Journal of Emerging Trends and Novel Research
JETNR.ORG | ISSN : 2984-9276
An International Open Access, Peer-reviewed, Refereed Journal

IoT-Based Food Spoilage Detection System

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Abstract

Food spoilage is a growing concern that causes large financial losses, health hazards, and unnecessary wastage of resources. The proposed IoT-based Food Spoilage Detection System aims to monitor and analyze environmental conditions that influence food freshness. The system is built using an ESP32 microcontroller connected with sensors such as DHT11 for temperature and humidity, a moisture sensor, and a pH sensor to detect chemical or microbial changes in food. A 16x2 LCD shows real-time readings, and the data is wirelessly sent to an Android application and web dashboard for remote observation. When the sensor values go beyond the defined safety limits, the system triggers a buzzer and sends an alert notification to the user. This setup helps in better storage management, reduces wastage, and provides early warnings about spoilage. The model can be implemented in homes, supermarkets, warehouses, and cold storage units to enhance food safety and public health. Overall, the system is low-cost, scalable, and capable of predicting food spoilage in real time.

Keywords: IoT, ESP32, DHT11, pH Sensor, Moisture Sensor, Food Spoilage Detection, Real-Time Monitoring, Smart Storage, Food Safety, Embedded Systems, Buzzer Alert, Android Application

1. Introduction

Food spoilage is one of the major challenges faced across the world, leading to loss of edible goods, economic damage, and health risks due to the consumption of spoiled food. Traditional inspection methods are often manual, time-consuming, and inaccurate.

With the advancement of the Internet of Things (IoT), it has become possible to create smart systems that can automatically monitor environmental conditions affecting food quality. The proposed IoT-based Food Spoilage Detection System continuously records temperature, humidity, moisture, and pH levels, which are crucial for maintaining food freshness. Whenever the recorded values cross a defined threshold, the system automatically

notifies the user through a mobile app and web interface, allowing early action before the food gets spoiled.

2. Literature Review

[1] This paper proposes an IoT-based food spoilage detection system that uses gas sensors to monitor ammonia and carbon dioxide released during decomposition. The system wirelessly transmits real-time data to the cloud, generating mobile alerts when gas levels exceed safety limits. It offers a cost-effective and reliable method for early spoilage detection, supporting improved food safety, reduced waste, and effective quality control in domestic and commercial environments.

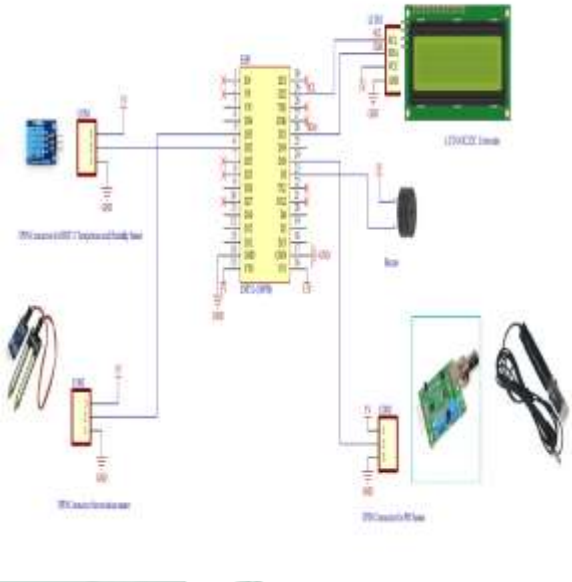
[2] The authors developed a system that continuously tracks temperature and humidity to maintain perishable food quality. Using low-cost sensors and a cloud interface, it provides real-time data and alerts users when conditions cross safe limits. This monitoring approach prevents microbial growth, minimizes spoilage, and extends shelf life. The system is efficient, affordable, and suitable for household refrigerators, cold storage, and food supply chains requiring constant environmental supervision.

[3] This study introduces a sensor-based model for detecting early meat spoilage using pH and odour sensors. The system identifies chemical and gaseous changes during bacterial decomposition, providing alerts before visible deterioration occurs. It ensures timely preventive actions, improving meat storage quality and reducing food wastage. The low-cost and scalable design makes it applicable to restaurants, cold storage facilities, and retail food sectors requiring quality assurance.

[4] The paper presents a wireless sensor network model for continuous food quality monitoring during storage and transport. Equipped with temperature, humidity, and gas sensors, the system transmits data to a cloud platform for real-time trend analysis and spoilage prediction. It enhances accuracy, scalability, and automation compared to manual inspections. The approach is valuable for warehouses and supply chains to maintain consistent food safety and reduce losses effectively

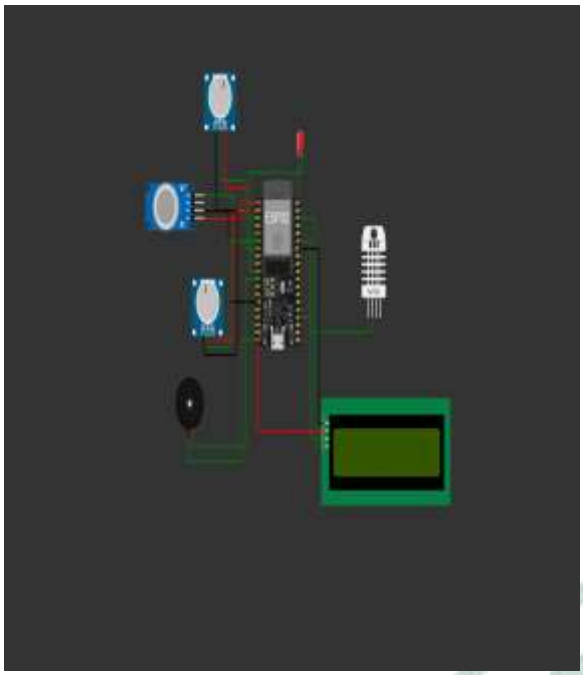
[5] This paper proposes an AI-based model for predicting bacterial growth and food spoilage using environmental data such as temperature, humidity, and gas concentration. The system analyzes sensor inputs to forecast spoilage trends and provide early alerts for preventive action. It improves decision-making, reduces wastage, and enhances food safety. The integration of AI and IoT offers an intelligent, scalable, and data-driven solution for efficient food quality management.

3. System Architecture



Components Used:

- ESP32 Microcontroller: Handles sensor data collection, processing, and Wi-Fi communication.
- DHT11 Sensor: Measures the temperature and humidity of the storage environment.
- pH Sensor: Detects acidity changes in food, indicating microbial growth.
- Moisture Sensor: Measures moisture levels that contribute to food decay.
- 16x2 LCD Display: Shows live sensor readings for local viewing.
- Buzzer: Provides an audible warning when abnormal readings are detected.
- Android Application & Web Dashboard: Display data remotely and send alerts to the user.



Working Process:

1. Sensors collect continuous readings of temperature, humidity, pH, and moisture.
2. The ESP32 microcontroller processes this data and compares it with preset threshold levels.
3. When abnormal readings occur, the system:
   - Activates the buzzer alarm,
   - Sends notifications to the Android app, and
   - Updates the cloud dashboard for remote users.
4. All readings are stored in a database for historical analysis and spoilage prediction.

4. Methodology

Hardware Implementation:

The ESP32 is connected to DHT11, moisture, and pH sensors through the Arduino platform. A regulated 5V power source ensures stable operation. The collected data is displayed on an LCD and transmitted to the cloud using Wi-Fi.

Software Implementation:

- Programming: Arduino IDE is used to code and integrate sensors.
- Data Storage & Display: Cloud platforms such as Thing Speak, Firebase, or Blynk are used for data storage and visualization.
- Mobile Application: Developed using MIT App Inventor for easy monitoring and notification services.

Threshold Conditions:

Parameter	Normal Range	Alert Trigger
Temperature	0℃-25℃	> 30℃
Humidity	40% – 65%	> 70%
pH	6.0 – 7.0	< 5.5
Moisture	< 60%	> 60%

5. Results and Discussion

The system was tested in different storage conditions such as room temperature, refrigeration, and humid environments. It successfully measured the environmental parameters and displayed them on both the LCD and the mobile application.

When temperature or humidity increased beyond the set limit, or pH levels dropped below normal, the system triggered alerts and buzzer notifications. The results proved that the system could predict spoilage trends efficiently and provide early warnings for preventive action.

6. Advantages

- Low-cost and power-efficient design.
- Enables real-time monitoring of multiple parameters.
- Prevents food waste and promotes safe consumption.
- Provides remote access and alert notifications.
- Easy to install and scalable for various applications.

7. Applications

- Households: To monitor perishable foods like milk, meat, or vegetables.
- Supermarkets and Retail Stores: To maintain product freshness and reduce loss.
- Cold Storages and Warehouses: To ensure ideal storage conditions.
- Food Transportation: To maintain freshness during shipping and logistics.

8. Future Scope

Future versions of the system can be improved by:

- Adding machine learning models for automatic spoilage prediction.

- Integrating gas sensors (CO_2, NH_3) to detect microbial activity.
- Using solar-powered modules for energy efficiency.
- Enhancing cloud analytics for long-term data visualization and decision-making.

9. Conclusion

The IoT-based Food Spoilage Detection System provides an affordable and practical approach to monitoring food freshness. Using ESP32 and sensors such as DHT11, pH, and moisture sensors, the system continuously tracks environmental conditions and alerts users in real time. This helps in reducing food wastage, improving storage management, and ensuring public health. The model can be implemented on both small and large scales to promote smart and sustainable food safety practices.

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