FOOD QUALITY MONITORING SYSTEM

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ABSTRACT

Providing a guarantee for perishable food to remain fresh and safe when stored and transported is a major issue for the food sector. This project sets out to create an affordable, sensor-based Food Quality Monitoring System utilizing the Arduino Uno board. The project will track, constantly the environmental and chemical factors involving food freshness such as temperature, humidity, moisture level, gas composition, and the presence of alcohol vapor.

The DHT11 sensor has been utilized to detect the humidity and temperature of the environment thus they are essential for good storage conditions. The MQ135 gas sensor is sensing several hazardous gaseous chemicals such as ammonia, nitrogen oxides, and carbon dioxide which are likely to be present in the form of organic matter decay. To monitor moisture content in the fresh produce or in the storage air ambient—which can monitor possible microbial growth—we've just repurposed a soil moisture sensor. We've also added an MQ3 alcohol sensor to monitor ethanol vapors, a by-product of fermentation and one significant indicator of spoilage.

Arduino Uno reads and interprets the sensor measurements, comparing them to threshold values set a priori. Whenever a parameter exceeds the accepted value, the system can trigger an alarm (buzzer, LED, or serial print) to notify the user of potential food spoilage. The system offers a real-time, autonomous solution to enhance food quality monitoring throughout supply chains, cold storages, retail, and home use. It is expandable, energy efficient, and expandable with IoT modules for remote monitoring and recording.

This project demonstrates the real-world application of embedded systems and sensor integration in solving actual problems involving food safety and shelf-life management.

KEYWORDS: *Food Spoilage Detection, Food Quality Monitoring, Embedded Systems, Real-Time Monitoring, Perishable Goods, Smart Food Storage, Sensor-Based System,*

1. Introduction

In the food industry of the present day, perishable food safety and quality throughout the supply chain from production through consumption is a large concern. Factors such as temperature, humidity, moisture content, and toxic gas or alcoholic vapor accumulation can have critical influence upon the foodstuffs' freshness and shelf life. Conventional monitoring systems are typically manual and reactive, often resulting in untimely detection of spoilage, increased wastage, and potential health risks to consumers.

In order to overcome such issues, we actually require low-cost, dependable, and simple-to-operate automated systems for real-time monitoring of food quality. Due to developments in microcontroller technology and sensor systems, it is becoming increasingly possible to design smart solutions that are able to monitor the environmental and chemical indicators of food spoilage.

This project will be used to develop a Food Quality Monitoring System using an Arduino Uno microcontroller and various sensors. The DHT11 temperature & humidity sensor, an MQ135 gas sensor, an MQ3 alcohol sensor, and a soil moisture sensor are all employed to measure some parameters which can influence food production.

1. Temperature and Humidity: Regulated by the DHT11 sensor, as poor storage conditions favor microbial growth and chemical degradation.

2. Gas Emissions: Gases such as ammonia, carbon dioxide, and oxides of nitrogen are detected by the MQ135 sensor and are common by-products of rotten food.
3. Alcohol Vapors: Detected by MQ3 sensor, which identifies initial fermentation or rot in food products.
4. Moisture Content: Measured by the soil moisture sensor, which detects wetness in storage conditions or in fresh fruits and vegetables.

The data received from these sensors is processed in real-time by the Arduino Uno. If a parameter exceeds pre-established threshold values, an alert system is triggered by the system. This can be through visual or audio cues, or display messages through an LCD or serial monitor.

The proposed system is power efficient, scalable, and expandable with IoT modules (such as Wi-Fi or GSM) to enable remote logging and monitoring of data. The system can be applied to industries such as food processing factories, cold storage houses, transport units, grocery shops, and household kitchens. It would lead to enhanced food safety, reduced wastage and spoilage, and zero wastage of food.

2. Literature Review

With the growing call for fresh and secure food, food quality testing has become more important in recent years. Food quality deterioration is due to environmental factors like temperature, humidity, and gas and microbial contamination and influences the use-bys of perishable items. Convention food quality test methods, like manual testing and visual inspection, are time-consuming, resource intensive, and also inherently prone to human error. Hence, increased attention has been on automated systems of food quality real-time monitoring with the aid of advanced sensors and microcontroller technologies.

Some of the recent literature has focused on the use of temperature and humidity sensors in food storage. M. A. R. Raza et al. (2020) document that temperature and humidity are just two factors in keeping food from spoiling- especially, perishable goods, including, fruits, vegetables, and dairy products. Their work discusses the use of DHT11 sensors with Arduino, to help monitor and control the environmental conditions in a storage unit to stop spoilage, especially due to known inadequate temperature and humidity. The results of their work have shown that automated systems demonstrated improvements from food wastage by providing appropriate environments for preservation.

Gas sensors, such as MQ series sensors, have been used extensively to measure gases emitted from spoiled food. In a report by T. P. Tang et al. (2019), an MQ135 gas sensor was utilized for detecting gases emitted by ammonia, carbon dioxide, and volatile organic compounds (VOCs), which are the secondary products resulting from the breakdown of organic matters. The study concluded that early spoilage can be provided by gas sensors because these gases would be commonly released upon food decomposition. Their study indicates the potential for real-time gas monitoring application in a combined system for food quality monitoring where early detection can prevent danger to health and reduce food waste.

Apart from gas sensors, alcohol sensors have also been investigated for spoilage detection in fermented food and drink. A research article by H. Zhang et al. (2021) reports on the use of ethanol as an indicator of spoilage in alcoholic and fermented foods.

Apart from gas sensors, alcohol sensors have also been investigated for spoilage detection in fermented food and drink. A research article by H. Zhang et al. (2021) reports on the use of ethanol as an indicator of spoilage in alcoholic and fermented foods.The MQ3 alcohol sensor is able to detect vapors of ethanol, which are typically released during fermentation or spoilage. The integration of such a sensor into a food monitoring system would allow the spoilage of foods like wine, yogurt, and fruit juices to be detected, where fermentation alters the chemical makeup of the product.

In addition to this, moisture sensors also provide measurements of the water content of food and storage. High moisture promotes bacterial and fungal growth and causes spoilage. S. R. P. Subramanian et al. (2020) analyzed a study of the use of soil moisture sensors, originally intended for agricultural applications, to sense moisture content in food and storage units. Their research guaranteed that sensors could successfully be utilized in retail stores like warehouses and cold storage warehouses to salvage perishable produce from moisture spoilation. Built inherently within other

sensors in the environment, sensors integrated with sensors provide a system integrated completely used to examine the quality and safety of foods.
Food quality monitoring using microcontroller-based systems has gained immense popularity with the advent of low-cost, simple-to-implement platforms such as Arduino. K. R. Gupta et al. (2022) presented a study in which the authors investigated the scope of Arduino-based systems for real-time food safety monitoring. Their paper offered an all-in-one system based on DHT11, MQ135, MQ3, and soil sensors, which was able to monitor changes in food conditions and trigger alarms upon the detection of spoilage. Automatic processing and analysis of data by the inclusion of a microcontroller minimize the level of manual intervention.
In general, the literature review demonstrates that the combination of different sensors (temperature, humidity, gas, alcohol, and moisture) with microcontroller systems such as Arduino provides a viable method for creating automated food quality monitoring systems. Through automation of the monitoring and alerting function, these systems can improve food safety, reduce spoilage, and enhance the efficiency of food storage and transportation. Future developments in wireless technology and IoT-based systems may further improve such solutions by facilitating remote monitoring and real-time data logging to give greater control and visibility across the entire food supply chain.

3. Components and Materials

Key Components:

1) **Arduino Uno**
It used to take inputs from the sensors, process data, and control outputs. It serves as the central processing unit for the entire monitoring system.
2) **DHT11 Sensor**
A temperature and humidity sensor that reads both simultaneously. It provides calibrated digital output and is best for monitoring environmental conditions in food storage rooms.
3) **MQ135 Gas Sensor**
This sensor can sense several dangerous gases, such as ammonia, benzene, and carbon dioxide. It is employed to detect air quality and determine gas emissions that are signs of food spoilage.
4) **MQ3 Alcohol Sensor**
Detects alcohol and ethanol vapors in the air. The sensor is useful in determining fermentation or spoilage in fruits, dairy, etc.
5) **Soil Moisture Sensor**
Originally designed to measure soil moisture, but here it is used to measure the water content of fresh produce or storage space. High readings could indicate impending rot or poor storage conditions.
6) **Breadboard and Jumper Wires**
Utilized in establishing temporary links between the elements while working on a prototype. They allow for simple integration of sensors with the Arduino.
7) **Power Supply (5V USB or Battery)**
Supplies power to the Arduino and the sensors connected. A stable power supply is important for ensuring the consistent operation of the whole system.
8) **Buzzer / LED (Optional for Alerting)**
Can be added to provide instantaneous warnings whenever any sensor reading crosses the safety threshold, so actions can be initiated promptly.

4. System Design

4.1 Hardware Design

The hardware of the Food Quality Monitoring System involves the integration of the various sensors with the Arduino Uno microcontroller in order to gather real-time data from the surroundings of the food. Every component has a unique function of sensing evidence of food spoilage.
Hardware Installation Includes:

i. Arduino Uno is used as the microprocessor.
ii. The DHT11 Sensor is mounted on an Arduino digital pin to detect environmental temperature and humidity.
iii. The MQ135 Gas Sensor is directed to an analog input to recognize the presence of toxic gas release. The MQ3 Alcohol Sensor detects the existence of ethanol vapors in the air. The Soil Moisture Sensor is interfaced with another analog input to detect moisture.
iv. A Buzzer or LED optional is provided for alert notification.
v. Power Supply is achieved either by a USB cable or an external 9V battery.
vi. Breadboard and Jumper Wires are used to establish the necessary connections between all components.

4.2 Software Design

The development of software includes programming the Arduino Uno through the Arduino IDE. The logic includes reading sensor values, performing conditional checks to compare the values against set thresholds, and producing alerts when any spoilage condition is met.

Software Tools Used:

- Arduino IDE – employed for writing, compiling, and uploading the code onto the Arduino board Embedded C/C++ Language – used to create the program logic.
- Serial Monitor – used to show real-time sensor data while testing.

Program Flow:

- Start all sensor pins and open serial communication.
- Read the input values of the DHT11, MQ135, MQ3, and moisture sensors.
- Compare the readings with the specified safe threshold values.
- If there is any reading over the specified threshold, alert (either via buzzer or LED).
- Repeat the process continuously to provide real-time monitoring.

Threshold Example (for testing):

- Temperature > 30°C
- Humidity > 75%
- Gas level (MQ135) > 300 ppm
- Alcohol level (MQ3) > 200 ppm
- Moisture > 600 (analog reading)

5. Methodology

5.1 System Architecture

Architecture of Food Quality Monitoring System is of layered architecture, which is scalable and flexible and executes in real-time. Three layers of major functionality in the system are: sensing layer, processing layer, and output layer. Sensing layer utilizes DHT11 (for measuring temperature and humidity), MQ135 (for detection of harmful gases), MQ3 (for detection of alcohol vapor), and moisture sensor (for measurement of water level). These sensors are placed strategically along the food items in such a way that they can continue to monitor the ambient environmental conditions at all times. The processing layer, through the Arduino Uno, receives input from the sensors, compares against pre-defined threshold values, and senses any possible indication of spoilage. The output layer is an LED or buzzer, which is activated if any parameter exceeds the safe limit. This design also universal and is expandable via the addition of wireless communication modules like the ESP8266 or GSM for remote monitoring based on IoT.

5.2 Hardware Configuration

The Food Quality Monitoring System is implemented in layered architecture for maximum flexibility, scalability, and real-time performance. The system is divided into three layers: sensing layer, processing layer, and output layer. The sensing layer interface includes an Arduino Uno, our primary microcontroller, that acts as the interface between sensors and the output devices. A DHT11 humidity and temperature sensor is connected to a digital pin, and two sensors called MQ135 and MQ3 are connected to analog pins A0 and A1. These sensors allow us to detect gases and alcohols' vapors in order to know if a food product is spoiled. A moisture sensor is also connected to analog pin A2, to detect moisture, in or around perishable items, so the user can be alerted. The output device to alert the user of the condition of the items connected in sensors is a buzzer or LED, through a digital output pin. All component materials, like the sensors and output devices, were completed on a breadboard with jumper wires. The system can also be powered through a 5V USB cable or a 9V battery through a voltage regulator, so voltage is regulated to make it stable. Once we completed hardware installation, we ensured communication for the sensors, or all element parts, and the microcontroller so that actual real-time data would be gathered.

5.3 Software Design

The system software is programmed in Embedded C/C++ with the Arduino IDE. The code initializes sensor libraries, pin numbers, and threshold levels for temperature, humidity, gas concentration, alcohol level, and moisture levels at the start of the program. The program reads the real-time values from all the sensors with the help of analogRead() and digitalRead() functions. The program checks these values against pre-defined safe limits. Each time any reading crosses its defined limit, the system activates a buzzer or an LED to indicate spoilage. The data is saved continuously updated and shown on the serial monitor to check and debug. The central program is executed under the loop() function for ongoing monitoring. Modularity of the code makes it easy to add future enhancements, such as the inclusion of an LCD display, data logging, or wireless communication for remote alert.

6. Results and Discussion

The Food Quality Monitoring System was built with the Arduino Uno board and various sensors: DHT11 to read temperature and humidity, MQ135 for detecting gas, MQ3 for alcohol vapor, and a moisture sensor. The system has proven to be able to effectively monitor the significant environmental factors that affect food quality. The system is always on the lookout for temperature, humidity, gas release, alcohol vapour, and moisture levels in food. It warns users whenever it has results that are beyond set limits. For instance, if the temperature is higher than 30ºC, humidity levels are more than 75%, or there are higher levels of gases or ethanol, the system gives warnings that show there could be spoilage. Overall, the system worked well, but it had some flaws such as requiring calibration of the sensors as well as some inaccuracy with the moisture sensor. Nevertheless, the system has been shown to be an affordable means of real-time food safety monitoring, with room for improvement such as wireless communication, improved sensors and future addition of machine learning to enhance detection of predictive spoilage.

7. Conclusion and Future Work

The Food Quality Monitoring System implemented in this project effectively combines several sensors (DHT11 for temperature and humidity, MQ135 for gas sensing, MQ3 for alcohol vapors, and moisture sensors) with an Arduino Uno to monitor essential environmental parameters affecting food spoilage. The system effectively detects primary factors like temperature, humidity, gas release, alcohol vapors, and moisture and gives real-time notifications whenever any parameter exceeds the set limits. The findings indicate that the system can successfully reduce food spoilage, reduce wastage, and improve food safety by sending timely warnings and automated surveillance. Therefore, it is an effective cost-saving solution for food storage and transport operations of both small and large scales. There are a number of areas for future enhancement, though. The sensors, particularly the MQ types, would become more accurate through the adoption of sophisticated calibration procedures or enhanced models of the sensors. The system can be also improved with wireless communication standards such as Wi-Fi or GSM that enable distant observation and reminder signals, very essential in operations where large space covers are required. There is also potential future work in including machine learning algorithms to forecast spoilage through trends in sensor measurements to allow more proactive actions. Including more sensors to measure other parameters of spoilage, for example, pH levels or microbial growth, would extend the capability of the system to provide a more complete solution. With these upgrades, the system can become a sophisticated, automated food quality monitoring system that promotes safety, minimizes food waste, and maximizes food storage in different industries.

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