed, and other components. this system uses blynk IoT software as an application in control and monitoring.

2.1 Hardware Design

Hardware design is built by designing and setting up the hardware needed by the system which consists of detection components such as sensors, controller components namely the NodeMCU ESP8266 microcontroller, exhaust fan drive components namely AC dimmers, exhaust fans, LEDs, and LCDs. This automatic exhaust fan is designed with an iron box measuring 60cm x 40cm x 20cm and placed on the kitchen wall with a height of 65cm above the frying stove. The design of this exhaust fan system can be seen through the design of the tool in Figure 2.

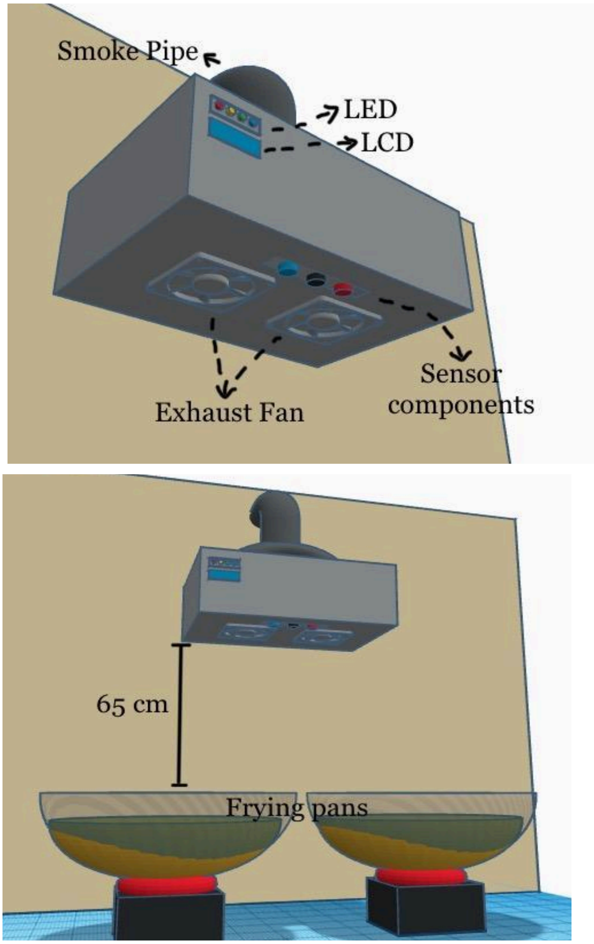

Fig. 2. Hardware design of Exhaust Fan Control System.

In solving the smoke problem in the production kitchen of MSME Crackers, this system is equipped with several sensors in detecting air quality during frying. There are 3 sensors used such as the MQ135 sensor that identifies the density of kitchen smoke generated from frying activities, the MQ7 sensor detects CO gas, and the DHT11 sensor as a temperature detector in the kitchen area. The sensor readings will be processed by the NodeMCU microcontroller using Tsukamoto fuzzy as an automatic controller for the exhaust fan. The output is sent to the AC dimmer to drive the exhaust fan according to the fuzzy logic results. The resulting output is the rotating speed of the exhaust fan based on the results of Tsukamoto fuzzy logic from sensor input according to the real-time kitchen situation so as to control smoke effectively and as needed. The results of sensor readings can be monitored directly on the LCD and LED indicators as a visual of the selected mode and the resulting speed. The working principle of this system can be seen through the block diagram of the exhaust fan control system shown in Figure 3 below.

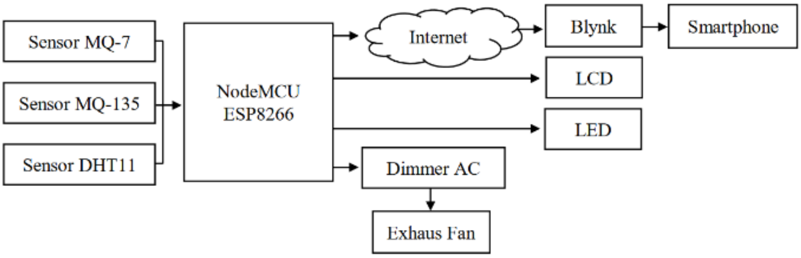

Fig. 3. Hardware Block Diagram of Exhaust Fan Control System.

2.2 Software Design

At this step, designing software on the NodeMCU that will be run through the Arduino IDE such as the implementation of Tsukamoto fuzzy logic that will use sensor data to determine the exhaust fan speed. In addition, the interface with the Blynk application allows users to monitor and control the system in real-time through a smartphone. The software design of this system is integrated with Blynk IoT software as a platform to control and monitor the sensor readings. This system integrates the MQ7 sensor for CO detection, MQ135 for smoke, and DHT11 for temperature monitoring which is connected to the NodeMCU ESP8266 microcontroller and then sends the data to the Blynk platform. Blynk acts as an IoT interface, allowing users to control and monitor the air quality in the production kitchen area. The system is also equipped with real-time notifications if sensor readings exceed a set threshold. This can be an important warning for workers to take precautions to reduce health risks associated with prolonged exposure to heat, smoke, CO gas and also keep the production kitchen environment safer and healthier.

Sensors detect smoke, temperature, and CO gas contained in the production kitchen area during the frying activity. The results of the sensor readings will be sent to Blynk IoT by the microcontroller with WiFi connectivity. The results of monitoring sensor data will be displayed on the Blynk IoT application that has been integrated with the hardware system. With Blynk IoT, workers can easily access and know the air quality in the production kitchen so that it can increase worker productivity in cracker production. The flow of software design in this exhaust fan control system can be seen in Figure 4.

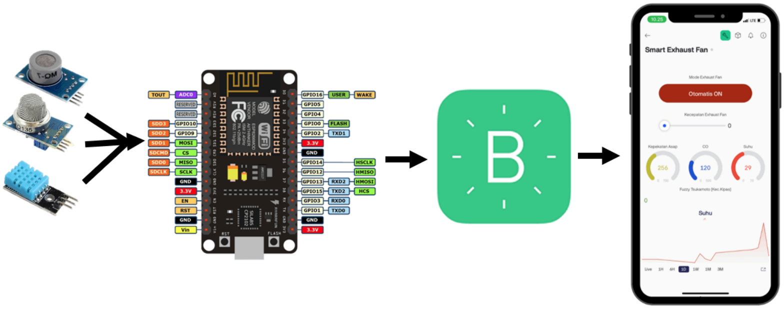

Fig. 4. Software Design Flow of Exhaust Fan Control System.

2.3 Exhaust Fan Control System Design

The system uses the Tsukamoto fuzzy algorithm to determine the rotating speed of the exhaust fan in automatic mode. This algorithm takes input from temperature, smoke, and CO sensors, and then issues fan speed PWM results based on Tsukamoto fuzzy defuzzification. The advantages of the Tsukamoto method are that it can handle imprecise data and is easy to understand [16]. This approach uses a fuzzy set with a monotonous membership function to express each rule. [17]. Additionally, it is necessary to represent each If-Then rule consequence with a fuzzy set and membership function. The result of the inference of each rule is given crisply based on a predicate, and the final result is obtained by a weighted average [18].

The first step in implementing Tsukamoto fuzzy logic as a controller in the kitchen smoke control system is fuzification by creating fuzzy sets and fuzzy membership functions for each input and output used in the system. In this system there are 3 inputs including temperature, smoke, CO gas, and 1 output, which is the rotating speed of the exhaust fan.

The temperature membership function has three input variables with each different range shown in equations (1), (2), and (3).

$$\mu \text{ cold } (x) = \{1 \ \frac{30-x}{30-25} \ 0 \ , If\ x \leq 25\,, If\ 25 \leq x \leq 30\,, If\ x \geq 30 \tag{1}$$

$$\mu \text{ normal } (x) = \{0 \ \frac{x-25}{30-25} \ 1 \ \frac{45-x}{45-40} \ , If\ x \leq 25\ atau\ x \geq 45 \ , If\ 25 \leq x \leq 30 \ , If\ 30 \leq x \leq 40 \ , If\ 40 \leq x \leq 45 \tag{2}$$

$$\mu \text{ hot } (x) = \{0 \ \frac{x-40}{45-40} \ 1 \ , If\ x \leq 40\,, If\ 40 \leq x \leq 45\,, If\ x \geq 45 \tag{3}$$

In the smoke membership function, there are three input variables with each different range shown in equations (4), (5), and (6).

$$\mu \text{ little } (x) = \{1 \ \frac{300-x}{300-200} \ 0 \ , If\ x \leq 200\,, If\ 200 \leq x \leq 300\,, If\ x \geq 300 \tag{4}$$

μ medium (x) =

$\{0 \ \frac{x-200}{300-200} \ 1 \ \frac{500-x}{500-400} \ , If\ x \le 200 \mid x \ge 500\ , If\ 200 \le x \le 300\ , If\ 300 \le x \le 400\ , If\ 400 \le x \le 500$

(5)

μ much (x) = $\{0 \ \frac{x-400}{500-400} \ 1 \ , If\ x \le 400\ , If\ 400 \le x \le 500\ , If\ x \ge 500$ (6)

In the CO membership function, there are three input variables with each different range shown in equations (7), (8), and (9).

μ low (x) = $\{1 \ \frac{200-x}{200-150} \ 0 \ , If\ x \le 150\ , If\ 150 \le x \le 200\ , If\ x \ge 200$ (7)

μ medium (x) =

$\{0 \ \frac{x-150}{200-150} \ 1 \ \frac{350-x}{350-300} \ , If\ x \le 150 \mid x \ge 350\ , If\ 150 \le x \le 200\ , If\ 200 \le x \le 300\ , If\ 300 \le x \le 35$

(8)

μ high (x) = $\{0 \ \frac{x-300}{350-300} \ 1 \ , If\ x \le 300\ , If\ 300 \le x \le 350\ , If\ x \ge 350$ (9)

In the exhaust fan membership function, there are three input variables with each different range shown in equations (10), (11), and (12)

$\mu\, pelan\ (x) = \{1 \ \frac{59-x}{59-57} \ 0\ , x \le 57\ , 57 \le x \le 59\ , x \ge 59$ μ slow (x) = $\{1 \ \frac{59-x}{59-57} \ 0 \ , If\ x \le 57\ , If\ 57 \le x \le 59\ , If\ x \ge 59$ (10)

μ medium (x) =

$\{0 \ \frac{x-57}{59-57} \ 1 \ \frac{71-x}{71-69} \ , If\ x \le 57 \mid x \ge 71\ , If\ 57 \le x \le 59\ , If\ 59 \le x \le 69\ , If\ 69 \le x \le 71$

(11)

μ fast (x) = $\{0 \ \frac{x-69}{71-69} \ 1 \ , If\ x \le 69\ , If\ 69 \le x \le 71\ , If\ x \ge 71$ (12)

After fuzification, the next step is to generate a fuzzy rule base which is based on the conditions needed in the cracker production kitchen. This rule is used in determining the value of each condition that meets the predetermined rules. The rule base that has been created based on the needs of the production kitchen conditions is shown in Table 1 below.

Table 1. Fuzzy Rules.

No	Fuzzy Rules
1	If temperature_cold AND smoke_little AND gas_low THEN fan_slow
2	If temperature_cold AND smoke_little AND gas_medium, THEN fan_slow
3	If temperature_cold AND smoke_little AND gas_high THEN fan_medium
4	If temperature_cold AND smoke_medium AND gas_low THEN fan_slow
5	If temperature_cold AND smoke_medium AND gas_medium THEN fan_medium
6	If temperature_cold AND smoke_medium AND gas_high THEN fan_fast

7	If temperature_cold AND smoke_much AND gas_low THEN fan_fast
8	If temperature_is_cold AND smoke_much AND gas_medium THEN fan_fast
9	If temperature_cold AND smoke_much AND gas_high THEN fan_fast
10	If temperature_normal AND smoke_little AND gas_low THEN fan_slow
11	If temperature_normal AND smoke_little AND gas_medium THEN fan_medium
12	If temperature_normal AND smoke_low AND gas_high THEN fan_fast
13	If temperature_normal AND smoke_medium AND gas_low THEN fan_medium
14	If temperature_normal AND smoke_medium AND gas_medium THEN fan_medium
15	If temperature_normal AND smoke_medium AND gas_high THEN fan_fast
16	If temperature_normal AND smoke_much AND gas_low THEN fan_fast
17	If temperature_normal AND smoke_much AND gas_medium THEN fan_fast
18	If temperature_normal AND smoke_much AND gas_high THEN fan_fast
19	If temperature_hot AND smoke_little AND gas_low THEN fan_medium
20	If temperature_hot AND smoke_little AND gas_medium THEN fan_fast
21	If temperature_hot AND smoke_little AND gas_high THEN fan_fast
22	If temperature_hot AND smoke_medium AND gas_low THEN fan_fast
23	If temperature_hot AND smoke_medium AND gas_medium THEN fan_fast
24	If temperature_hot AND smoke_ medium AND gas_high THEN fan_fast
25	If temperature_hot AND smoke_much AND gas_low THEN fan_fast
26	If temperature_hot AND smoke_much AND gas_ medium THEN fan_fast
27	If temperature_hot AND smoke_much AND gas_ high THEN fan_fast

The last step in implementing Tsukamoto fuzzy as an exhaust fan controller is to define the exhaust fan rotating speed output based on the defuzification results of Tsukamoto fuzzy logic. The results of the fuzzy inference generated in the fuzzy set will be converted to a real number (crisp set) in the defuzification stage of the fuzzy logic system [19]. In the Tsukamoto method, the defuzzification method used is the Center Average Defuzzier [17].

$$Z = \frac{\Sigma xi \cdot \alpha i}{\Sigma \alpha i},\ i = 1, 2, 3, \ldots \qquad (13)$$

3 Results

The exhaust fan control system is designed using Blynk as the control interface for the fan rotation speed. It can be controlled manually or automatically using Tsukamoto Fuzzy logic. The system hardware is connected to the Blynk software to monitor and control temperature, smoke, and CO sensor data in a cracker production kitchen. The system also includes a notification system. System testing was conducted during frying activities in the cracker production kitchen for 2 hours, and the test results are shown in the following Table 2.

Table 2. Table captions should be placed above the tables.

No	Temperature	Smoke	Gas CO	Z Calculation (Zi)	Z Testing (ZI)
1	52	400	405	71	70,9
2	52	398	405	71	70,923
3	52	397	405	71	70,909
4	53	398	405	71	70,909
5	53	397	405	71	70,909
6	53	397	404	71	70,923
7	52	396	403	71	70,942
8	52	397	404	71	70,923
9	52	396	403	71	70,942
10	52	397	404	71	70,923
11	52	396	404	71	70,923
12	52	397	403	71	70,923
13	51	434	249	70,1024	70,051
14	52	435	250	70,09	70,1
15	52	436	252	70,0784	70,1
16	52	435	250	70,09	70,051
17	52	434	249	70,1024	70,1
18	52	433	248	70,1156	70,051
19	51	432	248	70,1296	70,051
20	51	430	248	70,16	70,051
21	51	432	248	70,1296	70,051
22	50	430	248	70,16	70,051
23	50	432	249	70,1296	70,051
24	50	429	248	70,1764	70,051
25	50	428	247	70,1936	70,052
MAPE					0,09
System Accuracy					99,91

Table 2 presents the exhaust fan rotational speed control system test data derived from temperature, CO, and smoke sensor readings. This test was carried out by taking 25 data with 4 times testing the system within 2 hours. The test results show that the fan rotation speed generated by Tsukamoto fuzzy logic is varies based on the sensor readings in the production kitchen area, so that it can be more effective in controlling and reducing kitchen smoke generated by frying activities.

This exhaust fan control system has a monitoring feature that is used to monitor the readings of temperature, smoke, and CO sensors generated by the cracker production kitchen environment. The system monitoring results can be seen in Figures 5, 6, and 7.

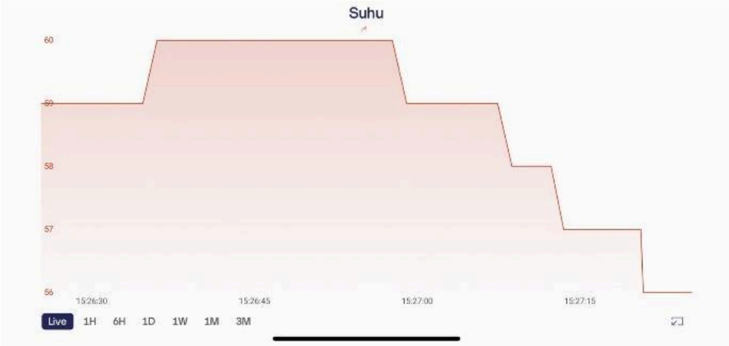

Fig. 5. Temperature Monitoring Results.

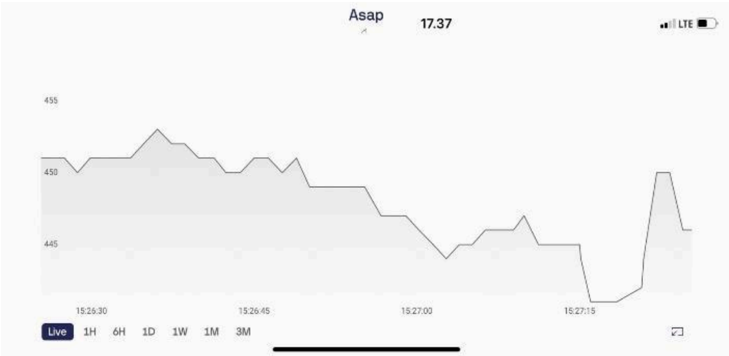

Fig. 6. Smoke Monitoring Results.

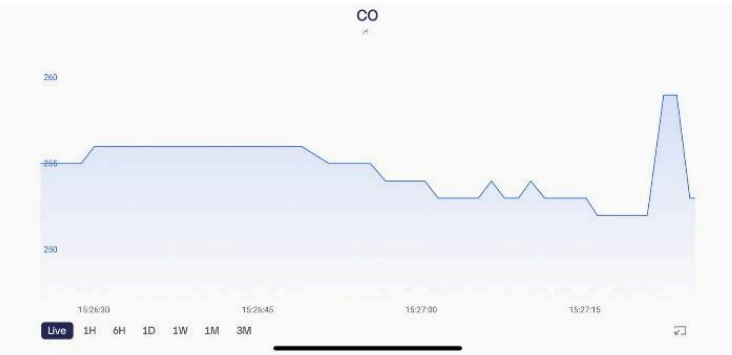

Fig. 7. Gas CO Monitoring Results.

The exhaust fan speed control system includes a notification feature to alert users during operation. This notification system provides both informational and warning notifications. When the system is activated for the first time, the Blynk software will send an informational notification in the form of text to indicate that the exhaust fan system is ready for use. This informational notification is depicted in Figure 8.

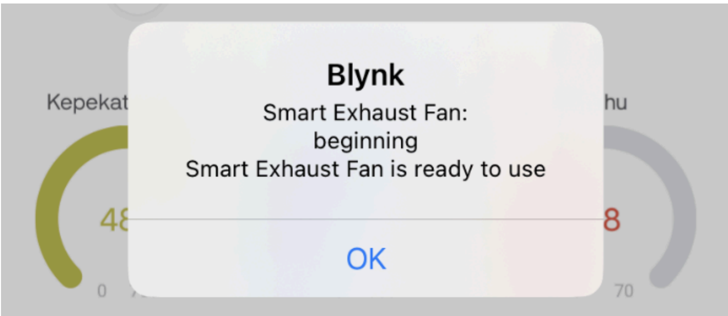

Fig. 8. Exhaust Fan System Initial Notification.

Switching the exhaust fan control system mode will also trigger a notification when changing the selected exhaust fan control mode. A notification of the exhaust fan control system mode switching can be seen in Figure 9 and 10 below.

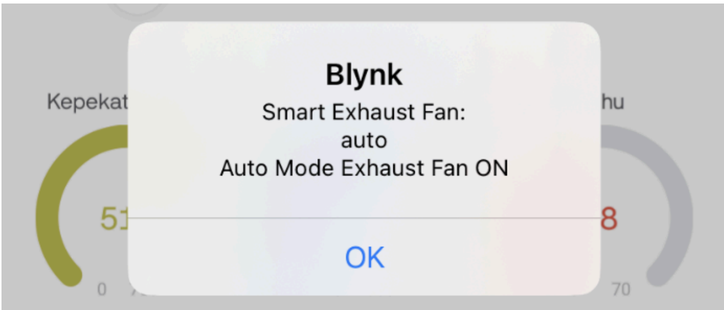

Fig. 9. Exhaust Fan System Auto Mode Notification.

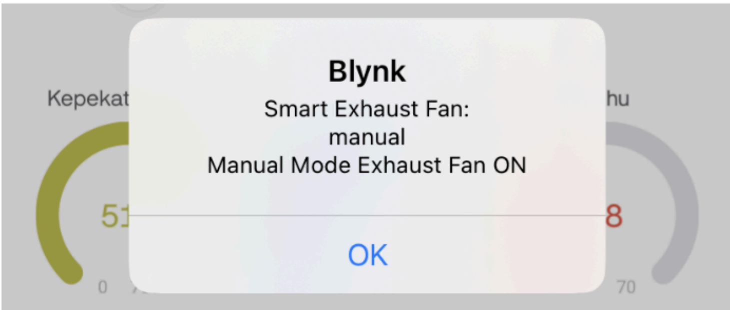

Fig. 10. Exhaust Fan System Manual Mode Notification.

The exhaust fan rotational speed control system is also equipped with warning notifications designed to alert the user when sensor readings detect temperature, smoke, and CO exceeding predetermined reasonable thresholds. There are 3 types of warning notifications with each warning notification for hot temperature, kitchen smoke thickness, and high dangerous CO gas.

This alert notification will be sent in real-time by Blynk IoT when the sensors used in the kitchen smoke control system detect smoke thickness, harmful CO gas, and high kitchen ambient temperature during cracker frying activities.

With the warning notification given by Blynk IoT when the sensor reading reaches a threshold, it can be used as a notification to workers to stay alert by taking preventive and mitigating actions in making the production kitchen area safe, comfortable, and reducing health risks by increasing productivity and effectiveness during cracker production. Figures 11, 12, and 13 show various warning notifications based on temperature, smoke, and CO values in this exhaust fan control system.

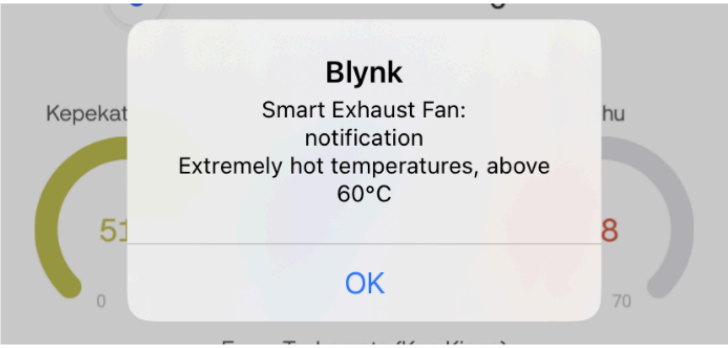

Fig. 11. Temperature Value Alert Notification.

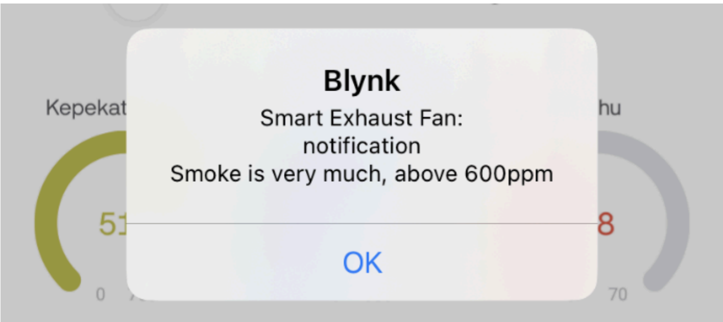

Fig. 12. Smoke Value Alert Notification.

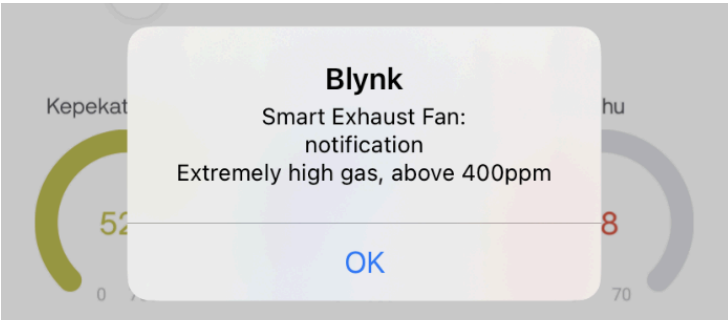

Fig. 13. Gas CO Value Alert Notification.

4 Discussion

The IoT-based exhaust fan speed control system allows for the manual or automatic control of fan rotation speed using Tsukamoto fuzzy logic based on temperature, smoke, and CO sensor readings. This is achieved through the Blynk application. In the Blynk application, the fan's rotational speed can be manually controlled by directly inputting the speed in the range of 1 to 3. Alternatively, the fan's rotational speed can be automatically controlled by selecting the automatic mode in the Blynk application. In automatic mode, the fan rotation speed is controlled based on fuzzy logic with inputs from temperature, smoke, and CO sensors in the cracker production kitchen environment. Testing the automatic mode with Tsukamoto fuzzy logic resulted in varying fan rotational speeds according to environmental conditions in the production kitchen. The 2-hour test, consisting of 25 test data and four trials, revealed that the system had an accuracy of 99.93% with an average absolute error percentage of 0.07%. This indicates that the exhaust fan control system can effectively operate based on the existing kitchen environmental conditions.

This system is also equipped with an IoT-based monitoring and notification system that will make it easier for workers to understand the conditions in the production kitchen environment and increase worker efficiency. The monitoring system through Blynk can monitor the reading results of temperature, smoke, and CO sensors that will be displayed through a smartphone. The notification system designed through Blynk IoT can also make it easier for workers to know the level of temperature, smoke, and CO contained in the air in the cracker production kitchen. Blynk will send a notification to alert if the sensor reading value detects the temperature, smoke, and CO value exceeding the specified set points.

5 Conclusions

There are two ways to regulate the exhaust fan speed control system: manually and automatically through the Blynk IoT application. Implementing IoT in this exhaust fan control system can facilitate users in using and controlling the exhaust fan directly so that it is more efficient, and workers can spend more time using the tool. This control system can help workers control the condition of the cracker production kitchen against changes in temperature, smoke, and CO in real-time. With the monitoring system and notification system provided, workers can easily monitor and know the results of temperature, smoke, and CO sensor readings to increase workers' effectiveness in producing crackers.

In the future, the real-time smart exhaust fan control will be developed using YOLO (*You only look once*).

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