ARDUINO-BASED INTELLIGENT SYSTEM FOR EARLY DETECTION AND ALERTING SPOILAGE IN FOOD

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ABSTRACT

With the increasing dependence on smart approaches like mobile phones, there is a need for easy and rapid solutions to everyday problems in today's technological age. An Arduino-based food detecting system is the foundation of this project. A few of the things that the microcontroller panel can do include reading inputs and outputs and activating the sensor. The typical practice of storing food in a refrigerator reduces the pace of bacterial production. It is important to identify and notify the user of some things that are either easily spoilt or have a short shelf life. The main idea behind this project is to use sensors to detect when food is starting to spoil. The system will continuously sense signals from the food and display the pH value of methane on a 16*2 LCD panel. It will also include a buzzer and LED lights, and it will send an alarm message to the registered mobile phone. -Arduino, MQ4 Methane gas sensor, LCD display, Wi-Fi ESP 8266, alert message, LED—these are the keywords for this spoiled food detector.

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I INTRODUCTION

An important goal in the fight against food waste is maintaining high standards of food safety and cleanliness. It is important to keep an eye on the food's quality and make sure it doesn't go bad due to environmental conditions like dark, humidity, and temperature. So, it's a good idea to put quality monitoring systems in grocery stores. The environmental factors that cause or speed up food deterioration can be tracked by these quality monitoring systems. Refrigeration, vacuum storage, and other future environmental controls [1][2].

With the advent of advanced technologies, food spoilage detection has seen a significant shift towards automation and real-time monitoring. Modern techniques, including the use of sensors are now being employed to monitor the key environmental factors contributing to spoilage. For instance, gas sensors can detect the release of gases like ethylene or carbon dioxide, which are indicative of spoilage, while temperature and humidity sensors help track conditions that accelerate deterioration[3][5].

As research advances, food spoilage detection is becoming more sophisticated, offering promising solutions for the food industry and consumers alike.

Food spoilage is a major challenge for the global food industry, contributing to significant economic losses, public health risks, and environmental impacts. Spoiled food not only leads to waste but can also pose serious health hazards due to the growth of harmful microorganisms like bacteria, molds, and yeasts. The ability to detect food spoilage at early stages is crucial for preventing these negative outcomes. However, traditional methods of spoilage detection, such as visual inspection, sensory evaluation, and manual testing, are often inadequate, subjective, and time-consuming.

Food spoilage detection methods are essential for ensuring food safety and quality. Several techniques are available, ranging from traditional methods to advanced technological approaches. Some common food spoilage detection methods are as follows

Sensory Methods

- **Smell/Taste**: Spoiled food often emits foul odors or develops unpleasant tastes. These sensory checks can detect the presence of bacteria, mold, or oxidation.
- **Touch**: Changes in texture, such as sliminess or mushiness, often indicate spoilage, especially in fruits, vegetables, and meat.

Microbiological Methods

- **Culturing**: Growing bacteria or fungi from food samples on selective media to identify spoilage microorganisms, like Lactobacillus, Pseudomonas, or molds.

- **PCR (Polymerase Chain Reaction)**: DNA-based techniques to detect spoilage-related microorganisms at a molecular level, offering rapid and specific results.
- **Enzyme Activity**: Spoiled food often has altered enzyme activity. Detecting specific enzymes associated with microbial growth (e.g., proteases or lipases) can indicate spoilage.

Chemical Methods

- **Ph Measurement**: A drop in Ph can indicate spoilage, especially in dairy or meat products. Spoiled food often becomes more acidic due to bacterial growth.
- **Volatile Compounds Detection**: Certain volatile organic compounds (VOCs) are frequently released during spoilage. Compounds including ammonia, sulphur compounds, and alcohols can be identified using gas chromatography (GC) and mass spectrometry (MS).
- **TMA (Trimethylamine) and Histamine Detection**: TMA levels rise in fish spoilage, while histamine can be an indicator in seafood spoilage, particularly in scombroid poisoning.

Electrical and Electronic Methods

- **Electronic Nose**: Devices that mimic the human sense of smell and detect volatile compounds released by spoiled food, using sensors that can identify patterns associated with specific spoilage conditions.
- **Impedance Spectroscopy**: Measures changes in the electrical properties of food, which can change due to microbial activity, indicating spoilage.
- **Near-Infrared (NIR) Spectroscopy**: A non-invasive technique that can analyze chemical composition and detect spoilage by identifying changes in water content, fat, and protein levels in foods.

Smart Packaging and Sensors

- **Gas Sensors**: Packaging with sensors that detect gases like carbon dioxide, ethylene, and ammonia, which are released during spoilage. These sensors can help monitor food quality in real-time.
- **RFID (Radio Frequency Identification) Tags**: Used to track the temperature and humidity conditions during transportation or storage, which helps detect spoilage risk based on environmental factors.

Optical and Imaging Techniques

- **Hyperspectral Imaging**: This technology captures a wide spectrum of light beyond visible wavelengths to detect subtle changes in food composition, such as microbial growth, color changes, or moisture loss.
- **UV-VIS Spectroscopy**: Detects changes in the food's absorbance properties as it spoils. This can be applied to various food types for spoilage detection without contact.

Biological Sensors Biosensors: These are devices that use biological materials (such as enzymes or antibodies) to detect microbial contamination or spoilage indicators, offering high sensitivity and specificity.

Temperature Monitoring

- **Thermal Sensors**: Continuous temperature monitoring during storage and transport can help prevent spoilage, as certain foods spoil faster when exposed to temperatures above or below their optimal range.

It is common practice, particularly in the food industry, to employ a mix of methods in order to guarantee thorough food spoilage detection, as each approach has its own set of benefits and drawbacks [4][6].

The primary objective of food spoilage detection is to develop and implement accurate, reliable, and efficient methods for identifying signs of spoilage in food at early stages to ensure food safety, quality, and minimize waste [7].

- To design systems capable of detecting spoilage at the earliest possible stage, before significant degradation occurs, ensuring timely intervention and reducing health risks associated with consuming spoiled food [8].
- To integrate advanced technologies such as sensors (e.g., gas, temperature, humidity), machine learning, and artificial intelligence to continuously monitor food conditions and predict spoilage in real-time without the need for manual inspection.: To create systems that provide real-time monitoring and instant alerts about spoilage, allowing food producers, distributors, and consumers to take immediate action, thereby preventing waste and ensuring food safety [9].
- To develop detection methods that help reduce food waste by providing early warning signs of spoilage, enabling better inventory management, improved shelf-life prediction, and optimized storage conditions [10][11]..

- To design cost-effective and scalable solutions that can be applied across various sectors of the food industry, from farms to supermarkets, ensuring broad applicability and practicality for both small and large-scale operations.
- To enhance overall food quality control systems by providing objective, automated assessments of food conditions, ensuring that only safe and high-quality products reach consumers.

II.PROPOSED SYSTEM

The system is proposed to detect the early food spoilage. This proposed system is designed by using hardware modules Arduino uno, MQ5 Sensor Module, DHT11 Sensor module, 16X2 LCD Screen, Connecting jumper wires and LDR Sensor and Power supply unit (Fig.1).

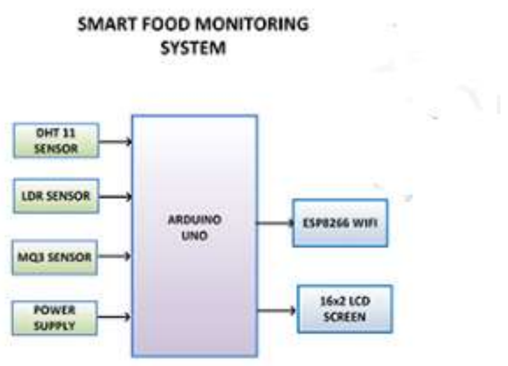

Fig. 1: Block diagram of Smart Food Monitoring System

III.WORKING PRINCIPLE

Early detection of food spoilage using proposed system, environmental parameters such as temperature, humidity, light, gas concentration, etc can be monitored by a sensor unit . The digital DHT-22 sensor will detect the food's humidity and temperature and transmit that information to the Arduino. The presence of ethanol can be detected by using the MQ3 alcohol sensor, an analog sensor module. Fruits release ethylene, a natural gas, when they ripen. During the ripening process, apples and bananas release more ethylene than other fruits. Light-dependent resistors (LDR) are utilized for light intensity sensing. The sensor readings are shown on the LCD (Liquid Crystal Display), a 16x2 screen. The Arduino receives the readings from these sensors. Equipped with an on-board UART, SPI, and interface, it has 14 general-purpose input/output (GPIO) pins, 6 pulse-width-modulation (PWM) pins, and 6 analog inputs. The NODE MCU receives the values from the Arduino.

An integrated WiFi module in the open-source NODE MCU firmware and development board uploads data to the cloud, which the ARDUINO UNO software then uses.

IV. IMPLEMENTATION

It is recommended to install an IoT device wherever food is stored. It reads data from the connected sensors (DHT22, the DHT11 module's successor) after it's turned on and installed correctly via Wi-Fi modem. For measuring humidity and temperature, the DHT11 is a popular choice. With a precision of ±1°C and ±1%, respectively, the sensor can measure temperatures ranging from -40°C to 80°C and humidity levels from 0% to 100%. Since the Arduino only has fourteen digital pins, a digital sensor like the DHT22 can be attached to one of them. An Arduino board's second digital pin is where you'll find this sensor attached. Because SnO2 has a reduced conductivity in pure air, the MQ4 Sensor is able to detect the presence of ethanol using this alcohol sensor module. Since the Arduino only has six analog pins, the MQ4 sensor, which is an analog sensor, may be linked straight to one of those pins. The Arduino board's A0 pin is where this sensor is linked.

One way to measure the brightness of a light is with a light-dependent resistor, or LDR. Like the five remaining Analog pins on the Arduino, the LDR sensor is an analog sensor that connects directly to an analog pin. The Arduino board's A1 pin is where this sensor is linked. By connecting the sensors to the Arduino board's pins, we can send the acquired values to the microcontroller. According to the code created in the Arduino software, we receive a display indicating the status of the food if the values received from the sensors approach critical values.

V. TESTED RESULTS

Various circumstances are used to test bananas using proposed system in this study presented in Table 1. Heat kills enzymes, while cold breaks down fruit cell walls, allowing contents to mix and causing abnormal browning, softening, and oxidation. Ripening is best accomplished in an environment with a relative humidity of 90–95 percent and a temperature range of 62°F –68°F. After evaluating the banana for approximately 7 to 9 days, the critical value of the ethylene gas can be determined and expressed in meter cubes (m3). Since more light will reach the bananas in an open area than in a closed box, the primary function of the light-dependent resistor (LDR) in this paper is to indicate to the user to do so when the intensity is high. Here, food is best stored in an airtight container within a refrigerator; otherwise, the humidity and temperature outside will have an impact on the bananas, which will cause them to spin over the milliseconds since the Arduino board started running the present program. After about fifty days, this number will overflow, or return to zero.Prior to food spoilage, we notify the user if the food has been exposed to high temperatures and humidity for at least two days. The typical shelf life of a banana is close to seven days when stored at room temperature. Once this time restriction has passed, the food will start to go bad. In addition, the data is shown on a 16x2 LCD display, which also shows the food's state and the results from the sensors. The user can keep an eye on the banana even while he's not in the room, which is why this is useful.

Fig. 2: Practical setup

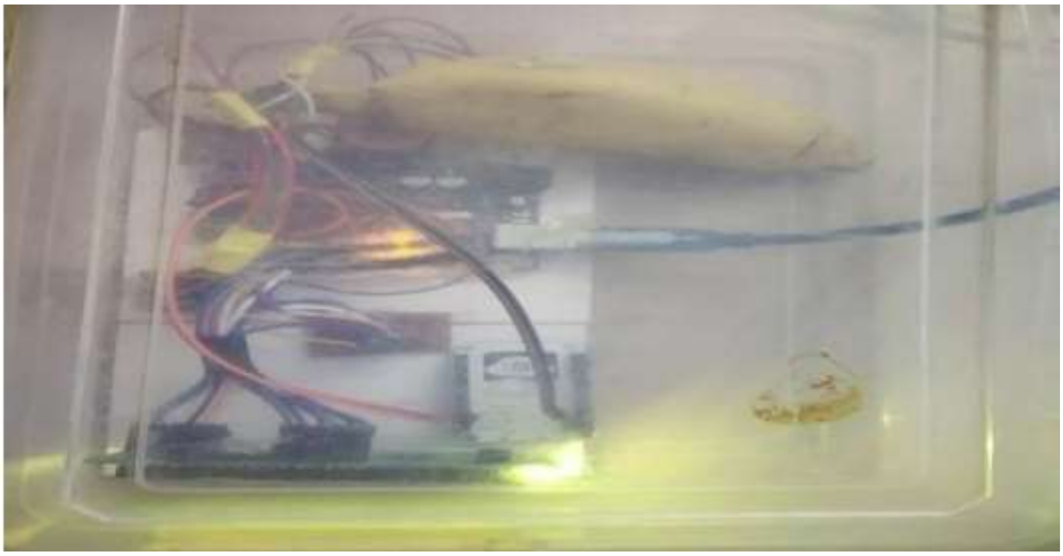

Fig 3 : Values displayed in LCD

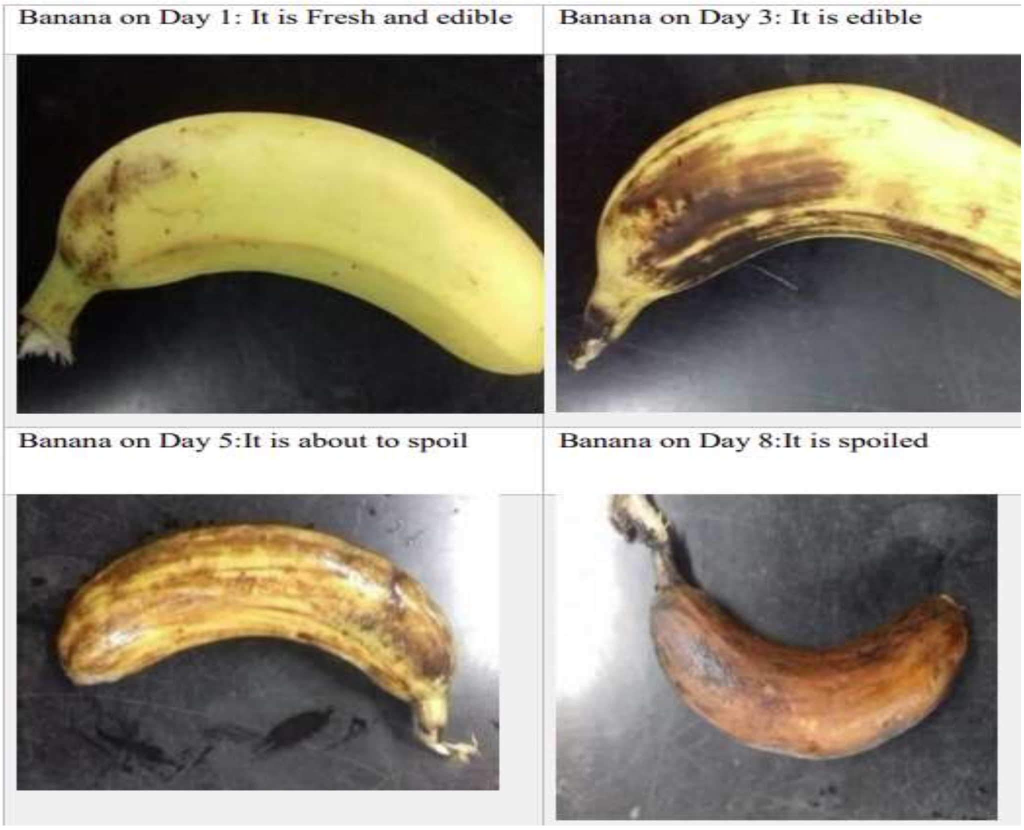

Fig.4: Practical testing of Banana on different days

Table 1 : Identification of banana spoilage using proposed system

S.no	Condition of Banana (At room temperature)	Gas Value (as shown by the MQ3 sensor) in meter cube
1		Banana is edible [50-58]
2		Banana is edible [60-68]
3		Banana is about to spoil [70-75]
4		Banana is spoiled [More than 75]

The Arduino Uno is the brains of the system, doing all the necessary operations. Because the sensors' outputs are linked to the Arduino's inputs, the microcontroller's primary function is to respond upon the data supplied by the sensors. To program an Arduino Uno, one must have knowledge of embedded C. In order to set up a connection for the Internet of Things, the Node MCU is linked to the Arduino Uno using the Wifi Module .

Details about the state of the food is shown on the LCD if the user is in close proximity to the storage area (Fig. .

Fig. 5 : Display of attributes according to its spoilage in proposed system

"Food is about to spoil" is the notification the user receives when the food is spoiling; in this case, "Bananas" are used as a test food. At any time this alert appears, the user can finish cooking the meal in record time. In the future, after the food has gone bad, the user will be able to see "Food spoiled" on the LCD screen, which will warn him not to eat the spoiled banana.

CONCLUSION

Even before there is outward evidence of deterioration, the gas detector may identify gas emission from various foods by early detection of gases like ammonia, methane, etc. The consumer is provided with the necessary information to track the expiration date of the food item. Keeping one's health in check and warding off unhealthy eating are both made easier with this. In order to keep consumption under control, the food processing sector makes use of technology to indicate the item's expiration date on the packaging. Since the majority of shoppers purchase packaged foods from malls, where the expiration date is a key characteristic, food item monitoring and detection is crucial. Addressing the important needs of minimizing food waste, enhancing transportation efficiency, and tracking food contamination can be achieved with an integrated IoT-based online monitoring method that utilizes smart logistics.

The experiment was a success, and now we know how to monitor humidity, temperature, and ethane gas data given out by spoiled food, particularly "BANANAS." Plus, we have LDR readings. Fruits release ethylene, a natural gas that aids ripening. Heat kills enzymes, while cold breaks down fruit cell walls, allowing contents to mix and causing abnormal browning, softening, and oxidation. Ripening is best accomplished in an environment with a relative humidity of 90–95 percent and a temperature range of 62–68 degrees Fahrenheit. Every day, the meal is tested and assessed under various settings. A plethora of such gadgets can be set up at the allocation site to improve quality control and monitoring. As a result, this Internet of Things paper includes a food monitoring device that tracks key metrics for improving food quality—temperature, humidity, and methane gas—in real time.

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