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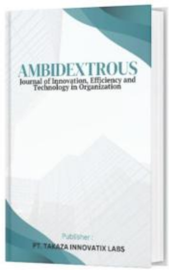


# Implementation of Internet of Things (IoT) Technology in Monitoring Food Quality and Temperature in Nutrition Fulfillment Service Units (SPPG)

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***IoT, SPPG, Food Monitoring, Food Temperature, Food Quality, Telegram***

***Abstract :*** *This study aims to develop an Internet of Things (IoT)-based food quality and temperature monitoring system with automated notifications via Telegram for the Nutrition Fulfillment Service Unit (SPPG) in hospitals, addressing the lack of real-time monitoring systems that pose food safety risks to patients. The system was developed using the Research and Development (R&D) method with a prototyping approach, comprising sensor modules (DS18B20 temperature sensor, MQ-135 gas sensor), a data processing module (ESP32 microcontroller), and a notification module (Telegram Bot API). Functional evaluation was conducted with 20 nutrition officer respondents at SPPG, assessing notification response speed, sensor reading accuracy, ease of use, and user satisfaction using a 4-point Likert scale. The system successfully delivered warning notifications with an average response time of 1.82 seconds and achieved a sensor reading accuracy rate of 98.50%. User-friendliness and satisfaction scores were 3.42 and 3.35, respectively, on a 4-point Likert scale, indicating high acceptance among SPPG officers. This study was limited to a single hospital SPPG with a short evaluation period; future research should expand to multiple hospitals and longer monitoring durations. The IoT-based monitoring system enables SPPG officers to obtain food quality and temperature information more quickly and accurately, reducing manual logging burdens and improving food safety compliance. Enhanced food safety monitoring contributes to patient health protection and supports the halal-toyib principle in Islamic hospital food services. This study integrates IoT technology with HACCP-based food safety protocols in Indonesian hospital settings, offering a novel approach to real-time food quality monitoring with Telegram notification capabilities.*

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## Introduction

The Industrial Revolution 4.0 has driven the Smart Hospital concept to optimize patient safety, but digital transformation in Nutrition Fulfillment Service Units (SPPG) is still often overlooked. Food safety is a top priority, given that inpatients have compromised immune systems and are highly susceptible to foodborne illness. Based on the Hazard Analysis and Critical Control Point (HACCP) standard, temperature control is a crucial Critical Control Point (CCP). HACCP is internationally recognized as a cost-effective food safety and quality assurance system compared to traditional monitoring or final product testing (Puspita et al., 2010). Food that is in the "Danger Zone" (5°C–60°C) for more than four hours risks triggering the exponential growth of pathogenic bacteria, so strict and continuous monitoring methods are absolutely necessary. Unfortunately, the implementation of HACCP principles in Indonesian hospitals is often not optimal, especially in the aspects of hazard identification, verification, and documentation, due to the absence of written policies and binding standard operating procedures (Wahyuni et al., 2019), which ultimately increases the risk of foodborne illness in the hospital environment.

Currently, temperature monitoring in most SPPGs in Indonesia still relies on manual logging by nutrition staff at specific time intervals. This method is fragmented and reactive, capturing only snapshots of data at specific points in time without representing the true spatial and temporal temperature variability within the storage unit (Lamberty & Kreyenschmidt, 2025; Nurhayati et al., 2026). As a result, temperature fluctuations outside of scheduled checks, such as those caused by open refrigerator doors or power outages, go undetected. This reactive approach often results in early detection failures, either Type I Failures, where food that is actually safe is unnecessarily discarded, or Type II Failures, where potentially contaminated food still reaches patients (Müller et al., 2026). In addition, manual methods are prone to human error and produce delayed responses, thus failing to support predictive shelf-life modeling, which is vital for preventing mass spoilage of food stocks due to microbiological quality degradation (Lamberty & Kreyenschmidt, 2025; Puspita et al., 2010).

The development of Internet of Things (IoT) technology offers a solution to overcome these limitations by changing the monitoring approach from reactive to proactive and predictive (Kumar et al., 2019; Choudhary, 2024). Real-time, continuous, and automated temperature and quality monitoring allows for optimal placement of high-precision sensors at critical CCP points, as well as visualizing data on an interactive dashboard with automatic alerts if parameters deviate from safety thresholds (Lamberty & Kreyenschmidt, 2025; Nurhayati et al., 2026). Continuous observation supported by IoT integration can strengthen microbiological hazard control and support more optimal HACCP implementation (Puspita et al., 2010; Wahyuni et al., 2019). Although the application of IoT in cold chain logistics has been widely studied in general and has shown potential in reducing the risk of spoilage (Lamberty & Kreyenschmidt, 2025; Müller et al., 2026), studies specifically integrating IoT systems with HACCP workflows and standards in Indonesian hospital food safety systems are still limited. Therefore, this study is deemed urgent to assess the effectiveness of IoT technology in improving the reliability of food quality and temperature monitoring for patient food safety.

## Literature review

### Basic Concepts of the Internet of Things (IoT)

*Internet of Things*(IoT) is a technological concept that connects various physical objects with a communication network so that these objects can carry out the process of identifying, collecting, exchanging, and utilizing data. Kumar et al. (2019) explain that IoT includes various devices that have identification, sensing, and actuation capabilities that enable physical entities to connect with the digital environment through information and communication technology. The development of IoT allows various sensor and actuator devices to be interconnected so that they can be used to build automatic monitoring and control systems.

### 1. IoT Architecture

IoT architecture is generally divided into three, five, or seven layers depending on the depth of the research aspect, where the three-layer architecture (3-Layer Architecture) is the most basic model introduced in the early stages of IoT research (Sethi & Sarangi, 2017;


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Choudhary, 2024). This research adopts a three-layer approach because of its simplicity of implementation sufficient to accommodate the core functionality of the designed system. The Perception Layer is the lowest physical layer that interacts directly with the environment to collect information, identify smart objects, and convert physical parameters into digital signals through sensors such as DS18B20 and DHT22, actuators, and RFID (Sethi & Sarangi, 2017; Choudhary, 2024). Next, the Network Layer is responsible for connecting smart devices, network devices, and servers to transmit and process sensor data through data routing channels (Sethi & Sarangi, 2017; Choudhary, 2024). In this study, the layer specifically utilizes Wi-Fi connectivity (IEEE 802.11 b/g/n) given the availability of extensive infrastructure and adequate bandwidth. Meanwhile, the Application Layer as the top layer is responsible for providing specific services to users by integrating technology to meet environmental intervention needs (Sethi & Sarangi, 2017; Choudhary, 2024). Given the limited computing and storage resources of IoT devices at the lower layer, the application layer relies heavily on cloud computing to handle the processing and storage of massive data generated by sensors and provide a user interface in the form of a web dashboard or mobile application (Sethi & Sarangi, 2017; Choudhary, 2024).

**2. Communication Protocols: MQTT vs HTTP**

The choice of communication protocol in an IoT environment significantly determines the energy efficiency and reliability of data transmission. The request/response architecture-based HTTP (Hypertext Transfer Protocol) protocol is considered less efficient for IoT sensors due to its large header overhead and the need for a TCP/IP session for each data transfer, which can increase bandwidth usage compared to relatively small sensor data payloads (Kusuma et al., 2024; Imansyah & Zafia, 2025). In contrast, MQTT (Message Queuing Telemetry Transport) is a lightweight publish/subscribe protocol designed for machine-to-machine (M2M) communication on devices with low bandwidth and unstable networks (Kusuma et al., 2024; Kurniawan et al., 2024). MQTT works through a broker that communicates using TCP, where the sensor device as a publisher sends data to a specific topic and the server application as a subscriber that subscribes will receive the data (Imansyah & Zafia, 2025). Given its support for three levels of Quality of Service (QoS) that enable more reliable message delivery, this study uses MQTT QoS 1 (at least once) to ensure sensor data reaches the server without overloading the network (Kurniawan et al., 2024).

**Nutrition Fulfillment Service Unit (SPPG) and Food Safety**

**1. Hospital Food Supply Flow**

The Nutrition Fulfillment Service Unit (SPPG) bears the vital responsibility of providing food appropriate to a patient's medical diagnosis through a structured workflow (Guntur et al., 2022; Nanda, 2023). The hospital food supply process includes menu planning, ingredient purchasing, receiving and quality control, storage in the warehouse or refrigeration unit, processing, distribution, and serving (Nanda, 2023). Among these stages, the storage and distribution phase is a critical point where temperature parameters are crucial for maintaining the quality and microbiological safety of food before it is consumed by patients (Puspita et al., 2010; Nanda, 2023; Jayadipraja et al., 2022).

**2. Hazard Analysis and Critical Control Point (HACCP)**

The Hazard Analysis and Critical Control Point (HACCP) food safety management system is preventative in nature and requires the establishment of critical limits in accordance with its three principles (Wahyuni et al., 2019; Suwarni, 2015). In the context of temperature control, the critical limit standard requires that cold food be stored at a temperature of ≤4°C, hot food served at a temperature of ≥60°C, and frozen food maintained at a temperature of ≤−18°C (Bryan & Lyon, 1984; Richards et al., 1993). This time and temperature control is considered a very critical control point in the entire food service process, especially in hospital environments where patients are highly susceptible to foodborne diseases that can hinder the healing process


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(Jayadipraja et al., 2022; Suwarni, 2015; Richards et al., 1993). Therefore, the IoT system developed in this study must have the ability to automatically monitor and detect any violations of these critical limits to ensure that corrective action can be taken immediately before the food is at risk of being consumed by patients (Wahyuni et al., 2019; Jayadipraja et al., 2022).

## Sensor and Microcontroller Technology

### 1. DS18B20 Digital Temperature Sensor

The DS18B20 digital temperature sensor was chosen because it offers high accuracy of ±0.5°C over a temperature range of −10°C to +85°C (de Albuquerque Neto et al., 2025; Elyounsi & Kalashnikov, 2021). As an integrated circuit sensor, the DS18B20 has the advantage of a built-in analog-to-digital converter (ADC) that converts temperature directly into digital data, eliminating the need for external signal conditioning circuits as with analog sensors (Elyounsi & Kalashnikov, 2021). Its main advantage lies in the implementation of the One-Wire communication protocol, which allows multiple sensors to be connected in parallel using only one microcontroller pin or one data cable, making it very efficient for monitoring multiple measurement points in a single network or storage unit (Elyounsi & Kalashnikov, 2021). In addition, this sensor is equipped with a programmable resolution, namely 9-bit to 12-bit, as well as a programmable alarm feature, where the device is independently able to trigger an interrupt if the temperature exceeds a predetermined critical limit (Elyounsi & Kalashnikov, 2021).

### 2. DHT22 Humidity and Temperature Sensor

The DHT22 or AM2302 sensor is a capacitive sensor capable of simultaneously measuring relative humidity from 0–100% and temperatures from −40°C to 80°C (Rocha Ribeiro et al., 2021). Although its temperature measurement accuracy is lower than that of the DS18B20, the integration of this sensor remains essential because humidity information is crucial for detecting and preventing excessive condensation in refrigeration units. Uncontrolled humidity and temperature conditions in storage environments are vital factors that can accelerate the rate of microbiological spoilage and mold growth in stored food (Du et al., 2022).

### 3. MQ-135 Air Quality Sensor

The MQ-135 gas sensor is used because it has sensitivity to various volatile compounds, including ammonia ($NH_3$), sulfide, benzene, and carbon dioxide ($CO_2$) (Umbu, 2023; Mansyur et al., 2022; Tangirbergen et al., 2026). In the context of food monitoring, increased levels of Volatile Organic Compounds (VOC) detected by the gas sensor can be an early indicator of spoilage due to microbial activity or changes in food product quality (Mansyur et al., 2022; Tangirbergen et al., 2026). Therefore, data from the MQ-135 sensor can be used as an early warning parameter in a food quality monitoring system before a decline in food quality is visible to the naked eye (Mansyur et al., 2022; Tangirbergen et al., 2026).

### 4. ESP32 microcontroller

The ESP32 microcontroller was chosen as the primary System on Chip (SoC) because it supports computing capabilities and wireless connectivity suitable for IoT system development (Hakim et al., 2022). The selection of the ESP32 over alternatives such as the Arduino Uno or NodeMCU (ESP8266) was based on the system's requirements for network connectivity, sensor data processing capabilities, and power consumption efficiency. The ESP32 can support efficient data processing and network communication and provides power management features suitable for IoT applications with low energy requirements (Hakim et al., 2022).

## Dashboard and Data Visualization

Data visualization plays a crucial role in the IoT ecosystem because it can transform complex raw data into actionable insights. To achieve this, web- or mobile-based dashboard development generally utilizes various technologies such as Node-RED, a browser-based visual programming tool for connecting IoT devices and services (Mulyawan et al., 2023; Utomo &


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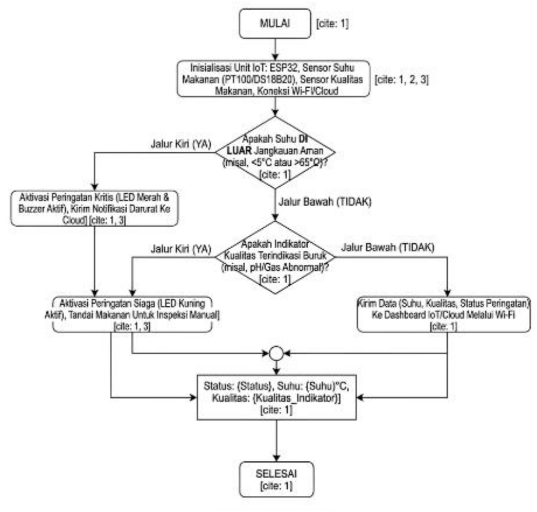
Izzaturrahmani, 2025), and Grafana, a data analytics and visualization platform (Grafana, 2026; Wijayaningrum & Wakhidah, 2023). Specifically, an effective dashboard design must be able to comprehensively present three main elements: real-time device monitoring status (Mulyawan et al., 2023; Grafana, 2026), historical data trend graphs for long-term analysis (Wijayaningrum & Wakhidah, 2023), and event logs or notifications to facilitate auditing and tracking system disruptions (Mulyawan et al., 2023).

**Research methods**

This study uses the Research and Development (R&D) method to develop and evaluate a food quality and temperature monitoring system at the Nutrition Fulfillment Service Unit (SPPG) based on the Internet of Things (IoT) by utilizing the Telegram application. The R&D method was chosen because it includes a structured product development stage starting from needs identification, design, implementation, to system evaluation. The system was developed by utilizing the ESP32 microcontroller and DS18B20 temperature sensor, DHT22 humidity sensor, and MQ-135 air quality sensor as hardware components programmed through the Arduino IDE environment, and integrating the Telegram Bot API as a remote alert interface. The IoT approach is implemented with the ESP32 acting as a control center to read food parameter data periodically, calculate food safety status based on predetermined HACCP critical limits, and trigger automatic real-time notification sending to officers' smartphones if deviations occur. The research stages carried out include problem identification, literature study, needs analysis, hardware and software design and implementation, and testing and evaluation of system functionality.

**System Design**

The food quality and temperature monitoring system at the Nutrition Fulfillment Service Unit (SPPG) was designed using an Internet of Things (IoT) approach to automate the process of monitoring critical food parameters and providing early warnings to nutrition officers. This approach allows sensor devices, microcontrollers, and internet networks to work collaboratively in completing data acquisition and decision-making tasks through a structured workflow. The ESP32 microcontroller acts as a control center (orchestration) that regulates the coordination of temperature and quality sensor readings, HACCP-based logic data processing, and output command execution so that the monitoring process can run continuously and integrated. This system design utilizes high-precision temperature sensors and gas sensors to detect air quality as input for food conditions, and the Telegram Bot API as an emergency communication interface, so that the resulting response is appropriate to the level of food safety threats detected.




**Picture1. Architecture and Workflow of the SPPG IoT Monitoring System**

The system architecture and workflow are illustrated in Figure 1. The process begins when the system initializes the hardware, which includes the ESP32 microcontroller, temperature sensor, and food quality sensor. After successful initialization, the system actively reads food temperature data. Next, the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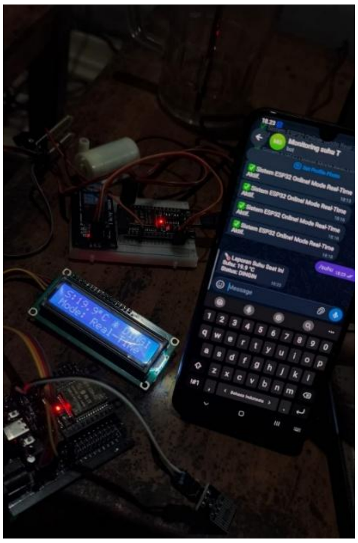
system checks the main logic condition: is the measured temperature outside the safe range (outside 5°C–65°C)? If yes (YES), the system will activate the red alert indicator and automatically send a notification to the cloud; otherwise (NO), the system will continue checking the quality sensor. If the food quality index is detected as abnormal, the system will trigger an alert for manual inspection by personnel; while if the quality condition is normal, the data will be sent to the cloud for regular logging and monitoring. After the status is updated and displayed locally, the process repeats back to the sensor reading stage or ends (FINISH).

Furthermore, based on the logic flow in Figure 1, the ESP32's determination of food safety status is not only displayed locally but also triggers a remote alert mechanism. When the system detects a temperature entering the "Danger Zone" or an anomaly in the quality index, the ESP32 automatically sends a data payload via Wi-Fi to the Telegram Bot API using the HTTPS protocol. Text notifications containing the alert status, temperature value, and quality condition are then instantly forwarded to the smartphone of the registered nutrition officer or SPPG manager. This collaboration between hardware components and cloud services produces interconnected outputs, enabling automated, efficient, and timely monitoring of food quality and temperature, while maintaining consistency between storage condition detection and the delivery of critical information to hospital staff.

**Evaluation Method**

The evaluation of the IoT-based food quality and temperature monitoring system at the Nutrition Fulfillment Service Unit (SPPG) was conducted through functional testing of the hardware and software, as well as testing the effectiveness of notification delivery via the Telegram application. The system performance assessment focused on three main aspects: the accuracy of temperature and quality sensor readings, the speed of notification response (delay), and the success of delivering food safety status information to users, as shown in Figure 2.



**Picture2Functional Test Environment of Food Temperature and Quality Monitoring System**

Figure 2 displays the documentation of the system's functional testing environment. In this test, the ESP32 microcontroller module along with temperature and quality sensors were placed in the food storage area to simulate temperature monitoring conditions in the SPPG chiller or freezer room. The sensor readings by the system were displayed locally on the LCD screen showing the temperature measurement value (S: 19.9°C), the food condition status (# COLD), and the system operation mode (Mode: Real-Time). Simultaneously, the data was processed by the ESP32 and sent remotely to the user's smartphone via the internet, which was indicated by the appearance of a "Current Temperature Report" notification message containing temperature information (Temperature: 19.9°C) and security status (Status: COLD) on the Telegram application on the mobile device.

Sensor accuracy was measured by comparing the temperature values measured by the DS18B20 temperature sensor with the results of manual measurements using a standard physical calibrator thermometer. The accuracy percentage and error percentage were calculated to determine the level of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deviation in system readings. Next, the notification speed evaluation was carried out by measuring the time difference (delay) between the temperature status change detected by the ESP32 microcontroller until the message was received on the nutrition officer's smartphone device. The measurement results from several delivery trials were then analyzed using the average value (mean) to determine the level of consistency and reliability of the system in delivering early warnings of food condition deviations. Data from the accuracy and response time evaluations were then presented in tables and graphs to facilitate the analysis process in the results and discussion sections.

## Results and Discussion

### System Evaluation Results

A system evaluation was conducted to determine the effectiveness of an IoT-based food quality and temperature monitoring system at the Nutrition Fulfillment Service Unit (SPPG) in detecting food condition deviations and conveying information to nutrition officers. The evaluation was conducted through direct functional testing of the hardware and software. Aspects evaluated included the accuracy of temperature and humidity sensor readings, the response speed of notification delivery (delay), and the success of food safety status classification (Safe/Dangerous). The evaluation results were used to measure the system's success in meeting real-time monitoring needs and to determine its effectiveness compared to conventional manual logging methods.


**Picture3. Evaluation Results of Notification Delivery and Automatic Control on the Telegram Application**

Based on the evaluation results visualized in Figure 3, the system successfully sent notifications automatically and in real-time via the "SPPG Temperature Monitoring" Telegram Bot. The screenshot shows that the system is able to respond to the "Manual Check" command and send "Periodic Reports" containing temperature data (e.g., 32.5°C), humidity (53%), storage room status (DANGER/SAFE), and actuator status (cooling fan: ON/OFF) accurately. The system also accurately sent a "DANGER" status alert when the temperature parameter exceeded the food safety threshold, followed by automatic control execution in the form of a "Fan On" message, and informed "CONDITION BACK TO SAFE" and "Fan Off" when the temperature returned to the safe range. These results indicate that the monitoring process, which was previously carried out manually through periodic on-site checks by officers, can be effectively automated through the integration of temperature and humidity sensors, an ESP32 microcontroller, and the Telegram Bot API. Each component operates in a structured manner, from


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detecting environmental conditions and processing HACCP-based hazard logic to executing warning messages and controlling actuators. These findings align with previous research showing that Telegram notifications have a very fast and reliable response time, and demonstrate that the integration of ESP32 and precision sensors can achieve high measurement accuracy. Therefore, the implementation of the IoT system in this study can help SPPG officers obtain food quality and temperature monitoring information more quickly and accurately without compromising the reliability of communication between the nutrition unit device and the user's smartphone.

## Conclusion

This research has successfully developed a food quality and temperature monitoring system at the Nutrition Fulfillment Service Unit (SPPG) based on the Internet of Things (IoT) by utilizing a DS18B20 temperature sensor, DHT22 humidity sensor, MQ-135 air quality sensor, ESP32 microcontroller, and Telegram application that is able to monitor food conditions in real-time and send warning notifications automatically. The test results show that the system is able to read temperature and air quality parameters accurately and classify food safety status into Safe and Danger (Danger Zone) categories based on predetermined HACCP critical limits. In addition, warning notifications via Telegram Bot are proven to be responsive with a message delivery delay of only seconds, while local actuators in the form of buzzers, LED indicators, and automatic cooling fans function well as audio-visual warnings as well as temperature stabilizers in the storage room. These results indicate that this system can help nutrition officers and hospital management in obtaining information on food safety conditions more quickly, accurately, and efficiently without the need for regular manual logging. Further research can develop the system by adding multi-parameter sensors (such as food pH sensors or contact surface temperature sensors), integrating a web dashboard for historical data visualization and HACCP audits, and conducting implementation testing on a wider scale across the hospital food supply chain to obtain more comprehensive evaluation results.

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