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IOT based Food Spoilage Detection System

Sadiya, Disha, Megha, Priyanka
Students, Department of Computer Engineering
Pimpri Chinchwad Polytechnic, Pune, India

Abstract: *Food spoilage is a major public health and food safety concern, and traditional manual freshness checking is often subjective, inconsistent, and time-consuming. This project presents an IoT-based food freshness monitoring system that detects early spoilage by continuously sensing gases and environmental conditions around stored food. The system uses MQ-3 and MQ-135 gas sensors to identify spoilage-related volatile compounds, along with a DHT11 sensor to measure temperature and humidity. An ESP32 microcontroller collects and processes the sensor readings in real time, displays live values locally on an OLED screen, and hosts an IP-based web dashboard for quick monitoring over a local network. Based on predefined threshold logic, the system classifies food quality into three levels—Fresh, Average, or Stale enabling faster and more reliable decision-making. For remote access and historical tracking, the ESP32 transmits live sensor data to Firebase Realtime Database, where it is stored as both current values and time-stamped records. A companion Android application retrieves this data to display real-time readings, food quality status, and history trends, providing a practical solution for smart kitchens, food storage units, and small-scale food quality control environments.*

Keywords: Food Freshness Monitoring, Food Spoilage Detection, Internet of Things (IoT), ESP32, MQ-3 Gas Sensor, MQ-135 Gas Sensor, DHT11, OLED Display, Web Dashboard, Firebase Realtime Database, Android Application, Real-Time Monitoring, Sensor Threshold Classification, Smart Food Storage, Food Quality Control

I. INTRODUCTION

Food spoilage is one of the most common causes of food-borne illness, unnecessary waste, and financial loss in homes, hostels, restaurants, supermarkets, and food storage units. In many real-world situations, freshness is still judged using manual methods such as smell, color, taste, or expiry date checks. These methods are not always reliable because spoilage can begin before visible changes appear, and different foods spoil at different rates depending on temperature, humidity, and storage conditions. As a result, manual checking becomes time-consuming, inconsistent, and sometimes unsafe.

When food starts to spoil, it releases specific gases and volatile compounds due to microbial activity and chemical breakdown. Detecting these gases gives an early indication of deterioration even when the food looks normal. This is where IoT (Internet of Things) becomes useful by using sensors to continuously monitor spoilage indicators and instantly report changes, we can make freshness checking faster, more accurate, and fully automated.

This project proposes an IoT-based Food Freshness Monitoring System that continuously monitors food storage conditions using gas sensors (MQ-3 and MQ-135) and an environmental sensor (DHT11). The ESP32 microcontroller reads sensor values in real time and uses predefined threshold logic to classify food quality into three categories: Fresh, Average, or Stale. The system also provides multiple ways to view the data:

- Local display on an OLED screen for quick on-site monitoring,
- An IP-based web dashboard hosted directly by the ESP32 for network viewing,
- Remote monitoring and history storage using Firebase Realtime Database, and
- A companion Android application that shows live readings, food status, and past records.

By combining real-time sensing, automatic classification, and cloud-based logging, this system helps users detect spoilage early, reduce food waste, and improve food safety. It is especially useful for smart kitchens, small food businesses, storage rooms, and any environment where continuous freshness monitoring is needed without depending on manual inspection.

II. LITERATURE SURVEY

K. Anusha, K. Uma, K. Jayasri, S. Kambham, and S. D. Dandamudi, "*IoT Based Food Spoilage Detection using Machine Learning Techniques*," 2024 International Conference on Advances in Computing, Communication and Applied Informatics (ACCAI), 2024, doi: 10.1109/ACCAI61061.2024.10602355. Findings: Demonstrates IoT + ML classification for spoilage detection and reports improved performance using standard metrics (precision/recall/F1).

B. V. Sai Nithin, K. S. Nithin, B. Sneha, and V. V. Kumar, "*Non-Destructive Approach for Detection of Food Freshness using IoT*," 2023 International Conference on Inventive Computation Technologies (ICICT), 2023, doi: 10.1109/ICICT57646.2023.10134232.

Findings: Presents a non-destructive IoT approach for freshness assessment, focusing on practical sensing + monitoring without damaging the food sample.

X. Ren, Y. Wang, Y. Huang, D. Sun, L. Xu, and F. Wu, "*E-nose System Using CNN and Abstract Odor Map to Classify Meat Freshness*," 2023 IEEE 6th Information Technology, Networking, Electronic and Automation Control Conference (ITNEC), pp. 1200–1204, 2023, doi: 10.1109/ITNEC56291.2023.10082128. Findings: Uses sensor-response pattern mapping ("odor map") + CNN to classify freshness, showing how ML improves discrimination versus raw-threshold logic.

X. Ren et al., "*A CNN-based E-nose using Time Series Features for Food Freshness Classification*," IEEE Sensors Journal, 2023, doi: 10.1109/JSEN.2023.3241842. Findings: Models e-nose signals as time-series features and applies CNN to improve classification reliability for freshness levels.

J. Luo, Z. Zhu, W. Lv, J. Wu, J. Yang, M. Zeng, N. Hu, Y. Su, R. Liu, and Z. Yang, "*E-Nose System Based on Fourier Series for Gases Identification and Concentration Estimation From Food Spoilage*," IEEE Sensors Journal, vol. 23, no. 4, 2023. Findings: Converts sensor signals into Fourier-based representations for robust gas identification and concentration estimation relevant to spoilage gases.

Y. Yang et al., "*A Low Power Single-Cantilever Gas Sensor Cell with Remarkable Recognition Capability for Food Freshness Related Gases*," 2024 IEEE SENSORS Conference, 2024, doi: 10.1109/SENSORS60989.2024.10785242. Findings: Proposes a low-power sensing approach targeting freshness-related gases—useful for long-running battery-powered monitoring devices.

Z. W. Bhuiyan, S. A. R. Haider, A. Haque, M. R. Uddin, and M. Hasan, "*IoT Based Meat Freshness Classification Using Deep Learning*," IEEE Access, 2024, doi: 10.1109/ACCESS.2024.3520029. Findings: Shows an IoT pipeline with deep learning for freshness classification, highlighting better robustness than manual inspection and simple thresholds.

M. R. M. Setyagraha and H. A. Nurqamaradillah, "*A Portable Real-Time Electronic Nose for Evaluating Seafood Freshness Using Machine Learning*," IEEE Access, 2025, doi: 10.1109/ACCESS.2025.3577128. Findings: Presents a portable e-nose with ML models for real-time seafood freshness evaluation, emphasizing practical deployment and real-time inference.

III. METHODOLOGY

The proposed IoT-based food freshness monitoring system follows a step-by-step methodology that converts real-world spoilage signals (gases + environment) into an easy freshness decision (Fresh/Average/Stale) and then makes the result available locally and remotely.

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1) System Initialization and Hardware Configuration

When the system is powered ON, the ESP32 initializes all connected modules including MQ-3, MQ-135, DHT11, OLED display, Wi-Fi network settings, Firebase configuration, and the web server. Since MQ gas sensors require stabilization, the system performs a short warm-up phase to avoid incorrect readings at startup.

2) Sensor Data Acquisition (Real-Time Sensing)

After initialization, the ESP32 continuously reads sensor values at a fixed time interval. MQ-3 and MQ-135 provide analog values representing the concentration of spoilage-related gases in the surrounding air. The DHT11 provides temperature and humidity readings, which are important because food spoilage accelerates in high temperature and high humidity conditions. Continuous sensing ensures real-time monitoring instead of periodic manual checking.

3) Noise Reduction and Data Conditioning

Raw sensor outputs can fluctuate due to electrical noise, airflow changes, and sensor drift. To improve reliability, the system applies basic data conditioning such as taking multiple samples and calculating an average (or using a simple moving average). This makes the classification stable and reduces false triggering.

4) Spoilage Estimation and Freshness Classification

The processed sensor readings are compared with predefined threshold levels. MQ sensor values indicate gas intensity, and DHT11 values indicate storage conditions. Using this logic, the system assigns a food freshness state:

Fresh: gas levels are low and stable; environment is within normal range.

Average: moderate rise in gas levels or unfavourable environment indicating early spoilage risk.

Stale: high gas concentration beyond limits indicating strong spoilage presence.

This classification approach is simple, fast, and suitable for real-time embedded execution on ESP32.

5) Local Display and User Feedback

The latest sensor readings and freshness label are shown on the OLED display. This provides instant on-device feedback without depending on the internet. Users can quickly check food quality near the storage container or monitoring unit.

6) IP-Based Web Dashboard Monitoring

To support local network monitoring, ESP32 hosts a web dashboard using its IP address. The dashboard displays live MQ-3, MQ-135, temperature, humidity, and freshness status. This allows multiple devices (mobile/laptop) on the same network to view the system status in real time.

7) Cloud Upload and Data Logging in Firebase

For remote access and historical analysis, the ESP32 sends data to Firebase Real-time Database. Two types of storage are used:

Live Data Node: stores the most recent sensor values and current freshness status (overwritten continuously).

History Node: stores time-stamped logs of readings for tracking trends and reviewing past spoilage patterns.

This ensures both real-time monitoring and permanent record maintenance.

8) Android Application for Live and History Monitoring

The Android application fetches data from Firebase and presents it in a user-friendly format. It shows real-time values along with freshness status and also displays historical records (date/time-based). This enables remote monitoring from anywhere, making the system practical for homes, restaurants, hostels, and food storage areas.

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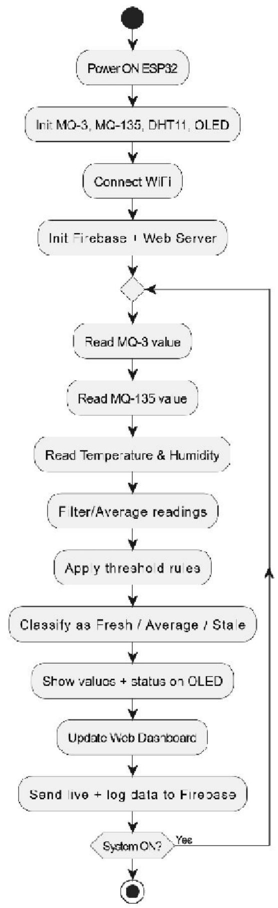

Fig: Flow Diagram

IV. RESULT & DISCUSSION

The developed IoT-based food freshness monitoring system successfully collected real-time readings from MQ-3, MQ-135, and DHT11 sensors using ESP32. The system displayed live values on the OLED, hosted an IP-based web dashboard, and uploaded both live + history records to Firebase Real-time Database, which were then visible in the
During testing, the sensor readings showed clear variation across different food conditions. In a fresh condition (newly stored food and normal surrounding air), gas sensor values remained low and stable, and the system consistently classified the quality as Fresh. In the intermediate stage (food stored for some time or kept in slightly warmer/humid conditions), gas readings increased moderately and the classification changed to Average. When spoilage became significant (strong odor, longer storage time, or unfavourable temperature/humidity), MQ sensor values increased sharply and the system marked the quality as Stale.

Discussion

The observations confirm that spoilage gases increase as food degrades, and MQ sensors provide a reliable indication of this change. The DHT11 readings helped explain faster spoilage transitions when temperature and humidity were higher, validating the importance of environmental monitoring. The threshold-based logic worked well for a practical prototype because it is fast, simple, and suitable for real-time embedded execution on ESP32.

The OLED and web dashboard provided immediate local monitoring, while Firebase logging enabled remote access and historical tracking. This combination makes the system useful for both household use and small-scale commercial food storage environments. A key finding was that gas sensor readings can fluctuate due to airflow and sensor drift, so averaging/filtering improved stability. For future enhancement, a machine learning model could replace thresholds for better accuracy across different food types.

Test Condition	MQ-3 (ADC)	MQ-135 (ADC)	Temp (°C)	Humidity (%)	Output Status
Fresh food / normal air	180–260	220–320	24–28	45–60	Fresh
Stored for few hours / mild odor	260–420	320–520	28–32	55–70	Average
Spoiled / strong odor	420–700	520–900	30–36	60–85	Stale

The table summarizes typical sensor behavior observed during testing. In the Fresh stage, MQ sensor ADC values stayed in lower ranges. As spoilage started, both MQ-3 and MQ-135 values increased, leading to the Average classification. When spoilage became high, the readings crossed upper thresholds and the system classified the food as Stale. Temperature and humidity trends also supported the results by showing faster spoilage progression in warmer and more humid conditions.

V. CONCLUSION

This project successfully demonstrates an IoT-based food freshness monitoring system that can detect spoilage trends using gas sensors (MQ-3, MQ-135) and an environment sensor (DHT11). The ESP32 continuously reads sensor values, applies threshold-based logic to classify food quality as Fresh, Average, or Stale, and provides real-time visibility through multiple interfaces OLED display, ESP32 IP-based web dashboard, and a cloud-connected Android application. Using Firebase Realtime Database, the system stores both live readings and historical logs, enabling remote monitoring and trend tracking. Overall, the solution reduces dependency on manual inspection, improves safety and decision-making, and offers a low-cost, scalable approach for smart kitchens, hostels, restaurants, and small food storage environments. Future enhancement can include ML-based classification to improve accuracy across different food types and storage conditions.

VI. ACKNOWLEDGMENT

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