Food Spoilage Detection System Using IoT

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ABSTRACT: Food spoilage is a complex and natural process that renders food unfit for consumption, resulting in significant economic and health implications. In today's environment, it is becoming increasingly important to reduce waste and ensure quality and safety in the food supply chain. This paper presents a user-friendly and cost-efficient system for determining food spoilage by monitoring gases, humidity, and temperature from foods using different sensors. In this system, food spoilage can be readily detected in real-time, which allows a speedy intervention and decreases the risks of consuming unsafe food. It's furthermore with cost-effective design and communication that it is accessible and practical to use whether applied for domestic or commercial consumption and helps reduce food waste.

Keywords: Food spoilage, Food safety, Real-time detection, Sensors, Food waste reduction.

I. INTRODUCTION

Food safety is one of the most significant global concerns dealing with massive public health and well-being implications. Effective measures include monitoring and detection of food spoilage throughout a food supply chain. Food can spoil for several reasons: microbial growth, enzymatic reactions, temperature, and humidity. In addition to compromising the quality and nutritional values of foodstuffs, this spoilage poses serious health risks to consumers, causing foodborne illnesses. Traditionally, the inspection methods for detecting food quality and spoilage are cumbersome, often requiring huge proportions of labor, time, and costs. These methods, being manual, are subjective and dependent on individuals for their proper implementation and therefore may be inclined toward human mistake and are not as strong in the element of safety regarding food in today's fast world. Increasing demand for high-quality and safe food necessitates more reliable and efficient solutions to monitor food safety effectively. Plus, current food technologies are advanced but always fail to detect some of the gases that come from spoilage; this could lead to health hazards. For this reason, food technology has developed some of the most advanced detection techniques. However, most of these systems continue to apply old manual methods that are not as effective at delivering prompt and accurate judgments regarding food quality. Considering the above issues, an innovative detection system on food spoilage is

being developed based on Internet of Things in order to have quality food in both residential and industrial settings. The system will detect the dangers of eating spoiled foods at real-time with early signs of degradation of the foodstuffs, hence dramatically elevating the standard of food safety. This project aims to enable the accurate identification of spoiled food no longer safe for consumption by making use of capable of sending alert messages to users in cases where spoiled food is detected, thus enabling them to take prompt action to reduce further negative health risks. In home and industrial settings, the alert messages can help in quick decision-making in order to avoid and reduce instances of food waste and enhance overall safety. The chief objectives behind this project include minimizing instances of food waste, enhancing food safety, and encouraging responsible consumption practices among the users. The IoT-based food spoilage detection system promises not only to enhance the quality and safety of the food but also make its consumption along with all other sustainable resources, in totality, more sustainable. This project will be merely one solution which benefits consumers, enhances public health, and fosters a culture of safety and awareness regarding food quality, helping to build a healthier society.

Key features of this Food Spoilage Detection System are:

I. Gas Detection Module: This module detects the specific gaseous emissions from spoiled food with the help of advance gas sensors monitoring the environment. If the concentrations of specific gases beyond set thresholds, are marked, then the system alerts the user through an automatically generated message.

II. Real-Time Monitoring: In this the system continuously monitors food quality. It helps to track advanced gas sensors that are able to detect specific gases released during the spoilage process. The real-time nature of the gas sensors, which continuously monitor the food environment, would be vital in preventing spoilage before it reaches a critical level where consumer health is seriously jeopardized. Besides, the system will be

the increase of gas emissions in real-time, thus allowing spoilage of food to be detected before it reaches its critical limit.

III. User Alert System: If food is spoiled the system immediately sends messages to the mobile phone registered by the user. This feature provides an early response, which can help to avoid the wasting of food and the risk of health threats from spoiled food.

IV. Convenience in multiple environments: It was designed to be used in homes, restaurants, and storage of food. Its ability to multitask ensures that diverse users can utilize this device efficiently while ensuring the current standards of food safety are maintained.

V. User Interface: It can allow easy interaction, setting up, and monitoring by a user-friendly interface. Users can access real-time data and alerts easily through their smartphones, which increases the overall user experience.

II. MOTIVATION

This project was motivated by urgent issues of food safety and reduced food waste-an important global challenge that hits public health, economic stability, and sustainability alike. As demand for safe and quality food from consumers is always there, the traditional assessment methods for food quality are no longer efficient because they have failed at these three elements: accuracy, efficiency, or timeliness. These primitive

inspection processes are very time-consuming and not nearly as fast as the modern food safety practices demand. Furthermore, food spoilage is a widespread issue, resulting in a lot of quantities of loss through food wastage, financial losses, and spread of food poisoning. The issues can be taken care of with an innovative approach of IoT for food safety in both household and industrial applications. As this project is aimed at being a continuous, automatic response to identifying food spoilage at the earliest instances possible, users will have the right choices made about consuming and storing food rightly. It will, therefore, bring about quality food safety, less waste, and sustainability in the handling of food to help consumers, business houses, and the environment at large.

III. RELATED WORKS

Advancement of IoT technology has a strong impact on the area of food quality monitoring. M. Prasanna et al. state that "this IoT-based system enables real-time monitoring of food quality, enhancing food safety and reducing waste"[1]. Similarly, P. Manjulamna et al. emphasize on the cost efficiency aspect and considers that "our research focuses on low-cost sensor-based systems that are capable of monitoring food freshness and spoilage" [2].

In this regard, innovative technologies have been introduced, including photochromic paper indicators, through which researchers are able to visually determine spoilage levels: "by using photochromic paper indicators, real-time visual determination of acidic food spoilage levels is possible"[3]. The incorporation of IoT technologies has also been realized; as Gogula et al. point out: "using IoT technologies enables the continuous detection of food spoilage through real-time data collection"[4].

The importance of sensors for the detection of spoilage cannot be put into words. S. Gogula et al. are in agreement to that very fact because "sensors that monitor volatile gases are crucial for the early detection of food spoilage in IoT applications"[5]. Further, M. R. Satyanarayana et al. discuss how "this novel approach combines gas sensors with IoT frameworks to enhance food storage monitoring effectively"[6]. The association of IoT with gas sensors presents a reliable method of spoilage detection, according to N. Rajesh et al., "integrating IoT with gas sensors provides a reliable method for spoilage detection in storage environments"[7].

The dynamic characteristic of food compounds allows for the detection of spoilage and, according to Y. Adedoyin et al., "our results show that IoT-based spoilage detection systems can greatly evaluate the alteration of food compounds"[8]. Moreover, public health dimensions are significant for IoT systems, as argued by Z. Wei et al.: "the application of IoT systems for detecting microbial contamination brings great advantages in public health dimensions"[9].

At the molecular level, A. N. Hamad et al. "an IoT system for food spoilage detection operates at the molecular level, thereby monitoring in an extremely accurate" 10 The sensors' calibration is also of high priority; N. Al-Saadi et al. conclude that "calibration of sensors to detect spoilage-related gases improve the IoT systems for monitoring food" 11.

M. M. El-Shafai emphasizes: "the use of metal-oxide semiconductor sensors is crucial for food freshness detection in IoT-based systems"[12]. Furthermore, high accuracy of e-nose prototypes in the identification of spoilage-related volatile compounds K. L. H. et al. obtained and validated: "e-nose prototypes exhibit high accuracy in identifying spoilage-related volatile

compounds that confirm IoT techniques" [13].

Scalability of spoilage detection in larger storage systems have been addressed by A. K. et al., and it stated that "IoT-enabled sensor arrays reveal the scalability and effectiveness of spoilage detection in larger food storage systems" [14]. Aligning with set protocols is very essential since there is an EPA guideline suggesting, "following EPA guidelines for volatile gas detection can significantly enhance the protocols in monitoring food spoilage" [15].

For example, Bluetooth Low Energy is energy efficiency as stated by A. Venkatesh et al.: "Bluetooth Low Energy and IoT technologies improve the efficiency of food monitoring systems"[16]. Another very significant implementations are waste management process automation. As claimed by P. Nemade et al., "an efficient IoT-based system enables automated food waste management while effectively detecting spoilage"[17].

Furthermore, the integration of IoT and machine learning technologies significantly improves the safety standards of food according to Nair et al: "by predicting expiry and reducing food wastage, IoT and machine learning technologies contribute significantly to food safety"[18]. According to R. H. et al., automated IoT systems play a paramount role in the management of food spoilage and reducing its waste: "automated IoT systems for food spoilage management are crucial in reducing food wastage"[19].

Machine learning models integrated with IoT sensors can accurately predict spoilage, optimizing supply chain management, as indicated by K. S. et al.: "machine learning models integrated with IoT sensors can accurately predict spoilage, optimizing the food supply chain"[20].

Finally, real-time data analytics play a crucial role in effective food management strategies. As stated by R. R. et al.: "Real-time data analytics in IoT food spoilage monitoring are essential for effective food management strategies"[21]. Scalability of monitoring solutions is provided by Bluetooth-enabled IoT devices as stated by K. A. et al.: "Bluetooth-enabled IoT devices provide scalable solutions for monitoring food freshness remotely"[22].

It further streamlines spoilage detection processes by integrating mobile communication systems, which enhances logistics as concluded by J. M. et al.: "integrating IoT with mobile communication systems streamlines spoilage detection processes, enhancing food logistics"[23].

Within this project, we are introducing a cost-effective and effective food spoilage detection system based on sensor technology to detect gas emission, humidity, and temperature in real time for improved food safety and less wastage.

IV. CURRENT CHALLENGES

Today, many businesses and families rely on simple visual inspections or expired dates to judge whether food is fresh or spoiled. These approaches are not very effective, in that they allow undetected spoilage or unnecessarily waste still-good edibles. Many of the electronic 1 monitoring systems already on the market are either too expensive or too complicated for use in a day-to-day basis and often concentrate only on one attribute of spoilage and do not offer much of an overall image of food quality.

V. METHDOLOGY

This paper will propose the development of a smart food spoilage detection system based on Internet of Things (IoT) technology. The methodology utilized includes the design and implementation of a multicomponent system where various modules interact in real time to watch over the freshness of foods. The main components and processes adopted for the methodology are summarized as follows:

1. System Design and Module Integration: The system has been designed to integrate multiple sensors and modules that collectively monitor critical indicators of food spoilage. This includes the phase of selecting apt sensors, circuit design, and planning of data flow.

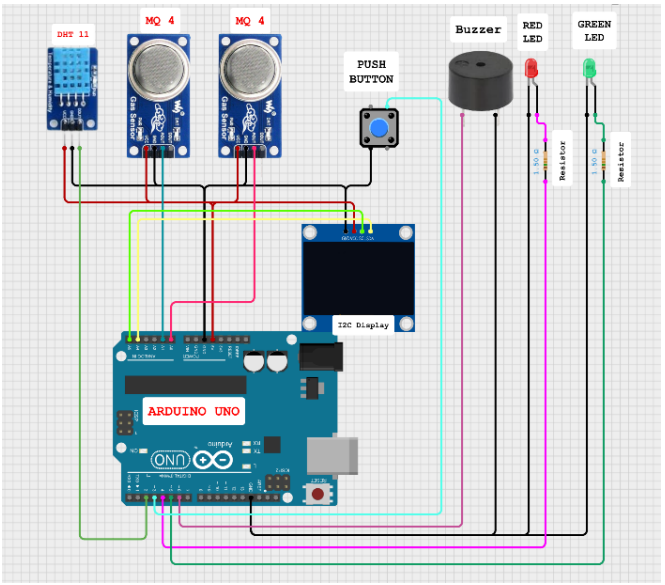
2. Data Collection and Real-Time Monitoring: The system is installed in refrigerators or pantries. In these places, sensors collect data concerning temperature, humidity, gas emissions, and pH levels at all times. These sensors are non-intrusive and are designed for easy installation in diverse storage environments.

3. Data Analysis and Spoilage Detection: The microcontroller calculates the data in real time, compares the reading with predefined thresholds from sensors, and applies advanced algorithms for the analysis of data to enable accurate freshness for food. If data points towards spoilage, system-based triggers alert

4. User Notification and Cloud Analytics: Once signs of spoilage have been identified, the system automatically sends notifications to the user through a mobile application or a web dashboard. The alerts have contents on the items affected and suggested actions. Moreover, all gathered data are stored in the cloud so that users can view historical data for patterns and adjustments in storage.

5. Testing and Validation of the System The final stage of all this is rigorous testing of the system to evaluate the robustness and reliability under varied scenarios and environments. The overall performance of the system would be judged based on its promptness and accuracy in detecting spoilage, and how effortless it makes handling integrated with other storage practices.

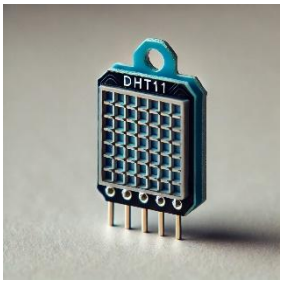
VI. SYSTEM ARCHITECTURE



i. MODULES USED

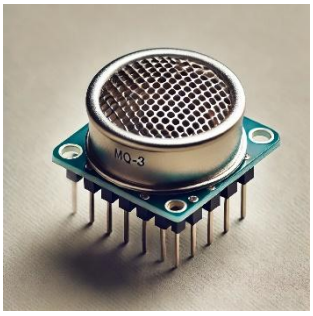
1. DHT11 Sensor:

Measures temperature and humidity, which can be an indication of developing conditions supporting the growth of food spoilage microorganisms



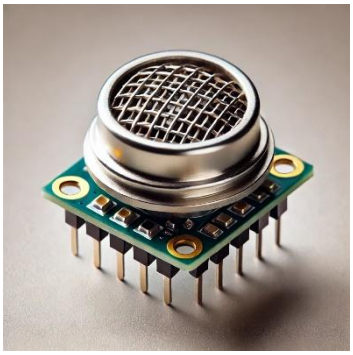
DHT11Sensor

2. MQ-3 Gas Sensor:
   Detects alcohols in gases, which are typically formed by foods during spoilage. It provides an analog output representative of gas concentration



MQ-3 Gas Sensor

3. MQ-4 Gas Sensor:
   Detects methane and other flammable gases that may indicate spoilage. The sensor also provides an analog signal that is proportional to gas concentration.



MQ-4 Gas Sensor

4. SH1106 OLED Display (128x64 resolution):
   The demonstration process will be the display of real-time sensor readings and status messages to the user.

SH1106 OLED Display

5. Push Button:
   It can start the measurement process when pressed, providing a simple user interface for controlling the system.

Push Button

6. Red & Green LED:
   It lights red for spoilt food or the appearance of a warning sign and lights green for fresh food this time with positive visual feedback.

Red & Green LED

7. Buzzer:

Sounds at time when system detects spoilage by giving an audible signal of it to the user

Buzzer

Arduino UNO:

8. It will perform all computations related to sensor signals, updates regarding display, LEDs, and buzzer signaling.

Arduino UNO

ii. WORKING

This project helps the user easily monitor the conditions in the stores for signs of food spoilage. When powered on, Arduino sets up the sensors and the OLED display with a "System Ready" message to let users know everything is in good working order. Checking for spoilage is simply a matter of pressing a button. This will activate the system to get readings from DHT11 pertaining to temperature and humidity and from MQ-3 and MQ-4 sensors relating to gas emissions like alcohol and methane, currently perceived as common indicators of food spoilage.

Arduino then compares these against certain thresholds to decide whether conditions prevail which can potentially lead to spoilage or not. If any value exceeds safe levels then, the system throws up a flag signal to alert the possibility of risk associated with spoilage. Last but not the least, on OLED display, time-sensing data from various sensors and a simple display showing, "Spoilage Risk" in case of hazard otherwise, "Conditions Sound.".

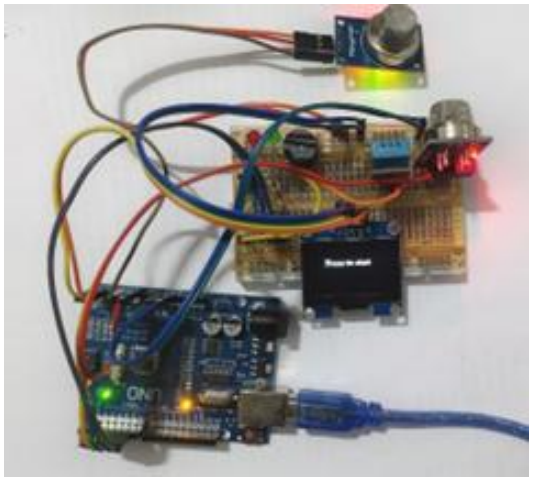
If everything is alright, a green LED lights, and a red LED lights if there has been spoilage. To phrase it in other words, if the system has determined that the food has spoilt, then the buzzer will keep on making a beep sound signal to alert the user. It either resets after an alert or monitors till it is switched off. The whole setup makes the users feel the danger of food spoilage; they will receive simple visual and sound alerts, making it perfect in keeping storage conditions in check.

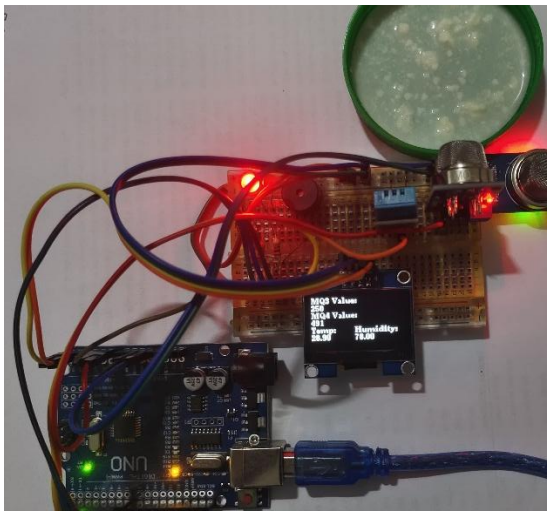
VII. RESULT

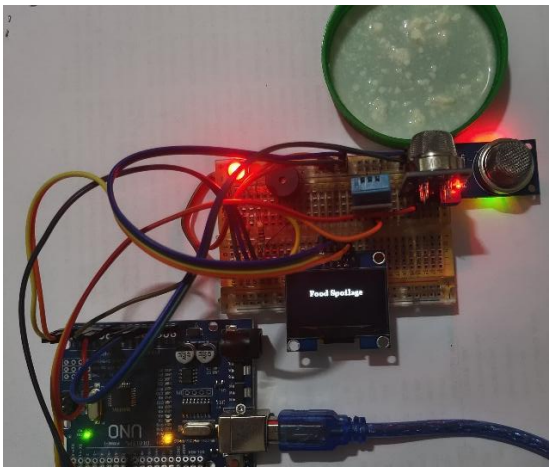
The food spoilage detection system implies monitoring of environmental conditions to prevent food spoilage. After activation, it reads the temperature and humidity with the DHT11 sensor, alcohol, and methane gases using MQ-3 and MQ-4 sensors, respectively. Arduino UNO then compares these readings to safety thresholds.

Results clearly appear on the SH1106 OLED: "Safe" if safe, and "Spoilage Risk" if hazardous. A green LED shows safety while a red LED with the buzzer gives visual and audio warnings in case of risk of spoilage. This is practical because it alerts users reliably and in

good time for storage monitoring to be timed in real terms.







VIII. CONCLUSION

By offering a practical and efficient means of providing for quality and safety, smart food spoilage detection systems utilize IoT technology in real-time monitoring to overcome common problems in food storage and management. Such systems can lead to healthier consumption habits and less waste. By making the system easy to use while also relatively affordable, this system may easily impact both the individual household and the food industry at large.

IX. REFRENCES

1. Prasanna, M., et al. (2024). An IoT-based system for real-time food quality monitoring. *Heliyon*, 10(4), e29066. https://doi.org/10.1016/j.heliyon.2024.e29066
2. Manjulamna, P., et al. (2024). Utilizing cost-effective sensor-based systems to measure food freshness and monitor spoilage. *International Journal of Research in Engineering, IT and Social Sciences*, 14(06), 542-549. ISSN 2250-0588.
3. (No date) *Photochromic paper indicators for acidic food spoilage detection* [Preprint]. doi:10.1021/acsomega.8b02570.s002
4. Gogula, S., Kumar, G., & Lahari, P. (2023). Food spoilage detection using IoT. *International Journal of Emerging Trends in Multidisciplinary Research*, 7(3). https://doi.org/10.46647/ijetms.2023.v07i03.041
5. Gogula, S., et al. (2021). IoT technologies enable early detection of food spoilage through sensors that

monitor volatile gases. *Frontiers in Public Health*, 9, 816226. https://doi.org/10.3389/fpubh.2021.816226

6. Satyanarayana, M. R., et al. (2022). A new IoT approach for food spoilage detection incorporates gas sensors to enhance food storage monitoring. *Foods*, 7(10), 168. https://doi.org/10.3390/foods7100168
7. Rajesh, N., et al. (2023). This study demonstrates the integration of gas sensors and IoT for effective spoilage detection in storage environments. *International Research Journal of Modern Engineering and Technology*, 5(5). https://www.doi.org/10.56726/IRJMETS50056
8. Adedoyin, Y., et al. (2018). Spoilage detection through IoT focuses on assessing changes in food compounds, ensuring freshness. *Molecular Food & Food Research*. https://doi.org/10.15406/mojfpt.2018.06.00194
9. Wei, Z., et al. (2023). Microbial contamination detection in food monitoring systems using IoT offers benefits for public health. *Frontiers in Microbiology*, 14, 1198124. https://doi.org/10.3389/fmicb.2023.1198124
10. Hamad, A. N., et al. (2022). An IoT system for food spoilage detection operates at the molecular level for precise monitoring in storage. *Molecules*, 27(6), 1906. https://doi.org/10.3390/molecules27061906
11. Al-Saadi, N., et al. (2020). Following air quality standards, IoT food monitoring calibrates sensors to detect spoilage-related gases. *IEEE Access*, 8, 224457-224465. https://doi.org/10.1109/MAP.2020.3003216
12. El-Shafai, M. M. (2011). This paper investigates metal-oxide semiconductor sensors in food freshness detection, noting environmental sensitivity. *Handbook of Metal-Microbe Interactions*. https://doi.org/10.1007/978-1-4419-0826-1
13. K. L. H., et al. (2018). E-nose prototypes with neural networks achieve high accuracy in detecting spoilage-related volatile compounds. *Scientific Reports*, 8, 26494. https://doi.org/10.1038/s41598-018-26494-2
14. A. K., et al. (2023). IoT-enabled sensor arrays in food freshness analysis highlight scalability for larger storage systems. *ACS Omega*, 8(1), 247-256. https://doi.org/10.1021/acsomega.8b02570
15. U.S. Environmental Protection Agency. (2021). EPA Guidelines for Volatile Gas Detection. EPA/600/R-21/116.
16. Venkatesh, A., et al. (2017). A food monitoring system based on Bluetooth Low Energy and Internet of Things. *International Journal of Engineering Research and Applications*, 7(3).
17. Nemade, P., et al. (2023). An efficient IoT-based automated food waste management system with food spoilage detection. *International Journal of Intelligent Systems and Applications in Engineering*,12(5s),434-449. Retrievedfromhttps://ijisae.org/index.php/IJISAE/article/view/3929
18. Nair, K., et al. (2021). Expiry prediction and reducing food wastage using IoT and ML. *International Journal of Electrical and Computer Engineering Systems*, 12(3), 155-162.
19. R. H., et al. (2023). An automated IoT food spoilage management system aims to reduce food wastage effectively. *International Journal of Research in Engineering and Technology*, 12(1).
20. K. S., et al. (2022). Machine learning with IoT sensors predicts spoilage, optimizing food supply chain management. *Food Control*, 132.
21. R. R., et al. (2022). Real-time data analytics in IoT food spoilage monitoring prove crucial for effective food management. *International Journal of Computational Engineering Research*, 10(5), 12-20.

22. K. A., et al. (2022). Bluetooth-enabled IoT devices for spoilage detection provide scalable solutions for remote freshness monitoring. *Journal of Food Science and Technology*, 59(3), 1136-1147.
23. J. M., et al. (2022). Integrating IoT with mobile communication systems streamlines the spoilage detection process in food logistics. *Research Journal of Applied Sciences, Engineering and Technology*, 17(1)