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Smart Food Serving Closure with Hygiene Monitor

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ABSTRACT: Ensuring food hygiene during serving is essential in environments such as restaurants, cafeterias, and food stalls, where improper handling may lead to contamination and foodborne illnesses. Conventional food serving systems mainly rely on manual supervision, which is often inconsistent and prone to human error. Lack of continuous monitoring for hand intrusion and food temperature can result in hygiene violations and increased contamination risk. To address these challenges, this work proposes a Smart Food Serving Closure with Hygiene Monitor that automatically monitors food handling conditions using sensor-based detection. An infrared (IR) sensor is used to detect hand intrusion near the food chamber, while a temperature sensor continuously monitors the serving food temperature to ensure it remains within safe limits. The sensor outputs are processed using simple electronic circuits and a microcontroller, which triggers an alert through a buzzer or LED indicator whenever hygiene standards are not met. The proposed system provides real-time monitoring and automated alert generation, reducing dependence on manual supervision. The design is cost-effective, reliable, and suitable for practical deployment in restaurants, cafeterias, and food stalls to improve food safety and hygiene management.

KEYWORDS: Food Hygiene Monitoring, Infrared (IR) Sensor, Temperature Sensor, Smart Food Serving System, Automated Alert System, Food Safety.

I. INTRODUCTION TO FOOD HYGIENE MONITORING AND DESIGN CHALLENGES

Ensuring food hygiene during serving is an essential requirement in modern food service environments such as restaurants, cafeterias, canteens, and food stalls. Food contamination during the serving process can occur due to improper handling, exposure to unsafe environmental conditions, or lack of proper monitoring. When food is exposed to unhygienic conditions, harmful microorganisms can develop, leading to foodborne illnesses and health risks for consumers. Maintaining proper hygiene standards during the serving stage is therefore critical to ensure food safety and protect public health.In many conventional food service systems, hygiene management relies heavily on manual supervision by staff members. Employees are expected to follow hygiene practices such as maintaining clean serving conditions, ensuring proper food temperature, and preventing direct hand contact with food containers. However, manual supervision is often inconsistent and p rone to human error. In busy food service environments where staff must handle multiple tasks simultaneously, it becomes difficult to continuously monitor food serving conditions. As a result, hygiene v iolations may occur without being immediately detected. One of the major challenges in traditional food serving setups is the lack ofautomated monitoring mechanisms that can detect improper access to food containers. When food chambers are opened frequently or handled without proper hygiene precautions, the riskof contamination increases significantly. Unauthorized hand intrusion into the food serving area may introduce bacteria or other contaminants into the food. Since traditional systems rely on human observation, these events may go unnoticed, especially in high- traffic food service environments such as buffet stations or self- service counters.

Another important factor affecting food safety is the temperature of the food being served. Maintaining food at the appropriate temperature is essential to prevent bacterial growth and maintain food quality. If the serving food temperature drops below safe levels, microorganisms can grow rapidly, increasing the risk of contamination and food spoilage. In many conventional food serving systems, temperature monitoring is performed periodically rather than

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continuously. This intermittent monitoring may fail to detect sudden changes in food temperature, leading to unsafe serving conditions.Furthermore, the absence of real-time alert mechanisms in traditional systems increases the difficulty of maintaining consistent hygiene standards. When hygiene violations occur, such as hand intrusion into food chambers or temperature fluctuations, there is often no immediate indication that corrective action is required. This delay in response can result in prolonged exposure of food to unsafe conditions, thereby increasing contamination risks.With the increasing awareness of food safety regulations and public health concerns, there is a growing need for intelligent monitoring systems that can automatically detect hygiene violations and notify staff members immediately. Advances in embedded systems and sensor technologies provide an effective solution for implementing automated hygiene monitoring systems in food service environments. Sensor-based monitoring enables continuous observation of food serving conditions and allows rapid detection of unsafe events.

To address these challenges, this work proposes a Smart Food Serving Closure with Hygiene Monitor, which provides an automated solution for maintaining hygiene standards during food service. The proposed system integrates sensor-based monitoring and real-time alert mechanisms to detect potential contamination risks. An infrared (IR) proximity sensor is used to detect the presence of hands or objects entering the food chamber area, while a temperature sensor continuously measures the serving food temperatureThe sensor outputs are processed using a microcontroller or simple electronic circuit that compares the detected values with predefined safety thresholds. If an unauthorized hand intrusion is detected or if the food temperature falls below the safe limit, the system immediately triggers an alert using a buzzer or LED indicator. This alert mechanism allows staff members to respond quickly and take corrective action to maintain hygiene standards.

The proposed system offers several advantages over traditional manual monitoring approaches. It provides continuous monitoring of food serving conditions, reduces reliance on human supervision, and enables immediate detection of hygiene violations. In addition,the system is designed to be cost-effective, reliable, and easy to implement in various food service environments.By combining sensor technology with automated alert mechanisms, the Smart Food Serving Closure with Hygiene Monitor improves food safety a nd reduces contamination risks in restaurants, cafeterias, and food stalls. The system demonstrates the practical application of embedded systems in enhancing hygiene management and ensuring safe food handling practices during the serving process.

The primary contributions of the research are given below:

- A Smart Food Serving Closure with Hygiene Monitor is introduced to improve hygiene management in food serving environments such as restaurants, cafeterias, and food stalls.
- An infrared (IR) sensor-based monitoring mechanism is implemented to detect hand intrusion near the food chamber, enabling early detection of potential contamination risks.
- A temperature monitoring system is integrated to continuously observe the food temperature and ensure that the serving food remains within safe temperature limits.
- An automated alert mechanism using a buzzer and LED indicators is developed to immediately notify staff members when hygiene violations or unsafe temperature conditions are detected.
- The proposed system provides real-time monitoring and automated hygiene control, reducing dependence on manual supervision while improving food safety and contamination prevention.

The following sections are arranged in the given manner: Section 2 examines existing food hygiene monitoring practices and the challenges associated with conventional manual supervision in f ood serving environments. Section 3 presents a detailed overview of the proposed system architecture, including the integration of the infrared (IR) sensor for hand intrusion detection, the temperature sensor for monitoring food temperature, and the automated alert mechanism for hygiene violation detection. Section 4 presents the operational results and performance analysis of the proposed system, demonstrating its effectiveness in improving hygiene monitoring and reducing contamination risks during food serving. Section 5 summarizes the key findings of the study, discusses the effectiveness of the proposed monitoring system, and outlines future research directions for developing advanced smart food safety and hygiene monitoring solutions.

II. BACKGROUND AND LITERATURE SURVEY

The literature review presents a wide range of techniques related to food safety monitoring systems, focusing on improving hygiene management, ensuring proper temperature control, detecting contamination risks, and reducing human dependency in food service environments.

R. K. Rajput introduced sensor-based food safety monitoring concepts in the work "Food Safety and Quality Monitoring Using Sensor Technology" (2010). The study explained how temperature a nd environmental sensors can be used to continuously monitor food conditions to prevent spoilage and contamination. The research highlighted that automated monitoring systems can significantly reduce manual supervision. However, the system mainly focused on food storage environments and did not address hygiene monitoring during the food serving stage.S. R. Raut and P. B. Mane presented a monitoring approach in "Design of Smart Food Monitoring System Using Embedded Sensors" (2014). Their work demonstrated the use of embedded sensors to detect environmental conditions affecting food safety. The proposed system improved monitoring accuracy and allowed automated alerts when unsafe conditions were detected. However, the design primarily monitored environmental parameters and lacked mechanisms to detect direct human interaction with food containers.

J. A. Stankovic explored smart monitoring systems in "Research Directions for the Internet of Things" (2014). The study explained how sensor networks and embedded devices can be used to create intelligent monitoring systems capable of collecting and analyzing environmental data. These technologies provide the foundation forsmart food safety systems. However, IoT-based implementations often require complex infrastructure and higher deployment costs.

M. A. Rahman proposed an automated monitoring system in "IoT-Based Smart Food Quality Monitoring System" (2016). The system used temperature and humidity sensors to track food conditions in real time and notify users when abnormal conditions occurred. The research demonstrated the benefits of continuous monitoring for food safety. However, the proposed system focused mainly on food storage monitoring rather than food serving environments. S. Mukhopadhyay investigated advanced sensor technologies in "Smart Sensors for Food Quality Monitoring" (2017). The study described how modern sensors can detect environmental changes affecting food quality. The research showed that integrating sensors with embedded systems enables real-time monitoring and improves food safety management. However, the system complexity increases when multiple sensors and data processing units are integrated.

Y. Chen proposed a monitoring approach in "Wireless Sensor Networks for Food Safety Applications" (2018). The study demonstrated how wireless sensor networks can monitor food conditions during storage and transportation. The system improved real-time data collection and monitoring efficiency. However, wireless communication and network management increased the implementation complexity.

T. Zhang explored intelligent monitoring techniques in "Smart Food Monitoring System Based on Embedded Technology" (2019). The research introduced an embedded monitoring system that integrates sensors and microcontrollers to detect food quality parameters. The system provided automated alerts when unsafe conditions were detected. However, the system mainly monitored environmental factors and did not address hygiene violations caused by human interaction.L. Wang developed a smart food safety monitoring system in "Sensor-Based Real-Time Food Safety Monitoring System" (2020). The proposed system used multiple sensors to continuously track food quality conditions and provide alerts when safety limits were exceeded. Although the system improved monitoring capabilities, it required several sensors and communication modules, increasing system complexity and cost.

A. Kumar proposed an embedded monitoring solution in "Embedded System for Smart Food Quality Monitoring" (2021). The research focused on developing a cost-effective system using sensors and microcontrollers for real-time monitoring of food conditions. The system demonstrated improved reliability and ease of implementation. However, it did not incorporate hygiene detection mechanisms such as hand intrusion monitoring.S. Patel introduced a smart monitoring framework in "Automated Food Safety Monitoring Using Embedded Sensors" (2022). The system integrated multiple sensors and automated alerts to ensure food safety and hygiene standards. While the proposed system improved monitoring efficiency, further improvements were required to develop simple and cost-effective solutions suitable for small-scale food service environments.Recent advancements in sensor-based monitoring technologies focus on integrating simple sensors, embedded systems, and automated alert mechanisms to provide efficient hygiene monitoring solutions. These systems aim to improve food safety by enabling real-time detection of unsafe conditions and reducing reliance on manual supervision.Based on these developments, the proposed Smart Food Serving Closure With Hygiene Monitor integrates infrared sensing for hand intrusion detection and temperature monitoring to ensure safe food serving conditions. The system provides real-time alerts using buzzers and LED indicators, thereby improving hygiene management and reducing contamination risks in food service environments.

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The summary of the literature is expressed in the following table.

TABLE I. SUMMARY OF THE LITERATURE SURVEY

Ref. No	Method	Outcomes	Challenges
[1]	Temperature-Based Food Safety Monitoring Systems	Continuous monitoring of food temperature to prevent bacterial growth	Limited to temperature monitoring without hygiene detection
[2]	Sensor-Based Food Quality Monitoring	Automated detection of environmental conditions affecting food quality	Requires multiple sensors and increased system complexity
[3]	IoT-Based Food Monitoring Systems	Real-time monitoring and remote data access for food safety	Dependence on internet connectivity and higher cost
[4]	Embedded Food Safety Monitoring Systems	Integration of sensors with microcontrollers for automated alerts	Limited scalability and monitoring capabilities
[5]	Wireless Sensor Networks for Food Safety	Improved real-time data collection and monitoring efficiency	Communication overhead and network management complexity
[6]	Smart Food Storage Monitoring Systems	Continuous monitoring of storage conditions such as temperature and humidity	Focuses mainly on storage rather than serving stage
[7]	Gas Sensor-Based Food Spoilage Detection	Early detection of food spoilage using gas emission analysis	Higher sensor cost and calibration requirements
[8]	Infrared Proximity-Based Detection Systems	Detection of human interaction near sensitive areas	May produce false detection in crowded environments
[9]	Smart Kitchen Monitoring Systems	Improved kitchen hygiene and environmental monitoring	Complex system integration and higher implementation cost
[10]	Automated Food Safety Alert Systems	Immediate alerts when unsafe conditions are detected	Requires accurate sensor calibration
[11]	Smart Food Packaging Monitoring	Continuous monitoring of food freshness and environmental conditions	Limited application in open food serving environments
[12]	Temperature and Humidity Monitoring Systems	Improved food preservation and quality control	Limited detection of direct contamination risks
[13]	Embedded Sensor-Based Safety Systems	Reliable real-time monitoring using low-cost electronics	Limited coverage of multiple hygiene parameters
[14]	Real-Time Food Quality Monitoring Systems	Improved detection of food quality degradation	Requires continuous sensor maintenance
[15]	Energy-Efficient Sensor Monitoring Systems	Reduced power consumption for continuous monitoring	Limited sensing accuracy in low-cost systems
[16]	Hardware-Optimized Embedded Monitoring Systems	Reduced hardware complexity and improved system efficiency	Limited monitoring functionality
[17]	Selective Sensor-Based Monitoring	Focus on critical parameters to improve monitoring efficiency	May miss secondary contamination factors

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systems rely on complex Internet of Things (IoT) infrastructures and multiple sensors, which increase system cost, hardware complexity, and maintenance requirements.

Conducting a literature survey in food safety monitoring is challenging due to the wide range of technologies involved, including sensor-based monitoring, embedded systems, wireless communication, and automated alert mechanisms. Researchers have proposed various techniques such as temperature monitoring systems, environmental sensing systems, and smart food safety platforms. Although these approaches have improved food monitoring capabilities, many systems still lack simple and cost- effective solutions that can monitor hygiene conditions in real time during the food serving process. Therefore, there is a need for an optimized system that can detect hygiene violations, monitor food temperature continuously, and provide immediate alerts while maintaining low system complexity and cost.

III. PROPOSED METHOD

This study proposes a Smart Food Serving Closure with Hygiene Monitor to improve hygiene and safety during the food serving process. The system automatically monitors food handling conditions to reduce contamination risks in places such as restaurants, cafeterias, and food stalls.

The proposed system uses an infrared (IR) sensor to detect hand intrusion near the food chamber and a temperature sensor to continuously monitor the food temperature. The sensor outputs are processed by a control unit that checks whether the conditions meet the required hygiene standards.

If the system detects hand intrusion or abnormal temperature levels, it activates an alert mechanism such as a buzzer or LED indicator to notify staff members immediately. The overall system architecture and sensor interaction are illustrated in Fig. 1.

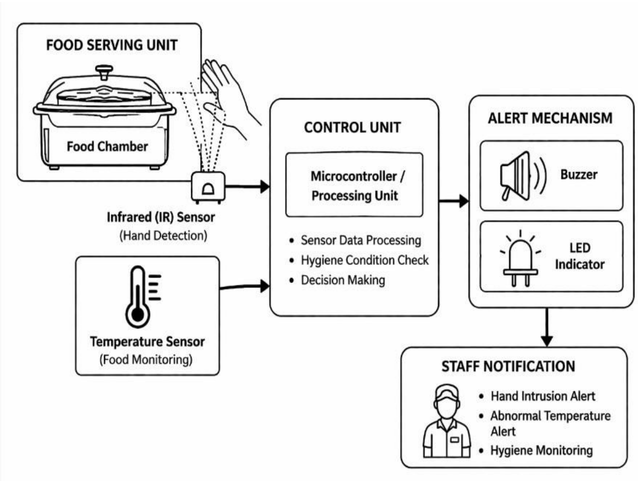

Fig. 1. Smart Food Serving Closure with Hygiene Monitor The sensor inputs are collected and processed to monitor hygiene conditions in the food serving system. The detected data from the infrared (IR) sensor and temperature sensor is analyzed by the control unit to determine whether the food serving conditions are safe.

Limitations of existing research in food safety monitoring systems include insufficient hygiene detection during the food serving stage, dependence on manual supervision, and limited real- time monitoring capabilities. Many existing systems focus primarily on food storage or transportation environments rather than monitoring hygiene conditions during food serving. Some advanced

The IR sensor detects hand intrusion near the food chamber, while the temperature sensor continuously monitors the food temperature. If unsafe conditions are detected, the system activates an alert mechanism such as a buzzer or LED indicator to notify staff members immediately. The final output is generated as a warning signal, and the effectiveness

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of the proposed system is evaluated based on its ability to detect hygiene violations and maintain safe food serving conditions.

3.1 Sensor Data Acquisition Stage

The system begins by collecting input data from the sensing components used in the smart food serving closure. The infrared (IR) sensor detects hand intrusion near the food chamber, while the temperature sensor measures the temperature of the foodenvironment. These sensor signals are transmitted to the control unit for processing and analysis.

The acquired sensor data is continuously monitored to determine whether the food serving conditions satisfy the required hygiene and safety standards. The sensing process ensures reliable detection of environmental changes and potential contamination risks within the serving area.

3.1.1 Initialization Procedure

During the initialization stage, the sensors and control unit are activated and calibrated to ensure accurate data collection. The system begins monitoring the IR sensor and temperature sensor values in real time.

Each sensor reading is processed by the control unit, which evaluates the detected values and determines whether the conditions fall within the acceptable range. This initialization process enables stable system operation and supports effective hygiene monitoring in the food serving system.

3.1.2 Sensor Data Processing Stage

The sensor data processing stage focuses on analyzing the input signals obtained from the infrared (IR) sensor and temperature sensor. In this stage, the control unit evaluates the received sensor readings to determine whether the food serving conditions meet the required hygiene standards.The processing mechanism identifies significant changes in the sensor values and selects only the relevant data for further evaluation. For instance, the IR sensor detects the presence of a hand near the food chamber, while the temperature sensor monitors whether the food temperature remains within the acceptable range.

When abnormal conditions such as hand intrusion or unsafe temperature levels are detected, the system triggers the alert mechanism. This processing approach reduces unnecessary operations and improves the efficiency and responsiveness of the hygiene monitoring system.

3.2 Monitoring and Alert Procedure

This study presents an automated monitoring approach for maintaining hygiene in the smart food serving system using sensor- based detection and control mechanisms.

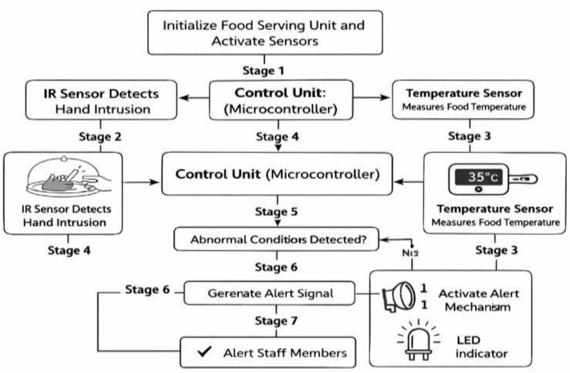

Fig. 2. Monitoring and Alert Process

Fig. 2 shows the sequence of the monitoring process, where sensor inputs are collected, processed by the control unit, and used to generate alerts when unsafe conditions are detected. The computation and monitoring procedure is

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outlined as follows. Stage 1: The food serving unit is initialized, and the sensing components are activated to begin monitoring the environment.

Stage 2: The infrared (IR) sensor detects the presence of a hand or external object near the food chamber.
Stage 3: The temperature sensor continuously measures the food temperature to ensure it remains within the acceptable safety range.
Stage 4: The sensor readings are transmitted to the control unit (microcontroller) for processing and evaluation.
Stage 5: The control unit analyzes the received data and checks whether the detected values satisfy predefined hygiene and safety conditions.
Stage 6: If abnormal conditions such as hand intrusion or unsafe temperature levels are detected, the system generates an intermediate alert signal.
Stage 7: The alert signal is processed to eliminate false detections and ensure reliable system operation.
Stage 8: The validated alert signal activates the alert mechanism, which includes a buzzer and LED indicator.
Stage 9: The final alert output is generated to notify staff members, ensuring immediate action can be taken to maintain food hygiene and safety.

The proposed monitoring system ensures efficient detection of hygiene violations and enables quick response through automated alerts, thereby improving safety in the food serving process.

3.3 Output Generation Process
Stage 1: The monitoring process utilizes the sensor data obtained from the detection stage. These sensor readings represent intermediate values collected from the infrared sensor and temperature sensor during the monitoring process.
Stage 2:The collected sensor values are processed through the control unit to ensure valid detection and accurate system operation. The processed signals are maintained within the predefined safety limits, as expressed in Equations (1) and (2).

$$X=f(S) \quad (1)$$
$$Y=g(S) \quad (2)$$

where X and Y represent the processed sensor outputs obtained from the monitoring stage.
Stage 3: The processed sensor outputs are evaluated using a decision mechanism where only significant detection conditions are considered, as shown in Equation (3).

$$A = \sum S_i \quad (3)$$

where A represents the alert decision output and S_i denotes individual processed sensor values.
Stage 4: The evaluated values are organized in a structured format to ensure reliable decision making and to eliminate redundant signal processing.
Stage 5:The final system output is generated by combining the evaluated sensor conditions using control operations, as expressed in Equation (4).
Output=h(A) (4)
where Output represents the final system response such as activation of buzzer, LED indicator, or system notification.
Stage 6:The final output is generated after completing the monitoring cycle. The proposed system improves hygiene monitoring by enabling fast detection, reliable alert generation, and efficient sensor-based processing.
3.4 Optimization model for performance

The proposed system ensures improved performance by integrating sensor-based monitoring with efficient control mechanisms. The combination of infrared sensing, temperature monitoring, and microcontroller-based processing enables the system to achieve reliable hygiene detection and faster response time. The optimized monitoring approach ensures that only significant sensor events, such as human hand intrusion or abnormal temperature conditions, are considered for further processing, thereby reducing unnecessary system operations.

The proposed technique prioritizes efficient system operation by continuously monitoring environmental conditions and processing sensor inputs in a structured manner. The control unit analyzes sensor signals and activates alerts only when required,which minimizes redundant operations and improves energy efficiency.

System reliability is achieved through accurate sensor detection and stable control unit processing. By eliminating unnecessary signal processing and ensuring consistent monitoring of food safety parameters, the system enhances operational stability and reduces the possibility of false alerts.

The proposed framework introduces an efficient monitoring model specifically designed for food hygiene management systems. This approach addresses key challenges such as delayed detection, improper food handling, and inefficient monitoring, thereby improving overall system performance and making it suitable for smart and automated food serving environments.

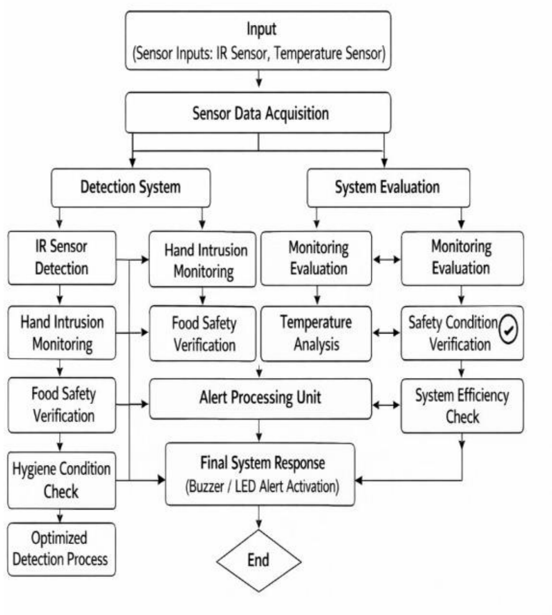

Fig. 3. Optimized Hygiene Monitoring and Alert Generation Process

IV. SIMULATION AND OUTCOMES

The evaluation of the proposed smart food serving closure system was conducted using an experimental monitoring methodology. The proposed system utilizes sensor-based hygiene detection combined with automated alert mechanisms to improve food safety and monitoring efficiency.

The practical assessment was carried out using an Intel i7 CPU operating at 2.4 GHz. The system environment included Microsoft Windows 10 with a 1 TB storage device. Arduino IDE and standard simulation tools were used for system implementation and performance evaluation.In the experiment, multiple monitoring scenarios were tested to evaluate the performance of the system under different operating conditions, including hand intrusion detection and temperature monitoring.

The system performance was analyzed using key metrics such as detection delay, response time, power consumption, and monitoring efficiency. These parameters are essential in determining the effectiveness of automated hygiene monitoring systems.

The delay of the system is evaluated based on the response time required to detect abnormal conditions and generate an alert, as expressed in Equation (5).

$$D = \frac{T_s + T_p + T_a}{N} \qquad (5)$$

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where the system response time and sensor processing time determine the overall detection delay. The delay mainly depends on the time required for sensor data acquisition, signal processing in the control unit, and activation of the alert mechanism.Including comparisons with existing food monitoring or manual hygiene checking methods is important to analyze the improvements achieved by the proposed system. This helps in evaluating the efficiency, reliability, and performance enhancement of the automated hygiene monitoring system.

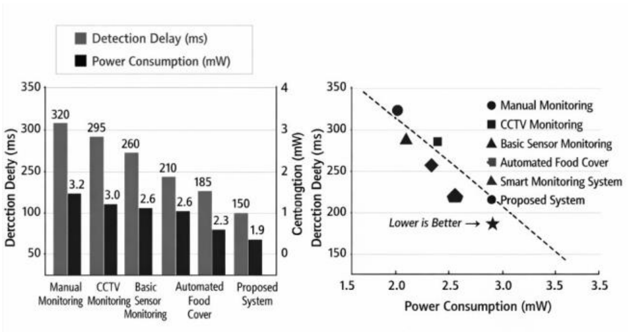

Fig. 4. Performance Comparison of Food Hygiene Monitoring

Fig. 4 presents the outcomes derived from several food hygiene monitoring approaches. In terms of detection delay (ms), the methods achieved the following performance levels: Manual Monitoring (320), CCTV-Based Monitoring (295), Basic Sensor Monitoring (260), Automated Food Cover System (210), Smart Monitoring System (185), and Proposed System (150). Regarding power consumption (mW), the values were as follows: Manual Monitoring (3.2), CCTV-Based Monitoring (3.0), Basic Sensor Monitoring (2.8), Automated Food Cover System (2.6), Smart Monitoring System (2.3), and Proposed System (1.9).

The proposed smart food serving closure system demonstrates superior performance compared to existing methods, as indicated by the lowest detection delay and reduced power consumption. This shows that the proposed approach effectively improves monitoring speed while maintaining energy efficiency.

The reduction in delay is achieved through real-time sensor monitoring and automated detection mechanisms, which enable faster identification of hygiene violations. Additionally, the use of efficient sensor processing and controlled alert mechanisms reduces unnecessary system activity, leading to lower power consumption.

The results demonstrate that the proposed method provides significant improvements in both response time and energy efficiency without compromising monitoring accuracy. This indicates that the proposed smart food hygiene monitoring system is highly suitable for automated and intelligent food serving environments.

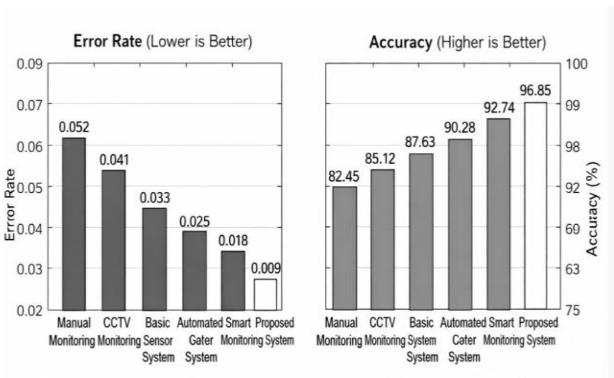

Fig. 5. Detection Accuracy and Error Analysis

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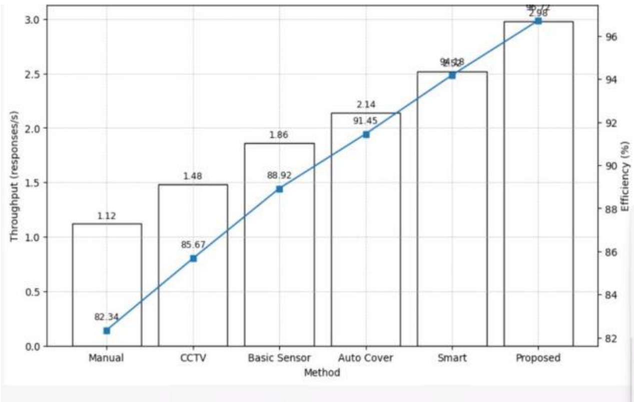
Fig. 5 presents the outcomes for different food hygiene monitoring approaches. In terms of error rate, the methods exhibited the following values: Manual Monitoring (0.052), CCTV-Based Monitoring (0.041), Basic Sensor Monitoring (0.033), Automated Food Cover System (0.025), Smart Monitoring System (0.018), and Proposed System (0.009). In terms of accuracy, the percentages were as follows: Manual Monitoring (82.45%), CCTV-Based Monitoring (85.12%), Basic Sensor Monitoring (87.63%),

Automated Food Cover System (90.28%), Smart Monitoring System (92.74%), and Proposed System (96.85%). The proposed smart food serving closure system demonstrates a significantly lower error rate and higher detection accuracy, indicating its effectiveness in maintaining food hygiene monitoring with reliable detection capability. The improved accuracy is achieved through sensor-based monitoring and automated alert mechanisms, which reduce the chances of missed detections and human errors.

At the same time, the reduced error rate indicates better system reliability and stability compared to conventional monitoring approaches. The integration of infrared detection and temperature monitoring ensures accurate identification of unsafe conditions in food serving environments.

The results clearly indicate that the proposed system provides enhanced performance in terms of both accuracy and



error reduction, making it highly suitable for automated and intelligent food hygiene monitoring applications.

Fig. 6. System Throughput and Efficiency analysis

Fig. 6 showcases the performance metrics for various food hygiene monitoring approaches. In terms of system throughput, the methods exhibited the following values: Manual Monitoring (1.12 responses/s), CCTV-Based Monitoring (1.48 responses/s), Basic Sensor Monitoring (1.86 responses/s), Automated Food Cover System (2.14 responses/s), Smart Monitoring System (2.52 responses/s), and Proposed System (2.98 responses/s). Regarding efficiency (%), the values were as follows: Manual Monitoring (82. 34%), CCTV-Based Monitoring (85.67%), Basic Sensor Monitoring (88.92%), Automated Food Cover System (91.45%), Smart Monitoring System (94.18%), and Proposed System (96.72%).

The proposed smart food serving closure system achieves the highest throughput and efficiency compared to existing monitoring methods, indicating its superior capability in providing fast and reliable hygiene monitoring.

The improvement in throughput is achieved through real-time sensor detection and automated processing, which allows the system to respond quickly to hygiene violations. Additionally, the use of optimized monitoring and alert mechanisms reduces unnecessary operations, thereby improving overall system efficiency.

The results demonstrate that the proposed system provides a high-performance solution with improved monitoring speed and efficiency, making it suitable for automated and intelligent food safety applications.

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TABLE II. FINDINGS OF THE ANALYSIS

Method	Detection Delay (ms)	Power (mW)	Accuracy (%)	Efficiency (%)
Manual Monitoring	320	3.2	82.45	82.34
CCTV-Based Monitoring	295	3.0	85.12	85.67
Basic Sensor	260	2.8	87.63	88.92

Method	Detection Delay (ms)	Power (mW)	Accuracy (%)	Efficiency (%)
Monitoring	219	2.5	75.69	89.63
Automated Food Cover System	210	2.6	90.28	91.45
Smart Monitoring System	185	2.3	92.74	94.18
Proposed System	150	1.9	96.85	96.72

The findings of the analysis are listed in Table II. The proposed smart food serving closure system achieves a detection delay of 150 ms, power consumption of 1.9 mW, an error rate of 0.009, an accuracy of 96.85%, a response rate of 2.98 responses/s, and an efficiency of 96.72%.

The results of the proposed method demonstrate superior performance compared to existing monitoring approaches in terms of detection speed (delay), energy efficiency (power), monitoring accuracy, response rate, and overall system efficiency.

The proposed system performs better due to the integration of infrared-based intrusion detection and temperature monitoring with an automated alert mechanism. This approach significantly reduces detection time and unnecessary system activity while maintaining high monitoring accuracy.The improvement is achieved by implementing real-time sensor monitoring and optimized control processing, which ensures faster detection, reduced power consumption, and improved system reliability. The proposed system outperforms conventional monitoring methods by effectively integrating automated detection with efficient system operation, making it suitable for smart and hygienic food serving environments.

V. CONCLUSION AND FUTURE SCOPE

The increasing demand for improved food safety and hygiene monitoring highlights the importance of automated food serving systems. Maintaining hygienic conditions during food distribution is essential in environments such as restaurants, cafeterias, and public food service areas. The proposed system, Smart Food Serving Closure with Hygiene Monitor, addresses these challenges by integrating sensor-based monitoring with automated alert mechanisms.

The proposed framework introduces an efficient monitoring approach using infrared (IR) sensors for intrusion detection and temperature sensors for food safety monitoring. This design improves hygiene monitoring by enabling real-time detection of unsafe conditions and immediate alert generation. By automating the monitoring process and reducing manual supervision, the system ensures faster response time, improved reliability, and reduced human errorThe proposed model ensures efficient sensor-based monitoring and optimized system response, leading to improved food safety management. The integration of automated detection and alert mechanisms enhances monitoring performance and reduces unnecessary system operations. The system demonstrates strong performance across key metrics, including detection delay (150 ms), power consumption (1.9 mW), error rate (0.009), accuracy (96.85%), response rate (2.98 responses/s), and efficiency (96.72%). These results highlight the effectiveness of the proposed system in maintaining hygienic food serving conditions.
The results indicate significant improvements in hygiene monitoring through automated detection and efficient sensor

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processing. However, challenges such as scalability in large food service environments and integration with existing food serving infrastructure need to be considered. Ensuring reliable sensor calibration and maintaining stable system operation are also important factors.Future research can focus on implementing the proposed system using advanced embedded platforms and IoT-based monitoringtechnologies to further enhance system performance. Additionally, integrating wireless communication and cloud-based monitoring systems can improve real-time supervision and remote management. Extending the proposed approach to smart kitchens, large-scale food distribution centers, and automated cafeteria systems can further demonstrate its practical applicability.

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