Implementation of an IoT-based Threshold Method for a Food Hazardous Substance Detection Tool

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***Abstract*— Food safety is a critical issue that has a direct impact on public health. Illegal addition of hazardous substances such as rhodamine B, melachite green, methanyl yellow, formalin, borax, and sodium hypochlorite are still commonly found in food products sold in the market. This research project aims to develop a tool for detecting hazardous substances in Internet of Things (IoT) based foods using a threshold method that refers to BPOM regulations. The threshold method refers to BPOM regulations. This system integrates two sensors: The TCS3200 sensor is used for RGB color analysis, and the HCHO sensor detects volatile compounds detecting volatile compounds. Test results show that this tool achieves 96.67% accuracy in identifying hazardous substances without producing false positives. The novelty of this research lies in combining both sensors into one system with real-time notification via Telegram. This research is novel because it combines both sensors into one system with real-time notifications via Telegram. It combines both sensors into a single system with real-time notifications via Telegram and ThingSpeak.**

Keywords*— Internet of Things, HCHO Sensor, TCS3200 Sensor, Threshold, Hazardous Substances.

I. INTRODUCTION

Food safety is a major concern because contaminated food can cause serious illness. The Food and Drug Administration (BPOM) has banned hazardous substances such as rhodamine B, methanyl yellow, malachite green, formalin, borax, and sodium hypochlorite due to their toxic effects on the human body [1],[2]. Therefore, many manufacturers prefer synthetic dyes because they are more economical, easier to apply, and more color stable than natural dyes [3]. Formalin and boric acid are examples of prohibited food additives in the preservative group, as stipulated in Regulation No. 33 of 2012 by the Minister of Health of the Republic of Indonesia concerning Food Additives (BTP) [4]. A qualitative test of ten samples of white tofu revealed the presence of borax and formalin. This indicates that the use of hazardous substances in food products remains a serious issue that requires further attention [5].

Previous studies have typically only detected one type of hazardous substance with a single sensor. This study introduces a new system that combines color and gas sensors with the BPOM threshold method and real-time IoT communication to overcome the limitations of multi-substance detection in previous [6],[7] studies used a single sensor to detect formaldehyde and TCS3200 based tools for detecting synthetic dyes [8]. This research makes an original contribution by designing an integrated detection system that uses HCHO and TCS3200 sensors to detect six types of hazardous substances in food based on color and content levels. The system uses a threshold method calibrated according to BPOM standards to determine the contamination hazard level. Sensor readings are processed through a simple classification threshold to determine if a substance is "safe" or "hazardous." When a substance exceeds the threshold, the system sends real-time notifications via the Telegram app and displays cloud-based data visualization using ThingSpeak. Thanks to multi-sensor integration, regulation-based threshold methods, and real-time notification and monitoring capabilities, this system uses IoT technology to help detect hazardous substances in food.

II. METHODOLOGY

A. Research Flowchart

This research flowchart is presented in the form of a flowchart to illustrate the entire research phase. This diagram is very important because it shows the steps that need to be taken during the planning phase in order for each level to be properly implemented.

Figure 1. Research Flowchart

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Figure 1 illustrates the seven main stages of this research: literature study, hardware and software preparation, system integration, system testing, data collection, data analysis, and conclusion drawing. The literature review aims to examine theories and previous studies related to sensors, the Internet of Things (IoT), and threshold methods. Next is the preparation of the hardware, which includes the TCS3200 sensor, HCHO sensor, ESP32, buzzer, LED, and power supply, as well as the software, which includes the Arduino IDE, the Telegram Bot library, and the ThingSpeak library. Integration combines the hardware and software to create a functioning system. The system is then tested to verify sensor function and data connectivity. Data is taken from sensor readings and notifications are generated. An analysis is performed to evaluate the system's accuracy. The final stage is drawing conclusions based on the analysis results and the system's overall performance.

B. Hardware Design

Syukri and Mukhaiyar designed a formaldehyde detection device using the HCHO sensor and NodeMCU ESP32, although the device is less accurate at low levels [7]. In this study, the system consists of a TCS3200 color sensor to read RGB values and an HCHO sensor to measure chemical content levels. The ESP32 microcontroller acts as a processing center because it has advantages in accuracy and power efficiency over other microcontrollers [9]. ESP32 can send data The reading results are sent to Telegram via a WiFi connection.

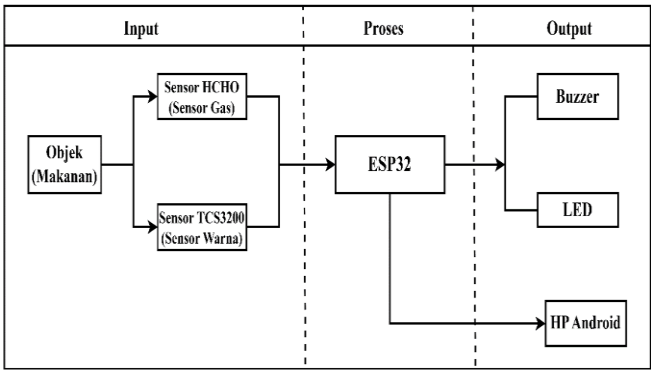

Figure 2: Hardware Block Diagram

Figure 2 shows the block diagram of the Internet of Things (IoT)-based food hazard detection system. Prayitno et al. developed an ESP32-based alcohol level detection system that transmits real-time data to Telegram. The system is divided into three main parts: input, processing, and output. The input section analyzes objects in the form of food samples using two types of sensors: the HCHO sensor detects formaldehyde gas content, and the TCS3200 color sensor reads RGB values that can indicate the presence of hazardous materials based on the typical color of certain chemicals.

Data from both sensors is sent to the ESP32, which acts as the processing center in the process section. The microcontroller processes the sensor data using the threshold method and determines whether the substance content is above the safe threshold. In the output section, the ESP32 activates the buzzer and LED indicators if dangerous substances are detected. Additionally, the detection results are sent in real time to an Android smartphone via the Telegram application, enabling users to monitor conditions remotely with an internet connection.

C. Threshold Method

Thresholding is a simple yet effective image segmentation technique in which a threshold value classifies pixels as background or object based on intensity or color [10]. Threshold method is used to determine the safety limit according to the ppm (parts per million) value. This threshold is determined according to BPOM Regulation No. 22 of 2023, which establishes a limit of 0 ppm for these hazardous substances [2]. The TCS3200 color sensor identifies the presence of dyes, such as Rhodamin B and Methanyl Yellow, based on captured RGB values. The HCHO sensor detects formalin and sodium hypochlorite compounds with high volatility [11].

TABLE I. HAZARDOUS SUBSTANCE THRESHOLDS BASED ON BPOM

No	Hazardous Substances in Food	Threshold (Ambang batas)	Category	Harmful/Not Harmful
1	Rhodamin B	0 ppm (Prohibited in food)	Harmful synthetic colorant	Harmful.
2	Methanyl Yellow	0 ppm (Prohibited in food)		Harmful.
3	Melachite Green	0 ppm (Prohibited in food)		Harmful
4	Formalin	0 ppm (Prohibited in food)	Preservative	Harmful
5	Boraks	0 ppm (Prohibited in food)	Chewy & Preservative	Harmful
6	Natrium Hipoklorit	0 ppm (Prohibited in food)	Bleaching agent	Harmful

The table above shows a list of some hazardous chemicals that are banned from use in food according to Food and Drug Administration (BPOM) regulations. Each substance has a threshold value of 0 ppm, which means its presence in food is not allowed at all. These substances include harmful synthetic dyes such as Rhodamin B, Methanyl Yellow, and Melachite Green; preservatives such as Formalin and Borax; and the bleaching agent Sodium Hypochlorite. All of these substances are categorized as hazardous because they can cause toxic, mutagenic, and carcinogenic effects if consumed by humans, even in small amounts. Therefore, the detection system is designed to recognize the presence of these substances even in low concentrations, and classify the measurement results as dangerous if the detection value is above or equal to 0 ppm.

D. Testing and Calibration

In previous research conducted by Siti F. Azzahra produced

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an IoT and Android-based tool with HCHO, MQ-3, and TCS3200 sensors capable of detecting food chemicals with 87% accuracy, although it requires recalibration [12]. Darmayanti et al. also conducted research using an IoT-based smart nose to detect preservatives such as formalin with high accuracy [13]. In this study, testing was carried out by mixing food samples with the following hazardous substances: Rhodamin B, Melachite green, Methanyl Yellow, Formalin, Borax, and Sodium Hypochlorite, each in several concentrations. A total of 10 samples were used, consisting of 6 containing hazardous substances and 4 control samples without additives. Each sample was tested 15 times to ensure consistency of readings, although only one representative value was recorded. The sensor data was calibrated and compared to the BPOM threshold reference values to assess the accuracy of the device.

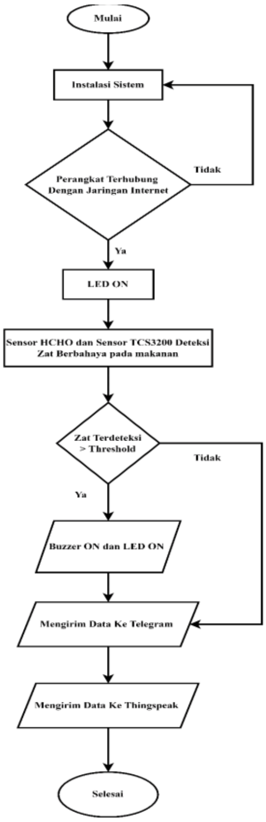

Figure 3. Software Flowchart

Figure 3 shows the flowchart of the Internet of Things (IoT)-based hazardous substance detection system. The process begins with the system installation stage which includes hardware and software configuration. Next, the system verifies the internet connection. If the device is not connected, the system will repeat the installation process. However, if the connection is successful, the indicator LED will light up to indicate that the system is ready for use.

Once the connection is active, the system will activate the HCHO sensor for harmful gas detection and the TCS3200 sensor for color analysis. The sensors will read the parameters of the food object, and then the readings will be compared with. is a predetermined threshold. If the detected value exceeds the threshold (≥ 0 ppm), the system classifies the substance as hazardous the substance as dangerous. The system is also equipped with a buzzer as a alarm when the detected gas concentration exceeds the preset threshold based on the based on the threshold method [7]. The system will then automatically send the detection result data to the Telegram application, and displays the graph in ThingSpeak on the user's Android device. If no harmful substances are detected, the system will return to the monitoring mode. The main goal of the Internet of Things (IoT) is to create an ecosystem in which devices can communicate, share information, and coordinate actions to improve efficiency and to improve efficiency and quality of life [14].

III. RESULTS AND ANALYSIS

The developed tool is able to identify all samples containing harmful substances and accurately distinguish them from samples that are safe. Are safe. The HCHO sensor can detect the level of hazardous substances in food down to a concentration of down to a concentration of 3 ppm, while the TCS3200 sensor measures RGB values that are converted to converted to detect the color characteristics of hazardous substances.

A. Hardware Design Results

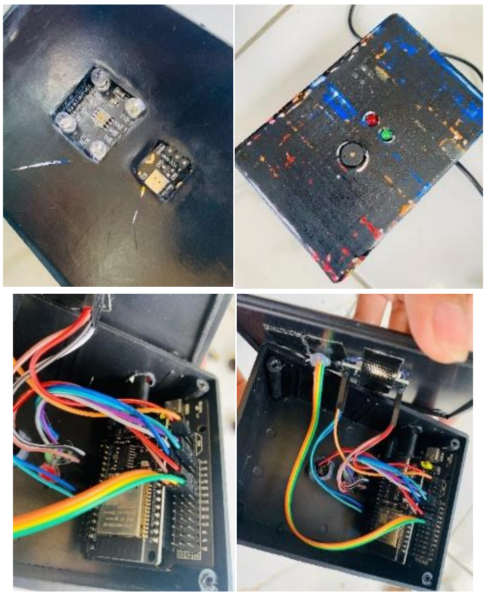

Figure 4: Hardware Design Results

This figure illustrates the device's internal and external appearance, including the sensors and microcontroller. The top view shows the user interface, which contains buttons and LED indicators. The inside houses the ESP32 microcontroller and sensor connections. At the bottom, the TCS3200 and HCHO sensors are attached to detect the color of synthetic dyes and the concentration of formaldehyde in food samples, respectively.

B. Software Suite Results

1) Telegram Notification

Notifications were successfully sent via Telegram in real

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time when the level exceeded the threshold. This allows users to receive immediate information to take preventive measures. The figure below shows a notification that appears in Telegram when harmful substances are detected in the food in Table 2.

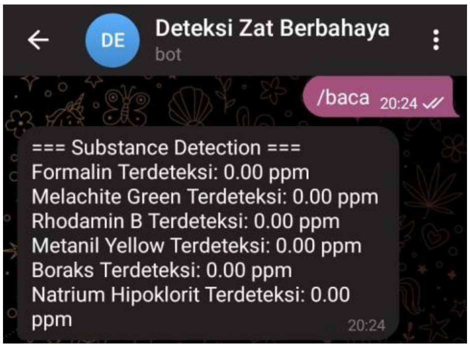
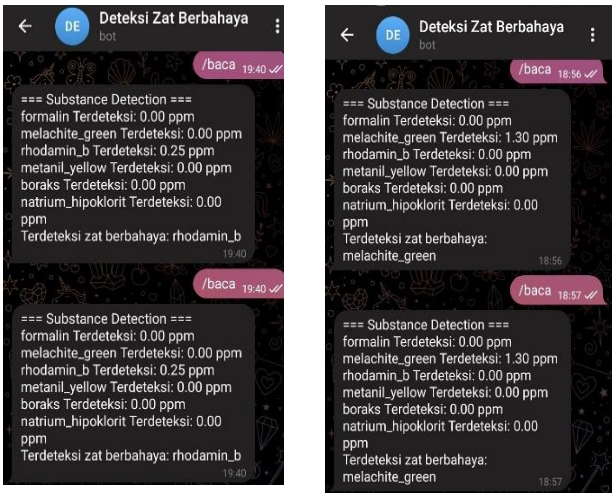


Figure 5. The safe food notification is displayed on the Telegram application

Figure 5 shows a notification sent by the system to the Telegram app on an Android device. This notification appears after the user sends the /read command to the Hazardous Substance Detection bot. The system then responds by displaying the detection results for six types of hazardous substances: Rhodamine B, Methyl Yellow, Malachite Green, Formalin, Borax, and Sodium Hypochlorite. The detected levels are displayed in parts per million (ppm). In the example shown, all hazardous substances were detected at 0.00 ppm, meaning no hazardous substances were found in the tested food samples. This display provides users with quick, real-time information to ensure food safety. Kurniawan [15]. has proven the effectiveness of using Telegram Bot as a chemical monitoring system. Meanwhile, food containing harmful substances will appear as shown below:



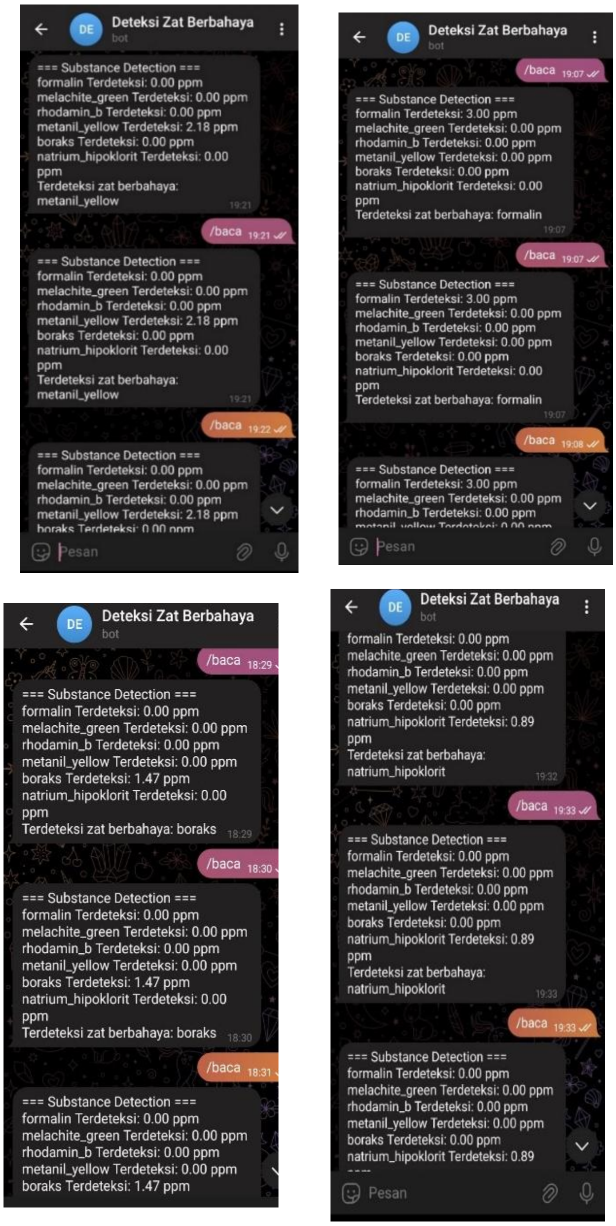


Figure 6. Telegram Notification Results Display Warning of Dangerous Substances

2) Thingspeak Notification

The Thingspeak notification is a graph showing the results of experiments carried out. Each sample type was tested 15 times and found to contain harmful substances: agar containing Rhodamine B, kojo cake containing Malachite Green, Mi Kuning containing methylene yellow and formalin, and vermicelli containing borax and sodium hypochlorite. Figure 7 below shows the graph of the experimental results:

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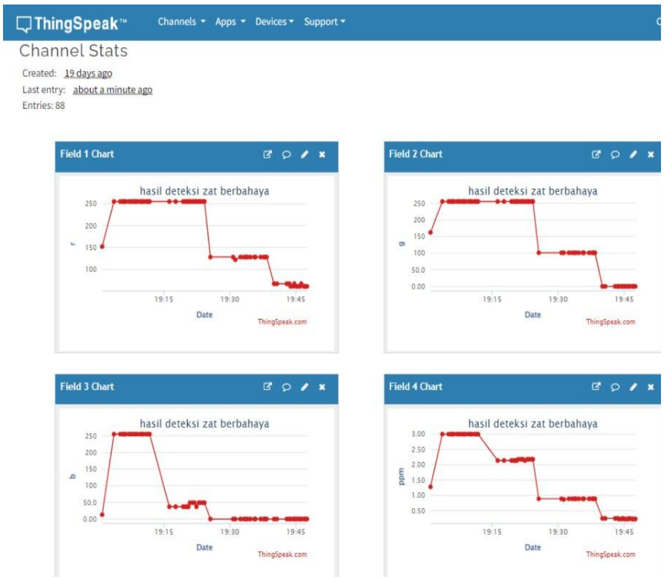

Figure 7. Graphical Result Display of Thingspeak Hazardous Substance Warning

C. *Tool Testing Results*

Several types of food samples were tested to detect the presence of hazardous substances using the designed tools. Each sample type was tested 15 times to ensure consistent results, and the most frequent value was used for the final representation. Parameters observed include the type of hazardous substance detected; the color value in RGB format from the TCS3200 sensor; the substance concentration value in parts per million (ppm), obtained from conversion results; and a description of the presence of hazardous substances, based on the threshold determined by BPOM.

TABLE II. TEST RESULTS OF DETECTION OF HAZARDOUS SUBSTANCES IN EACH FOOD SAMPLE

Name Of Food Sample	Hazardous Substances in Food	R, G, B Result	PPM Value	Information
Kue Kojo	–	–	0,00	Not Harmful
Bihun	–	–	0,00	Not Harmful
Mi Kuning	–	–	0,00	Not Harmful
Agar-agar	–	–	0,00	Not Harmful
Agar-agar	Rhodamin B	(67, 0, 0)	0,25	Harmful
Kue Kojo	Melachite Green	(158, 162, 13)	1,30	Harmful
Mi Kuning	Methanyl Yellow	(255, 255, 49)	2,18	Harmful
Mi Kuning	Formalin	(255,255,155)	3,00	Harmful
Bihun	Boraks	(183, 155, 37)	1,47	Harmful
Bihun	Natrium Hipoklorit	(128, 101, 0)	0,89	Harmful

Table II shows the test results for ten food samples. Four of the samples (Kojo Cake, Vermicelli, Yellow Noodles, and Agar Agar) showed no hazardous substances in several tests. This is indicated by RGB values that did not change significantly and a ppm value of 0.00. These results indicate that the samples are safe and do not contain hazardous materials. However, other tests of the same samples revealed hazardous substances with significant RGB and ppm values. For example:

- Agar showed rhodamine B with an RGB value of (67, 0, 0) and a concentration of 0.25 ppm, indicating the presence of harmful textile dyes.
- Kojo Cake contained Malachite Green, with an RGB value of (158, 162, 13) and a concentration of 1.3 ppm. Malachite Green is a hazardous industrial dye.
- Yellow noodles were found to contain methanyl yellow and formalin with concentrations of 2.18 and 3.00 ppm, respectively, indicating a potential toxic risk.
- Vermicelli was found to contain borax and sodium hypochlorite, with ppm values of 1.47 and 0.89, respectively. Both of these chemicals are hazardous if consumed.

This section discusses the system's accuracy, demonstrating that it achieved a score of 96.67%. A comparative analysis was conducted on four food samples and six substances, with each sample tested 15 times. Three tests failed due to improper sensor placement and network interference. These tests were based on BPOM thresholds. This section emphasizes the importance of real-time notifications via Telegram and ThingSpeak to facilitate preventive action. The results of this study were compared with those of previous research, which achieved a maximum accuracy of 87%. This highlights the improvement of the current system. F. Azzahra's [12]{Formatting Citation} research used the same method, but it had lower accuracy and did not integrate multiple sensors. Therefore, this study's results demonstrate the device's ability to distinguish between safe and unsafe samples based on color detection and conversion of ppm values from the sensor using the threshold method.

IV. CONCLUSION

A food hazardous substance detection system based on the Internet of Things (IoT) and using a threshold method has been successfully developed and implemented. This study makes a novel contribution by integrating two types of sensors (HCHO and TCS3200) into a single system that can detect up to six types of hazardous substances in food. The system detects substances based on color and concentration levels measured in parts per million (ppm) according to BPOM standards.

Test results showed the system achieved an accuracy rate of 96.67%, with an error rate of approximately 3%, due to limitations in sensor precision and network instability during testing. This system also features real-time notifications via Telegram and ThingSpeak, distinguishing it from previous studies that mostly focused on detecting a single substance without automated alerts. Other advantages of this system include ease of use, low cost, and real-time monitoring capability. Future work is recommended to enhance the system by adding the ability to detect more types of hazardous

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substances and by integrating artificial intelligence technologies to improve classification accuracy and enable automated decision-making based on sensor data.

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