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The Implementation of a Cooling and Storage System for Bakpia Pathok Based on IoT Technology (Case Study: Bakpia Pathok 79)

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ABSTRACT

Bakpia Pathok 79, a food product made from flour, has a short shelf life and faces challenges in maintaining quality due to inadequate storage and conventional cooling methods. This study aims to design a temperature control and spoilage detection system for Bakpia Pathok 79 using gas sensors and the DHT-22 temperature sensor. Over a 6-day test period, results indicated that bakpia is best consumed immediately after cooling and remains optimal until the fourth day. In showcase 1, the MQ4 sensor detected methane levels below 195 ppm, and the MQ3 sensor detected ethanol levels below 300 ppm. In showcase 2, the MQ4 readings were below 200 ppm, and the MQ3 readings were below 260 ppm. The highest temperature of bakpia before cooling was 32°C, stabilizing at 29°C within 7 minutes. The system connects to an Android application for real-time temperature monitoring and spoilage detection, providing notifications when the bakpia is ready for packaging. Test results show the system is effective in detecting spoilage and accurately monitoring temperature.

Keywords: *Bakpia Pathok, Freshness Food Detection, Android Application, Temperature, Gas*

1. INTRODUCTION

Bakpia is a food product that is an acculturation of Chinese snacks and has survived for decades to become an icon of the city of Yogyakarta [1]. Bakpia Pathok 79 is an example of a food product made from flour with a short shelf life, facing challenges in maintaining its quality. Food products and their production processes have specific characteristics that affect product quality and assurance during production [2].

When cooling bread in the bakery section with an air temperature of about 26.0±1.0°C, the final temperature of the bread reaches 26°C. This condition supports the growth of Bacillus bacteria, which can cause the bread to become brittle [3]. When bakpia comes out of the oven at a temperature of around 90 degrees, it takes more than an hour to cool to the appropriate temperature for packaging, which is around 35 degrees. In those factors, we will find ways to regulate the optimal humidity and temperature for storing bakpia. Generally, foods like bread are stored at room temperature and will last approximately 3 days, but if stored at temperatures below 10 degrees, they can last more than 10 days [4].

To maintain product quality, it's essential to have storage that can detect food spoilage processes and extend the shelf life of bakpia using the Internet of Things (IoT) [5]. The concept of the "Internet of Things" aims to enhance the benefits of constant internet connectivity, as well as the capacity to manage and share data. This idea is typically used in various industries that require continuous data information, including monitoring or control [6]. The IoT system can detect early signs of bakpia's suitability by detecting gases produced during spoilage. This study aims to develop a temperature control and early spoilage detection system for Bakpia Pathok. The proposed system includes a showcase that allows users to control storage via a smartphone and detect spoilage in bakpia. The showcase will be equipped with a DHT22 sensor to measure temperature, and several gas sensors such as MQ4 to measure methane levels and MQ3 to measure ethanol levels. Additionally, a cooling fan will be used during the bakpia cooling process, which can also be controlled via smartphone by the user. These tools aim to maintain the specific characteristics that affect product quality and assurance during production. Furthermore, a website will be provided to help consumers easily monitor the quality of the bakpia [7].

2. LITERATURE REVIEW

2.1 An IoTML Based Food Freshness Detection System

This system [6] to conduct food quality control by creating a device that can detect food spoilage using MQ2 and MQ135 sensors, and utilizes IDE and SQLYOG as its platforms. The sensors developed in this research can detect gases such as carbon monoxide (CO), ammonia (NH3), and benzene (C6H6). The primary gas sensors used are MQ2 and MQ135. These sensors detect gases like benzene, ammonia, and carbon monoxide when food is spoiled. In this study, MQ3 and MQ4 sensors will also be used to detect ethanol and methane gases, along with a temperature sensor that can be monitored through an application and website.

2.2 Design and Development of IoT-Based Temperature and Humidity Control System for Rice Storage

Focuses on an IoT-based temperature and humidity control device for rice storage [8] The device uses a DHT22 sensor for temperature and humidity detection and a cooling fan to regulate heat, with data displayed on a 16x2 LCD screen. The project aims to develop, test, and assess the device's feasibility through a design and build approach, including needs analysis, device assembly, evaluation, and revision. It employs an ESP32 microcontroller, relays for controlling lights and the cooling fan, and a Kodular-built application with Firebase for remote monitoring. Functional testing resulted in a 100% component functionality score and a 91% usability score, classifying the device as "Very Suitable." The device assists rice entrepreneurs in maintaining rice quality by measuring temperature and humidity and enabling remote monitoring via an IoT application. Future enhancements will include adding methane and ethanol gas sensors for spoilage detection and expanding monitoring capabilities via an application and website.

2.3 Prototype of Temperature and Humidity Monitoring Device for Oyster Mushroom House Based on IoT

A system for an oyster mushroom cultivation house was developed [9] using a DHT22 sensor to detect temperature and humidity, with data transmitted to a NodeMcu ESP8266 microcontroller for IoT monitoring via Thing Speak. A relay controls the Ultrasonic Mist Maker and Peltier Cooling Kit, maintaining ideal conditions based on the mushrooms' age. An LCD screen displays real-time conditions, and a DC fan helps distribute water vapor evenly. This system provides precise control over the environment, ensuring optimal mushroom growth. Users can access this data via a wireless network or website to monitor mushroom quality.

3. METHODS

3.1 Study Area

This research was conducted at Bakpia Pathok 79, a home-based business located in Sukorejo Wetan, Rejotangan, Tulungagung. Bakpia Pathok 79 was chosen after a survey revealed several challenges hindering its growth.

3.2 Research Design

The stages of this research involve research and development, referring to a process used to develop and test what is known as "research-based development." [10]. This approach involves systematic steps: identifying and analyzing the problem, developing and validating the initial model, revising it, conducting preliminary testing, revising again, performing field trials, final revisions, and implementing the product. These steps ensure the model meets educational needs and is validated for successful everyday use. [11].

3.3 Block Diagram

The block diagram illustrates the showcase and display rack design for efficiently storing Bakpia Pathok. The system includes several sensors crucial for maintaining Bakpia quality. A DHT22 sensor monitors the temperature. After users set the desired temperature, the sensor reads the current temperature and uses a relay to activate a fan or heater for regulation., depending on the specified temperature [12].

In addition to temperature monitoring via the application, there is a sensor to detect spoilage in the stored Bakpia [13]. The MQ3 sensor detects ethanol gas, which indicates spoilage, and the MQ-4 sensor detects methane gas, another spoilage indicator. If any anomalies are detected, a notification is sent to the application [14].

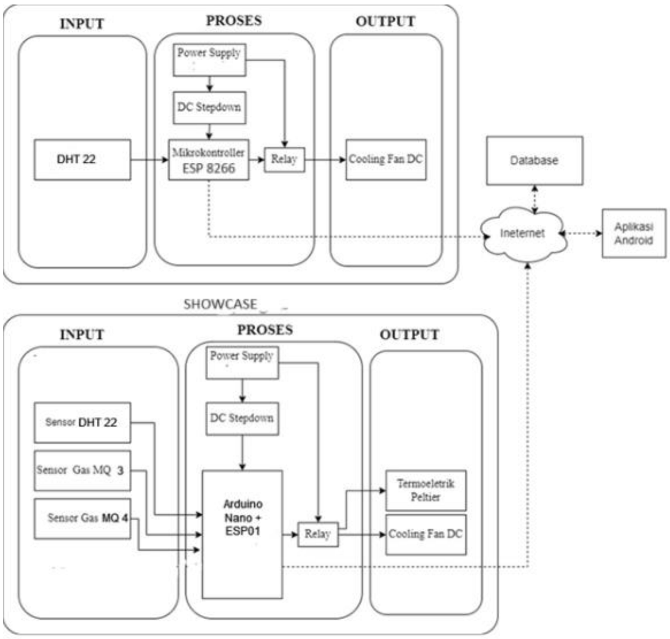


Figure 1. System Block Diagram

3.4 Flowchart Showcase

The system workflow starts with voltage input and initialization, then displays temperature and gas measurements from the DHT22 sensor. If the gas resistance meets or exceeds the threshold, it indicates Bakpia spoilage [15]. The MQ3 sensor detects spoilage via high ethanol levels, and the MQ4 sensor detects high methane levels. If gas resistance is below the threshold, the app shows “No spoilage detected.” If the temperature exceeds the threshold, the Peltier and cooling fan activate; if it's below the threshold, cooler air is used.

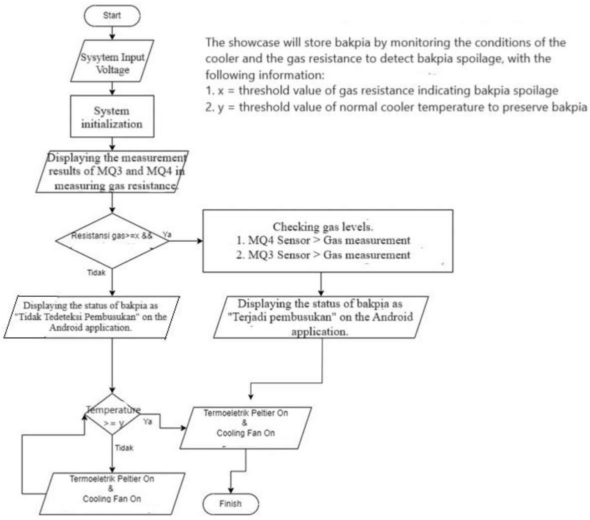


Figure 2. Flowchart Showcase

3.5 Flowchart Cooling Rack

In the cooling rack shown in Figure 3.6, the system first initializes the sensors [16]. Once the sensors detect the Bakpia temperature, the fan activates if it exceeds the set threshold, and a notification appears on the Android app. The fan turns off when the temperature returns to the desired range [17].

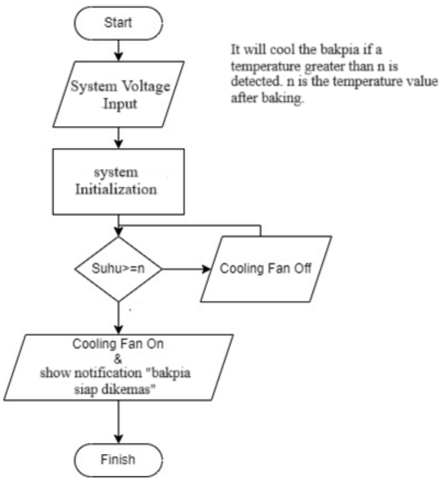


Figure 3. Flowchart Cooling Rack

4. RESULTS AND DISCUSSION

4.1 Result Software and Hardware

1. Website Interface

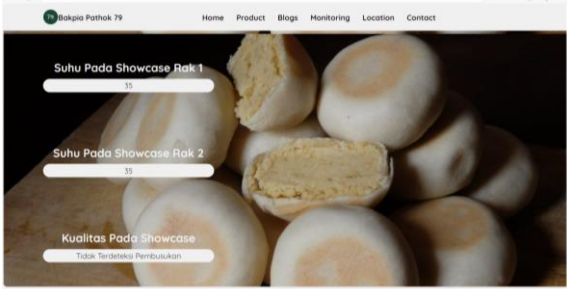


Figure 4. Monitoring Page

2. Application Interface

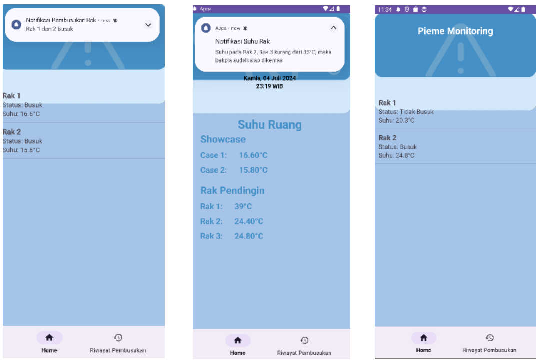
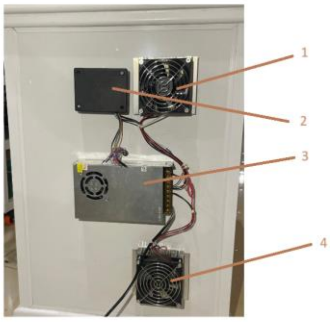


Figure 5. History in the Application Page

3. Showcase Hardware



1 . TEC kit
2. Mikrokontroller
3. Power Supply
4. TEC kit

Figure 6. Back View of the Showcase

Figure 7. showcase Rack

All components are connected to an Arduino Nano microcontroller in a showcase, including two ethanol gas sensors, two methane gas sensors, and temperature sensors. MQ3 and MQ4 sensors on each shelf detect alcohol and methane gases, respectively, indicating spoilage. DHT22 and DHT11 sensors measure temperature on different shelves. An ESP01 WiFi module sends data to a server, and a Thermoelectric Cooler helps regulate temperature in the showcase. The setup includes two DHT22 sensors, and MQ3 and MQ4 sensors on each shelf. Existing tables or figures are presented with sufficient explanations and by including numbers and titles.

4. Cooling Rack Hardware

Figure 8. Cooling Rack

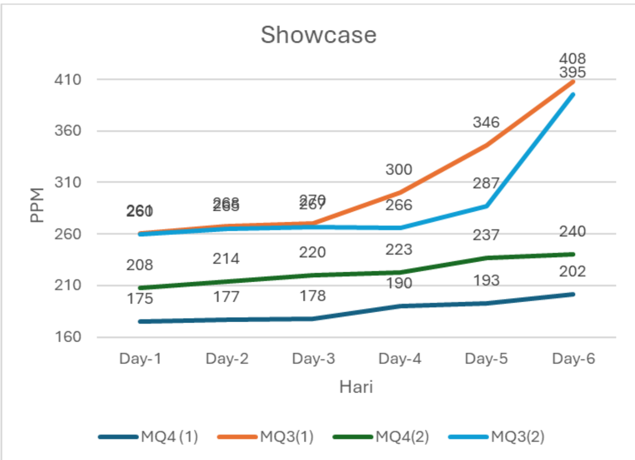
All components will be connected to an ESP8266 microcontroller. The system will be installed in a three-tiered cooling rack, each level equipped with temperature sensors. The first tier will use a DHT22 sensor, while the second and third tiers will use DHT11 sensors. These sensors measure the temperature on each rack. Based on the detected temperature, the system controls fans on each rack. Each rack is equipped with two fans connected via relays, which regulate when the fans turn on and off to maintain optimal temperature.

4.2 Testing Result

1. Showcase Testing

Table 1. Testing Result MQ3 and MQ4

Day	Showcase 1					
	MQ4	MQ3	Temp	MQ4	MQ3	Temp
Day1	175	261	17.8	208	260	20.00°
Day2	177	268	18.9	214	265	21.90°
Day3	178	270	18.8	220	267	19.80°
Day4	190	300	19.2	223	266	19.50°
Day5	193	346	17.4	237	287	20.30°
Day6	202	408	18.0	240	395	20.10°



Notifications on the Android application for Showcase 1 are set up to alert users when the MQ4 sensor detects methane levels above 195 ppm or the MQ3 sensor detects ethanol levels above 330 ppm. Notifications are sent if either sensor exceeds its threshold, or if both do. No alerts are generated if both readings are below their respective limits. This configuration ensures timely warnings of potential spoilage, enabling users to act quickly to preserve the quality of the bakpia. The system's ability to differentiate between gas levels enhances the reliability of spoilage detection. By integrating notifications into a user-friendly Android app, users can easily monitor their bakpia storage, making the monitoring system both effective and convenient. This proactive approach helps maintain product quality and extends the shelf life of the bakpia by utilizing the Internet of Things for efficient storage management.

The pH testing on the spoiled bakpia is conducted to ensure that the spoiled bakpia contains methane gas. If the pH shows a value of 6.8, it is assumed to already contain methane bacteria, which are bacteria that produce methane gas.

Table 2. pH testing in Spoilage Bakpia

MQ4	MQ3	Temp
Bakpia 1	7.31	spoiled
Bakpia 2	7.23	spoiled
Bakpia 3	6.97	spoiled
Bakpia 4	6.93	spoiled
Bakpia 5	6.87	spoiled

As shown in Table 2, spoiled bakpia has a pH greater than 6.8. Five experiments confirm that spoiled bakpia produces methane, which can be used to gauge the level of spoilage. Longer storage or fermentation leads to increased gas production due to the biosynthesis of pyruvate, resulting in acetone, acetate, and alcohol. Consequently, as storage time increases, pH decreases, and ethanol content rises. This is because *Saccharomyces cerevisiae* undergoes pyruvate biosynthesis during storage, producing more gas over time.

2. Cooling Rack Testing

Testing on the cooling rack is conducted to ensure that the sensors on the cooling rack and the fan are working properly.

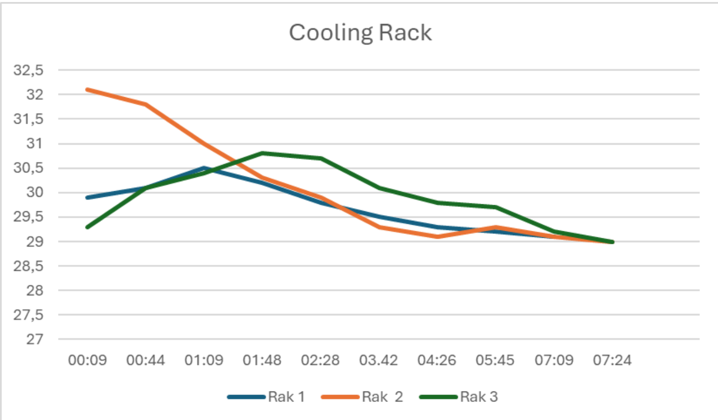


Table 3. Funcional Testing of Rack 1

Cooling Time	Temp	Fan	Notification
00:09	29.90°	Active	No
00:44	30.10°	Active	No
05:45	29.20°	Active	No
07:09	29.10°	Active	No
07:24	29.00°	Non active	Bakpia Rak1 dapat dikemas

Table 4. Funcional Testing of Rack 2

Cooling Time	Temp	Fan	Notification
00:09	32.10°	Active	No
00:44	31.80°	Active	No
05:45	29.30°	Active	No
07:09	29.10°	Active	No
07:24	29.00°	Non active	Bakpia Rak1 dapat dikemas

Table 5. Funcional Testing of Rack 3

Cooling Time	Temp	Fan	Notification
00:09	29.30°	Active	No
00:44	30.10°	Active	No
05:45	29.70°	Active	No
07:09	29.20°	Active	No
07:24	29.00°	Non active	Bakpia Rak1 dapat dikemas

Testing on each client yielded very positive results. The designed automated system can function effectively according to requirements. Data transmission from each client to the website operates in real-time.

Discussion

Results of Data Collection for Each Spoilage Gas

The results for each spoilage gas are shows the results of MQ testing to detect spoilage gas from bakpia pathok conducted over 6 days. From the data, it was found that bakpia is best consumed right after cooling. Bakpia can still be optimally consumed from the first to the fourth day, where spoilage gas levels remain below 195 ppm for MQ4 in Showcase 1, below 300 ppm for MQ3 in Showcase 1, below 200 ppm for MQ4 in Showcase 2, and below 260 ppm for MQ3 in Showcase 2.

Discussion of Data from Cooling Rack Testing

Data collected from each cooling rack shows temperature readings the temperature testing results from each cooling rack. It shows that the highest temperature of bakpia before cooling reached 32 degrees the highest temperature recorded for bakpia was 30.5 degrees. Cooling Rack 3 the highest temperature reached was 31 degrees. After conducting three trials on each cooling rack, the average final temperature after 7 minutes was consistently 29 degrees.

CONCLUSION

Based on the design, testing, and data collection, the following conclusions are drawn: A Bakpia Pathok storage system has been developed using an Arduino Nano microcontroller, with MQ4 methane and MQ3 ethanol sensors detecting spoilage at 195 ppm for MQ4 and 330 ppm for

MQ3 in showcase 1, and 230 ppm for MQ4 and 300 ppm for MQ3 in showcase 2. It uses a TEC cooler for air cooling and an ESP8266 microcontroller to monitor the temperature of Bakpia, cooling it from a maximum of 31°C to 29°C before packaging, and sending notifications when ready. The system is integrated with an Android application for monitoring and provides notifications for spoilage and packaging readiness. Successful testing has shown accurate notifications and temperature monitoring via the application, with data transmitted to Firebase by ESP8266 and ESP01 microcontrollers. Spoilage data classification indicates that spoilage gas production increases with storage time, with ethanol gas levels rising due to bacterial fermentation and methane gas presence confirmed by comparing pH levels of spoiled Bakpia, which show a pH above 6.86. This suggests that increasing alcohol gas levels result from the declining pH caused by methane gas.

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