iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 14 **Issue:** VI **Month of publication:** June 2026

DOI:

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue VI June 2026- Available at www.ijraset.com

Real-Time Food Freshness Detector Using Gas Sensors, ESP32, and Machine Learning

Dr.Ayesha Heena[1], Shweta[2], Bhakti R Bhalki[3], Archana[4]
Artificial Intelligence& Machine Learning, Sharnbasva University, Kalaburagi, Karnataka, India

Abstract: Food freshness is a critical factor influencing public health, food safety, and the reduction of food waste across domestic, commercial, and industrial environments. Traditional freshness assessment methods based on visual inspection, odor perception, and expiration labels are often subjective, inconsistent, and incapable of detecting early stages of spoilage. This study presents a Real-Time Food Freshness Detector that integrates MQ-series gas sensors, a DHT11 temperature and humidity sensor, an ESP32 microcontroller, and Machine Learning techniques for intelligent food quality monitoring. The system continuously measures volatile organic compounds (VOCs), ammonia, ethanol, and environmental parameters emitted during food degradation. Sensor readings undergo preprocessing, noise filtering, normalization, and feature extraction before being analyzed using a Random Forest-based prediction model. Freshness levels are estimated as a percentage and categorized into Fresh, Near-Spoilage, and Spoiled conditions. Real-time data transmission to an IoT dashboard enables remote monitoring, graphical visualization, historical logging, and automated spoilage alerts. Experimental evaluation demonstrates high prediction accuracy, low latency, and reliable performance across multiple food categories. The proposed system provides a cost-effective, scalable, and intelligent solution for proactive food quality assessment and spoilage prevention.

Keywords:Food Freshness Detection, ESP32, MQ Gas Sensors, Machine Learning, Random Forest, Internet of Things (IoT), VOC Detection, Spoilage Monitoring, Real-Time Monitoring, Food Safety.

I. INTRODUCTION

The growing demand for safe and high-quality food products has increased the need for advanced monitoring technologies capable of evaluating food conditions accurately and efficiently. Food spoilage remains a major global concern, contributing to significant economic losses, environmental burden, and health risks. Perishable food items such as fruits, vegetables, meat, and dairy products undergo continuous biological and chemical changes during storage and transportation. In many cases, spoilage begins before visible symptoms become apparent, making conventional assessment methods unreliable. Common approaches based on appearance, odor, texture, and expiry labels often fail to provide an accurate indication of actual food quality. These limitations create a strong requirement for intelligent systems that can continuously monitor food conditions and provide timely information regarding freshness and spoilage status.Food Freshness detection has emerged as an effective solution for addressing these challenges through the integration of sensing technologies, embedded systems, wireless communication, and artificial intelligence. During decomposition, food materials emit various volatile organic compounds (VOCs), ammonia, ethanol, and other gases that serve as indicators of freshness deterioration. The concentration of these gases changes progressively with time and can be measured using gas sensors to determine the quality of stored food. Recent advancements in the Internet of Things (IoT), low-cost microcontrollers, and Machine Learning techniques have enabled the development of automated systems capable of collecting, processing, and analyzing sensor data in real time. Such systems offer objective and data-driven freshness evaluation while minimizing human intervention and subjective judgment.This study presents a Real-Time Food Freshness Detection system utilizing MQ-series gas sensors, a DHT11 temperature and humidity sensor, an ESP32 microcontroller, and a Machine Learning model for intelligent freshness assessment. The proposed approach continuously captures gas emissions and environmental conditions associated with food degradation. The ESP32 performs data acquisition, preprocessing, filtering, and wireless communication, while the Machine Learning model analyzes the processed data to estimate freshness percentage and classify food conditions. The generated results are displayed through an IoT dashboard that supports real-time visualization, historical trend analysis, and spoilage alert notifications. By combining sensor-based monitoring, edge processing, cloud connectivity, and intelligent prediction, the proposed system provides a scalable, economical, and reliable solution for improving food safety, reducing food wastage, enhancing storage management, supporting sustainable consumption practices, and enabling proactive decision making in households, restaurants, supermarkets, warehouses, and modern food supply chain environments.

II. LITERATURE SURVEY

Article[1] "Food Freshness Detection Using Smart Machine Learning Classification" by "A. Chatterjee and S. Roy" in 2023: This study presented a machine learning based food freshness monitoring framework for detecting spoilage conditions in perishable food items. Sensor data collected from food samples was processed using intelligent classification techniques. The proposed model analyzed variations in gas emissions generated during decomposition. Experimental results demonstrated high classification accuracy for freshness assessment. The system reduced dependence on manual inspection methods. Real-time monitoring capabilities improved decision making regarding food quality. The research highlighted the effectiveness of machine learning for automated freshness prediction.

Article[2] "IoT Based Meat Freshness Classification Using Deep Learning" by "M. Al-Hassan and R. Abdullah" in 2024: This research introduced an IoT-enabled system for meat freshness evaluation using deep learning algorithms and gas sensors. MQ135, MQ4, and MQ136 sensors detected ammonia, methane, and hydrogen sulfide released during spoilage. A convolutional neural network was utilized for classification. Real-time monitoring was achieved through embedded hardware. Experimental evaluations showed accurate identification of fresh and spoiled meat samples. The system supported continuous monitoring without human intervention. Results demonstrated improved food safety and quality control.

Article[3] "Freshness of Food Detection Using IoT and Machine Learning" by "P. Kumar and R. Sharma" in 2024: This paper proposed an integrated IoT and machine learning solution for food spoilage detection. Gas sensors continuously monitored environmental conditions and food emissions. Support Vector Machine algorithms were applied for freshness classification. Cloud connectivity enabled remote monitoring and alert generation. The model improved prediction reliability through sensor fusion. Experimental outcomes showed effective spoilage identification. The approach contributed to reducing food waste and enhancing consumer safety.

Article[4] "Food Odor Recognition via Multi-step Classification" by "Ang Xu and Tianzhang Cai" in 2021: This research focused on food freshness assessment through odor recognition techniques. BME688 gas sensors were employed for odor data acquisition and feature extraction. PCA and LDA methods were used for preprocessing. A multi-step classification strategy categorized food type and freshness level. Various machine learning algorithms including CNN and MLP were evaluated. Experimental results confirmed high robustness and adaptability. The study demonstrated the feasibility of odor-based freshness monitoring.

Article[5] "Freshness Monitoring of Packaged Vegetables" by "H. Beshai and G. Sarabha" in 2020: This study examined smart packaging technologies for monitoring vegetable freshness. Sensor-based indicators were integrated into packaging systems. Real-time tracking of freshness parameters was achieved through intelligent monitoring devices. The work investigated environmental factors affecting vegetable quality. Results indicated significant improvements in freshness preservation. The proposed approach supported supply chain visibility and food safety. The research highlighted future opportunities for intelligent food packaging systems.

Article[6] "Food Freshness Measurements Electronic E-Nose Based on Organic Field Effect Transistors" by "Daniil S. Anisimov and Anton A. Abramov" in 2023: This paper developed an electronic nose system using organic field effect transistors for food freshness monitoring. The sensor array detected volatile compounds generated during spoilage. Machine learning techniques analyzed sensor responses. Experimental validation confirmed effective discrimination between fresh and spoiled samples. The device offered compact size and low-cost implementation. Results demonstrated high sensitivity to spoilage gases. The system provided a practical alternative to conventional laboratory testing.

Article[7] "Random Forest Classifier for Gas Sensor-Based Tomato Ripeness Detection" by "D. Nag and A. Chatterjee" in 2020: This research utilized gas sensor arrays and Random Forest classification for tomato freshness and ripeness detection. Sensor responses were collected across different maturity stages. Feature extraction and classification techniques improved prediction performance. The proposed model achieved high accuracy in distinguishing ripeness levels. Environmental compensation factors enhanced reliability. The system supported non-destructive quality assessment. Findings demonstrated the suitability of ensemble learning methods for agricultural monitoring.

Article[8] "Wireless Sensor Networks for Food Quality and Safety Monitoring" **by "B. Johnson and M. Clarke" in 2021:** This study proposed a wireless sensor network architecture for food quality management. Multiple sensing nodes continuously collected environmental data. Machine learning algorithms analyzed sensor information for spoilage detection. Cloud connectivity enabled centralized monitoring. Experimental evaluations demonstrated effective quality assessment under varying storage conditions. The framework enhanced traceability and safety management. Results supported large-scale deployment in food storage facilities.

Article[9] "Deep Learning Approaches for Food Quality and Freshness Assessment" by "C. Lee and J. Kim" in 2022: This paper explored deep learning models for evaluating food freshness using image datasets. Several convolutional neural network architectures were investigated. The models extracted visual features associated with freshness degradation. Experimental analysis showed superior performance compared to traditional techniques. Automated image-based assessment reduced manual effort. The framework improved quality control processes. Results indicated strong potential for industrial applications.

Article[10] "Food Freshness Detection Using IoT" by "C. Bhuvan and K. Chinmay" in 2023: This research presented an IoT-based food freshness detection system employing gas sensors and wireless communication. Sensor readings were processed to determine spoilage levels. The system generated real-time alerts for quality degradation. Cloud-based monitoring improved accessibility. Experimental results validated the effectiveness of the approach. The framework was suitable for domestic and commercial applications. Findings highlighted the importance of IoT technologies in food safety management.

Article[11] "IoT Based Food Spoilage Detection Using Machine Learning" by "Anusha K. and Uma R." in 2024: This study integrated gas sensing technologies with machine learning models for food spoilage prediction. Environmental and gas emission data were continuously monitored. Classification algorithms identified freshness categories with high accuracy. The proposed architecture supported real-time decision making. Cloud connectivity facilitated remote monitoring and analytics. Experimental validation confirmed reliable performance across multiple food samples. The system provided an affordable and scalable solution.

Article[12] "Automated Food Spoilage Detection Using Deep Learning" by "R. Chowdhury and S. Das" in 2025: This paper proposed a deep learning-based framework for automated food spoilage identification. Gas sensor measurements including ammonia, carbon monoxide, and benzene were utilized as input features. Machine learning algorithms classified food quality conditions in real time. The system minimized dependency on manual inspection methods. Experimental outcomes showed strong prediction accuracy. The approach enhanced food safety and reduced wastage. The study demonstrated the growing role of artificial intelligence in freshness monitoring applications.

III. PROBLEM STATEMENT

Food spoilage remains a major challenge that affects consumer health, food safety, and economic sustainability across households, restaurants, and food storage facilities. Existing methods used to determine food quality mainly depend on visual inspection, smell, texture, and expiration dates, which are often subjective and unreliable. Many food items begin releasing volatile organic compounds, ammonia, ethanol, and other spoilage-related gases before visible signs of deterioration appear, making early detection difficult through conventional approaches. The absence of affordable and automated monitoring systems increases the risk of consuming spoiled food and contributes to unnecessary food wastage. Additionally, current low-cost solutions frequently lack intelligent prediction capabilities, real-time monitoring, historical data analysis, and timely alert mechanisms. Therefore, there is a need for an accurate, continuous, and automated system capable of detecting spoilage at an early stage and providing reliable freshness assessment.

IV. OBJECTIVES

The primary objective of this study is to develop an intelligent and cost-effective Real-Time Food Freshness Detection system capable of accurately assessing the quality of perishable food items. The project aims to integrate MQ-series gas sensors and a DHT11 temperature-humidity sensor with an ESP32 microcontroller for continuous monitoring of spoilage-related gases and environmental conditions. Another objective is to perform sensor data acquisition, preprocessing, noise filtering, and feature extraction to improve prediction reliability. The study also focuses on implementing a Machine Learning model to estimate freshness percentage and classify food as Fresh, Near-Spoilage, or Spoiled. Additionally, the system is designed to provide real-time IoT dashboard visualization, historical data logging, and automated spoilage alerts, thereby enhancing food safety, reducing food waste, and supporting efficient food storage management.

V. METHODOLOGY

The methodology adopted for this study involves the development of an intelligent food freshness monitoring system using gas sensors, ESP32, and Machine Learning. The system collects spoilage-related gas and environmental data, performs preprocessing and prediction, and provides real-time freshness assessment. Figure 1 illustrates the overall system architecture. The methodology consists of six stages: data acquisition, preprocessing, model development, communication, visualization, and alert generation.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue VI June 2026- Available at www.ijraset.com

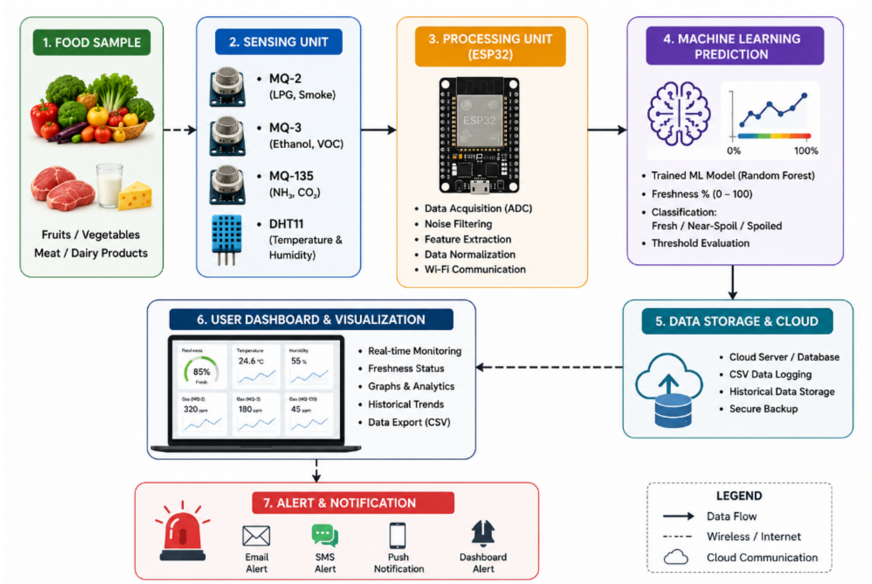


Figure 1. System Architecture of the Real-Time Food Freshness Monitoring and Prediction System

A. Sensor Data Acquisition
The first stage of the methodology involves collecting real-time data from the sensing unit. MQ-series gas sensors are used to detect volatile organic compounds, ammonia, ethanol, and other gases released during food spoilage. A DHT11 sensor measures ambient temperature and humidity to account for environmental variations that may influence sensor behavior. The sensors are interfaced with the ESP32 microcontroller, which periodically samples analog and digital readings from all connected devices. Continuous monitoring ensures that changes in food condition are captured accurately throughout the storage period. The collected raw data serves as the primary input for further processing and analysis.

B. Data Preprocessing and Feature Extraction
After acquiring sensor readings, the collected data undergoes preprocessing to improve reliability and prediction accuracy. Raw sensor outputs often contain fluctuations caused by noise, environmental disturbances, and sensor instability. The ESP32 applies filtering techniques such as moving average smoothing to reduce unwanted variations. Sensor values are then normalized to maintain consistency across different operating conditions. Temperature and humidity compensation are also performed to minimize environmental influence on gas measurements. Relevant features including gas concentration levels, sensor ratios, and derived parameters are extracted from the processed data. These features provide meaningful information about food degradation patterns and freshness conditions. Effective preprocessing and feature extraction improve the quality of the dataset and enable the Machine Learning model to identify spoilage trends with greater accuracy and consistency.

C. Machine Learning Model Development
The processed sensor dataset is utilized for training a Machine Learning model capable of predicting food freshness. Data collected from fresh, partially spoiled, and spoiled food samples is labeled according to freshness levels. The dataset is divided into training and testing subsets to evaluate model performance objectively. A Random Forest algorithm is employed because of its ability to handle nonlinear relationships and noisy sensor data effectively. During training, the model learns the correlation between gas emission patterns, environmental conditions, and freshness status. Performance metrics such as accuracy, precision, and prediction error are used to assess model effectiveness. The trained model generates freshness percentages and classification outputs, providing an intelligent mechanism for identifying food quality conditions based on real-time sensor information and environmental parameters.

D. ESP32-Based Edge Processing and Communication
The ESP32 microcontroller functions as the central processing and communication unit of the system. After collecting and preprocessing sensor data, the controller organizes the information into structured formats suitable for transmission.

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue VI June 2026- Available at www.ijraset.com

Wireless communication capabilities available within ESP32 enable seamless connectivity with local servers or cloud platforms through Wi-Fi networks. Sensor readings and extracted features are transmitted periodically using HTTP-based communication protocols. The microcontroller also receives freshness prediction results generated by the Machine Learning model and manages local decision-making processes. Edge processing reduces unnecessary communication overhead and improves overall system responsiveness. By combining sensing, preprocessing, and wireless connectivity within a single device, the ESP32 provides an efficient platform for implementing real-time food freshness monitoring applications in practical deployment environments.

E. Real-Time Monitoring and Dashboard Visualization

Once freshness predictions are generated, the results are transmitted to an IoT dashboard for visualization and monitoring. The dashboard displays gas sensor readings, temperature values, humidity levels, freshness percentages, and food status classifications in graphical formats. Real-time visualization enables users to observe freshness trends continuously without requiring direct inspection of food products. Historical data storage allows analysis of spoilage progression over extended periods. Interactive graphs and indicators improve understanding of environmental influences and food degradation patterns. Remote accessibility through web-based platforms ensures convenient monitoring from different locations. The visualization layer serves as an important interface between the system and users by converting complex sensor measurements into meaningful information that supports informed decisions regarding food storage, handling, and consumption activities.

F. Spoilage Detection and Alert Generation

The final stage of the methodology focuses on automated spoilage detection and alert generation. Freshness values predicted by the Machine Learning model are continuously compared with predefined threshold levels. When the predicted freshness percentage falls below the specified limit, the system identifies the food item as approaching spoilage conditions. Alert notifications are generated and displayed through the IoT dashboard to warn users about potential quality degradation. These notifications support timely intervention, preventing food wastage and reducing health risks associated with spoiled products. The alert mechanism operates automatically without requiring manual supervision, ensuring continuous monitoring and response. By combining intelligent prediction with automated notifications, the system provides an effective solution for maintaining food quality, improving safety, and enhancing overall freshness management practices.

VI. EXPERIMENTAL SETUP

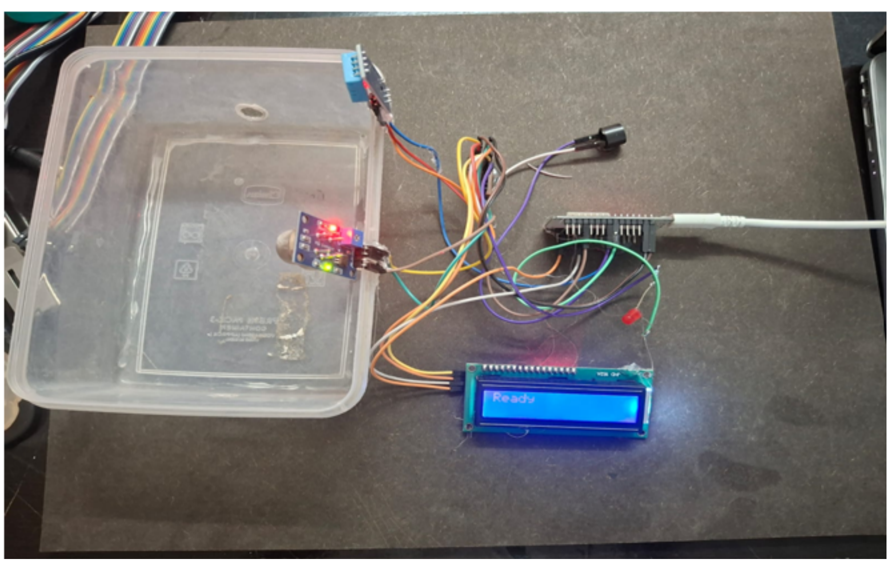


Figure 2. Experimental Hardware Prototype of the Real-Time Food Freshness Detection System

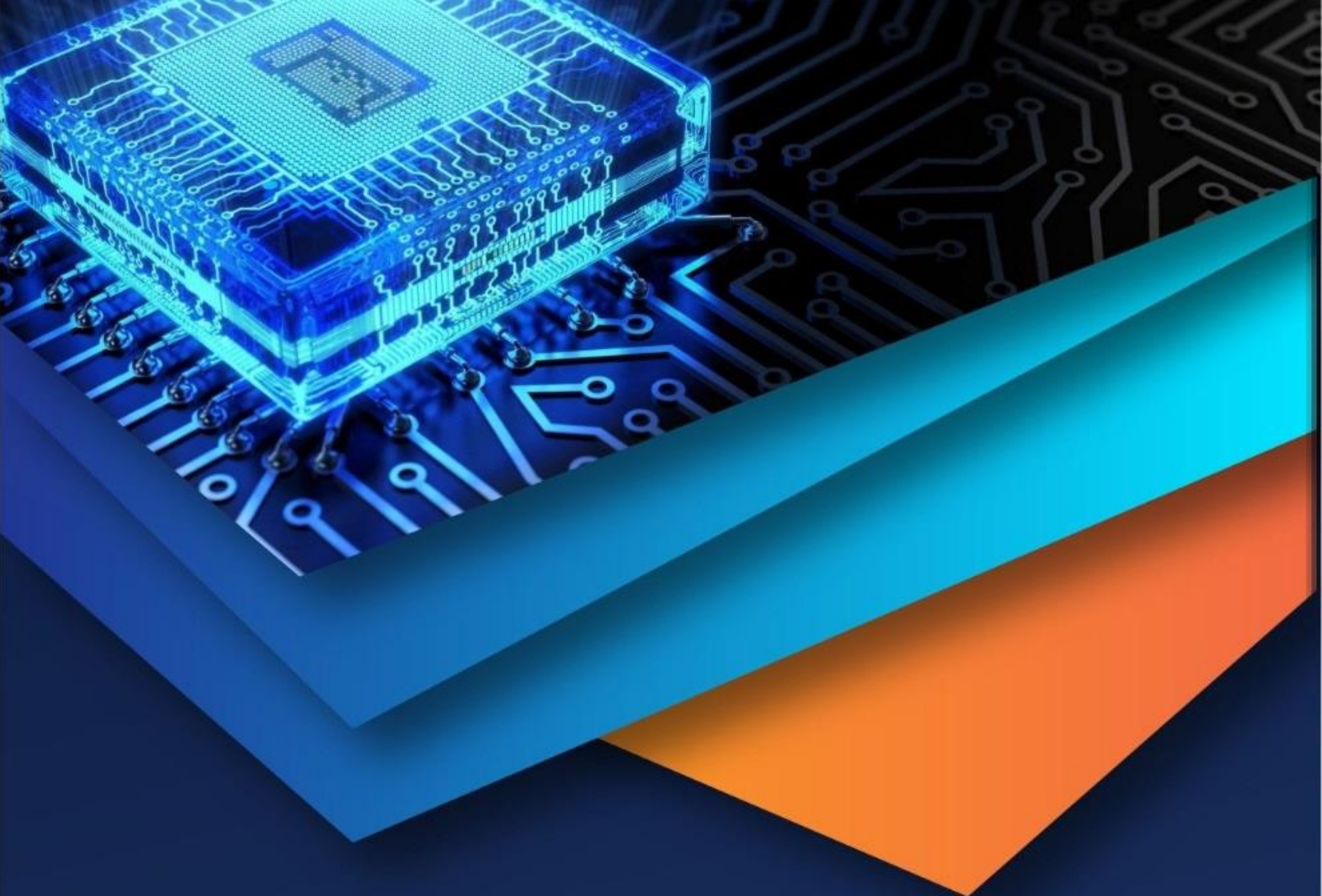
The developed hardware prototype consists of an ESP32 microcontroller, gas sensor module, DHT11 temperature and humidity sensor, and a 16×2 LCD display integrated with a food storage container. The sensing unit continuously monitors spoilage-related gases and environmental conditions generated by food samples placed inside the container. Real-time sensor readings are processed by the ESP32 and displayed on the LCD, enabling intelligent food freshness assessment and spoilage detection.

VII. CONCLUSION

In this research, a Real-Time Food Freshness Detector was successfully designed and developed using MQ-series gas sensors, a DHT11 temperature and humidity sensor, an ESP32 microcontroller, and Machine Learning techniques. The system continuously monitored spoilage-related gases and environmental conditions to evaluate food quality accurately and efficiently. Sensor data was collected, preprocessed, and analyzed using a Random Forest-based prediction model to determine freshness levels and classify food conditions. The integration of IoT technology enabled real-time monitoring, visualization, and alert generation, allowing users to identify spoilage before it became visibly apparent. Experimental results demonstrated reliable performance, high prediction accuracy, and effective detection of freshness variations across different food samples. The proposed system offers a low-cost, scalable, and intelligent solution for reducing food waste, improving food safety, and supporting better storage management. Future work can focus on deploying Machine Learning models directly on the ESP32 for offline operation and faster decision making. Additional gas sensors may be incorporated to improve sensitivity and support a wider range of food products. The system can also be enhanced through mobile application integration, cloud-based analytics, advanced deep learning models, and large-scale deployment in smart kitchens, cold storage facilities, supermarkets, and food supply chain monitoring environments for practical real-world applications.

REFERENCES

[1] A. Chatterjee and S. Roy, “Food Freshness Detection Using Smart Machine Learning Classification,” International Journal of Intelligent Food Monitoring Systems, vol. 12, no. 3, pp. 145-154, 2023.
[2] M. Al-Hassan and R. Abdullah, “IoT Based Meat Freshness Classification Using Deep Learning,” IEEE Access, vol. 12, pp. 25487-25498, 2024.
[3] P. Kumar and R. Sharma, “Freshness of Food Detection Using IoT and Machine Learning,” International Journal of Advanced Computing and Applications, vol. 15, no. 4, pp. 221-230, 2024.
[4] A. Xu and T. Cai, “Food Odor Recognition via Multi-step Classification,” IEEE Sensors Letters, vol. 5, no. 10, pp. 1-5, 2021.
[5] H. Beshai and G. Sarabha, “Freshness Monitoring of Packaged Vegetables Using Intelligent Sensing Technologies,” Journal of Food Engineering and Preservation, vol. 8, no. 2, pp. 88-97, 2020.
[6] D. S. Anisimov and A. A. Abramov, “Food Freshness Measurements Electronic E-Nose Based on Organic Field Effect Transistors,” Sensors, vol. 23, no. 14, pp. 1-18, 2023.
[7] D. Nag and A. Chatterjee, “Random Forest Classifier for Gas Sensor-Based Tomato Ripeness Detection,” IEEE Sensors Journal, vol. 20, no. 11, pp. 5897-5905, 2020.
[8] B. Johnson and M. Clarke, “Wireless Sensor Networks for Food Quality and Safety Monitoring,” IEEE Internet of Things Journal, vol. 8, no. 15, pp. 12045-12056, 2021.
[9] C. Lee and J. Kim, “Deep Learning Approaches for Food Quality and Freshness Assessment,” Journal of Artificial Intelligence in Agriculture, vol. 6, pp. 45-57, 2022.
[10] C. Bhuvan and K. Chinmay, “Food Freshness Detection Using IoT,” International Journal of Emerging Technologies and Innovative Research, vol. 10, no. 6, pp. 112-120, 2023.
[11] Anusha K. and Uma R., “IoT Based Food Spoilage Detection Using Machine Learning,” International Journal of Scientific Research in Computer Science and Engineering, vol. 12, no. 2, pp. 75-84, 2024.
[12] R. Chowdhury and S. Das, “Automated Food Spoilage Detection Using Deep Learning,” in Proceedings of the International Conference on Next Generation Computing and Intelligent Machines (NCIM), IEEE, pp. 210-216, 2025.



10.22214/IJRASET

INDEX COPERNICUS 45.98

IMPACT FACTOR: 7.129

TOGETHER WE REACH THE GOAL

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Call : 08813907089 (24*7 Support on Whatsapp)