Food Spoilage Detection Using IoT

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Abstract: *In today's living environment, advanced sensors are used to detect potential problems that may affect the health of a human being. In this paper, we have implemented an easy-to-use and cost-effective micro-system to detect whether the food is rotten or not by monitoring the expelled gases from solid food and obtaining pH value of liquid food using sensors and then transmitting the data through wireless communication. The solid food is monitored using MQ-4 gas sensor and the liquid food is monitored using pH sensor.*

1. Introduction

Food safety is one of the most important problems which can cause hazardous impact on human health. In this paper, the proposed system has two modules. The first module is to detect whether the solid food is spoiled or not and the second module is to detect whether the liquid food is spoiled or not. Food spoilage means the colour, flavour, taste and nutritional value of a food is unsuitable and not edible to human. Food spoilage occurs when different components in food react with each other or some other component which changes the food's characteristics. There are several techniques to preserve food for longer duration but they cannot preserve the food forever. Food spoilage may occur due to bacteria and fungi, microorganisms, enzymes, air, temperature. Spoilage bacteria and fungi consume unprotected food and produce waste products. Bacteria and fungi will multiply as long as nutrition and water are present. An electronic nose can be used to detect the food spoilage due to fungi and bacteria [6][8][12]. Pathogenic microorganisms can cause food-borne illness. These microorganisms grow at room temperature. Pathogenic microorganisms grow without noticeable change in appearance, odour and taste. These microorganisms mostly grow on canned food with unnoticeable change in odour and taste. An electronic nose can be used to detect microbial canned food spoilage based on the gases released from the food [4]. Enzymes are responsible for ripening process in fruits and vegetables. If fruits and vegetables are overripen then they are spoiled. Oxidation and temperature affect storage time and food deteriorates at higher temperatures. The decayed food can be identified by testing the solid food using liquid sensors and testing the liquid food using acidity sensor [2]. The spoiled food can also be detected using the signal waves that are obtained from the sensor that is used to collect information of various gases that are released from food [3]. Rotten and stale food is usually detectable by odour. Many toxic gases, even in parts per billion ranges, are produced from corrupted and rotten food and can endanger the human health. When the solid food is spoiled it releases several gases among which methane is highly hazardous. In this module we implemented a system which detects whether the food is eatable or not using a MQ-4 sensor by detecting methane gas that is expelled from the solid food. The liquid food has a property known as pH value. pH is the unit of measure that describes the degree of acidity or alkalinity. It is measured on a scale of 0 to 14. If the H+ concentration is greater than OH-, the material is acidic; i.e., the pH measurement is less than 7. If the OH- concentration is greater than H+, the material is basic, with a pH value greater than 7. If equal amounts of H+ and OH- ions are present, the material is neutral, with a pH of 7. The liquids with pH value less than or equal to 7 are said to be consumable by humans. But every liquid has its own pH range. If the pH value of the liquid is within its prescribed range then the liquid can be consumed. Here, we use a pH sensor which detects the pH of liquid food. When the liquid food is spoiled its pH value changes thereby changing the taste of liquid. So, this pH value is monitored by pH sensor. In this project, we have tested the pH value of milk and water. The pH value range of milk is around 6.5 to 6.7. The pH value range of drinking water is around 6.5 to 8.5. Spoiled milk is the result of an overgrowth of bacteria that compromises the quality, flavour and texture of milk. When milk begins to spoil, it develops an unpleasant, rancid odour. It may begin to develop a slimy, chunky texture and dingy, yellow colour. With rise in acidity, casein (major protein in milk) particles form clusters to form a mass. The liquid that separates out is known as "whey" and the mass left over act as raw material for "cottage cheese". The spoiled milk and contaminated water can be detected using an electronic tongue which detects the pH value of liquid[9][10][11]. The detection of food spoilage plays an important role in our daily life. A normal human being can detect whether the food is spoiled or not by sensing the odour of food. But if a person suffers from olfactory impairment (Anosmia) then he cannot detect whether the food is spoiled or not as he cannot sense the odour. So, an electronic nose is very important to overcome the hazardous events associated with Impaired Olfactory function [5]. An electronic nose is widely used to detect the spoiled food during transport and storage [1][7].

2. Related Work

The main goal of the paper is to develop a system which can detect spoiled food. As per the existing literature P. P. Jose, N. D. Bobby, V. Ragul, P. L. Babu and P. J. J. Dinesh[2] proposed a method for detecting spoiled food based on sensors. The spoiled solid food is detected by using the liquid sensors and the spoiled liquid food is detected by using the acidity sensors. The circuit generates minute signals which indicate the early detection of food spoilage. Geoffrey C. Green1, Adrian D.C. Chan and Rafik A. Goubran[1] explained an approach for monitoring spoiled food with an electronic nose based on a metal-oxide sensor array. In this study, the food considered are: homogenized milk, 18% cream, yoghurt, eggs and sour cream. These foods were purchased fresh and left out at room temperature over a period of 7 days to accomplish the spoilage process. A total of 100 samples were recorded from the experiment. As a result, the e-nose discriminates food samples on a given day throughout the measurement period. The patterns that are formed from the result indicate the how the food is spoiled at each measurement period. T. B. Tang and M. S. Zulkafli[10] explained an approach for assessing the freshness of milk using an electronic tongue. The freshness of milk is assessed based on the pH value of milk.

3. Methodology

The design and implementation of this system is divided into two modules. The first module is to identify whether the solid food is spoiled or not. The second module is to identify whether the liquid food is spoiled or not.

3.1 Solid Food Spoilage Detection

When the solid food is spoiled it releases several gases among which methane is highly hazardous. In this paper, we have used a semiconductor sensor i.e., MQ-4 Gas sensor to detect the methane gas concentration as it can sense the methane gas at lower concentration also. The MQ-4 sensor detects methane gas at a range of 300-10000ppm. To design the system the hardware requirements are Arduino Uno, MQ-4 gas sensor, LCD Display, ESP8266 Wi-Fi module and power supply board. The Arduino Uno is powered by connecting the 5V and GND pins of Arduino to the 5V and GND pins of power supply board. The VCC and GND pins of MQ-4 sensor are connected to the 5V and GND pins of power supply board and the Analog Output pin of MQ-4 sensor is connected to the analog pin A0 of Arduino Uno. The data pins D4, D5, D6, D7, the enable and reset pins of the LCD display are connected to the digital pins 8, 9, 10, 11, 12, 13 of the Arduino respectively. The Vss, READ/WRITE, LED Negative pins of LCD are connected to the GND pin of the Arduino and the Vdd and LED Positive pins of LCD are connected to the VCC 5V pin of the Arduino. The VE pin of LCD display is connected to a potentiometer. The data pins D0, D1, D2, D3 of the LCD display are unused because we are using 4-bit output. The 3.3V and Enable (EN) pins of ESP8266 Wi-Fi are connected to 3.3V pin of Arduino Uno and the GND and RESET pins of ESP8266 Wi-Fi are connected to GND pins of power supply board. The RX, TX pins of ESP8266 Wi-Fi are connected to RXD, TXD pins of Arduino Uno respectively. Now we use a 12V adapter to give power to the power supply board. The ESP8266 Wi-Fi module should be connected to the Wi-Fi network that is specified in the software. The MQ-4 gas sensor is placed near the food that is to be tested. If the ppm value of the methane gas released from food exceeds 300ppm then the food is said to be spoiled. When the food is tested the result is displayed on the LCD Display, Serial monitor and a notification is sent to the user’s mail.

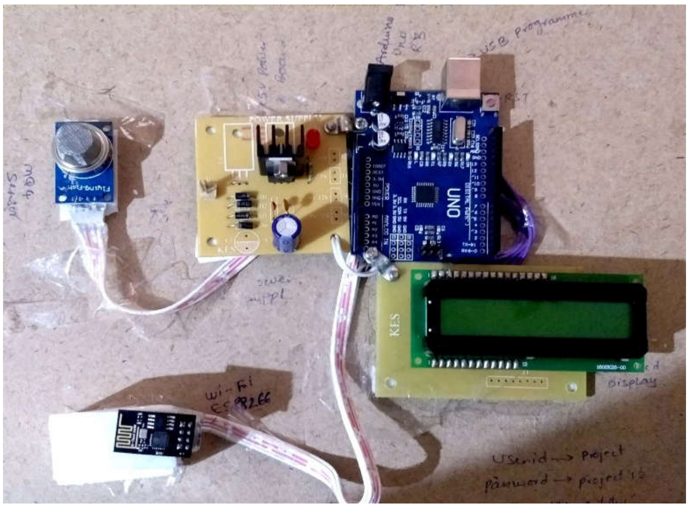


Figure 1. Solid Food Spoilage Detection

3.2 Liquid Food Spoilage Detection

The liquid food has a property known as pH value. The liquid food is spoiled means the pH value of the liquid is not in its pH value range. So, to detect the pH value of a liquid we use pH sensor. To design the system the hardware requirements are Arduino Uno, pH sensor, Buzzer, NodeMCU ESP8266 Wi-Fi module. The VCC and GND pins of pH meter are connected to the 5V and GND pins of Arduino respectively. The analog output pin of pH meter is connected to the analog pin A0 of the Arduino. The GND pin of NodeMCU is connected to the GND pin of Arduino and the TX and RX pins of NodeMCU are connected to the digital input/output pins D2, D3 of Arduino respectively. The VCC and GND wires of buzzer are connected to digital input/output pin D13 and GND pin of Arduino respectively. The software requirements are Arduino IDE and Blynk Application.

First of all, open the Blynk application and set the project name as pH meter. Then click on Choose device and select Nodemcu. Make sure you set the connection type to wi-fi and then click on the create button, an authentication token will be sent on your email id, which will be then used in the programming, simply copy and paste it in programming. Click on the screen and search for the LCD widget and add it. Click on the LCD, Select Advanced and click on the pin and select Virtual Pin V2. Now the Blynk Application is ready to use.

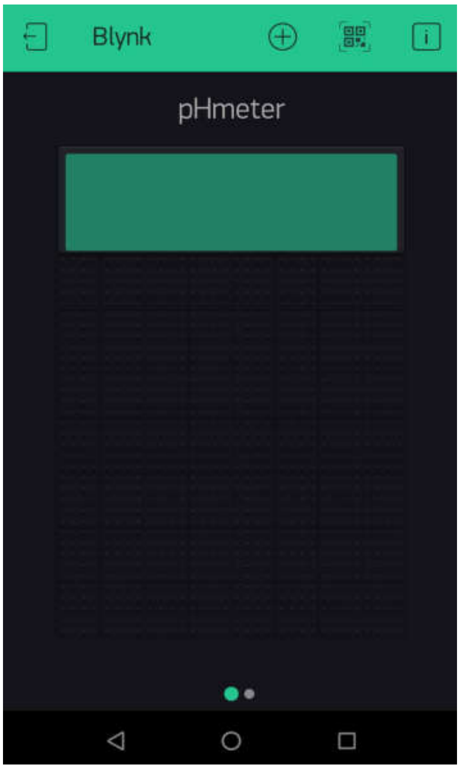


Figure 2. Blynk Application

The pH sensor is kept in the liquid that is to be tested. If the pH value of the liquid is greater than 8.5 or less than 6.5 then the tested liquid is said to be spoiled (liquids tested are milk, water). When the liquid is tested the result is displayed on the LCD widget in the Blynk application, Serial monitor and buzzer does appropriate action.

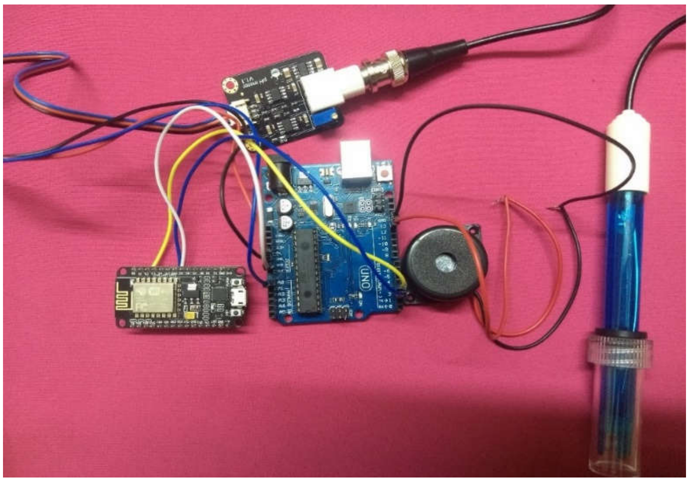


Figure 3. Liquid Food Spoilage Detection

4. Experimental Results

4.1 Result for Solid Food

The system is tested on cooked food and banana. The cooked food is tested in daily intervals and we have observed that temperature plays a vital role in food spoilage. The cooked food that is stored at room temperature is spoiled within 8-10 hours, whereas, it is spoiled or decayed after 24 hours when placed in refrigerator.

A raw banana is tested over a period for 5 days and we have observed that at high temperature, the raw banana is quickly ripened and when still stored at high temperature it is spoiled quickly by emitting ethane, methane gases.
The result of the tested food is displayed on the LCD Display and along with it an email is sent to the user.

Test Case-1: When Stored Food is Tested

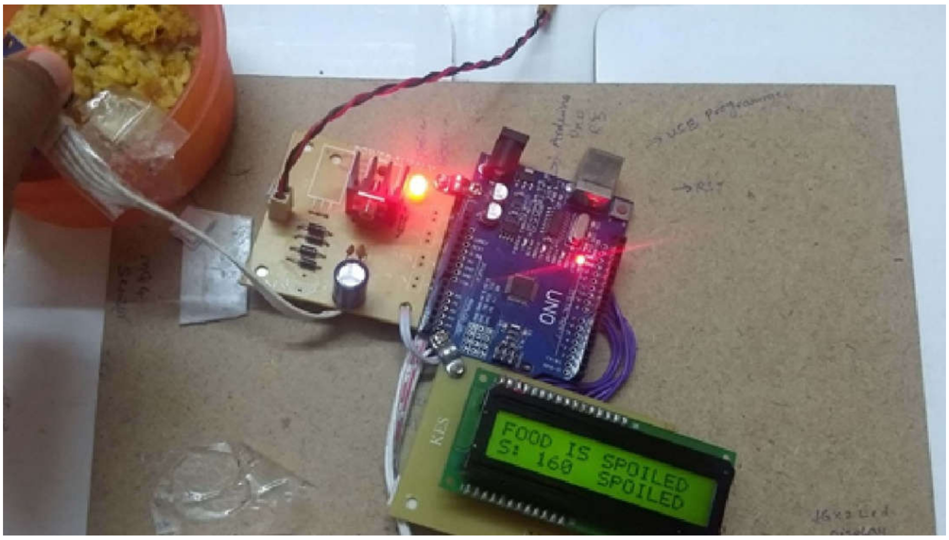


Figure 4. Output on LCD Display

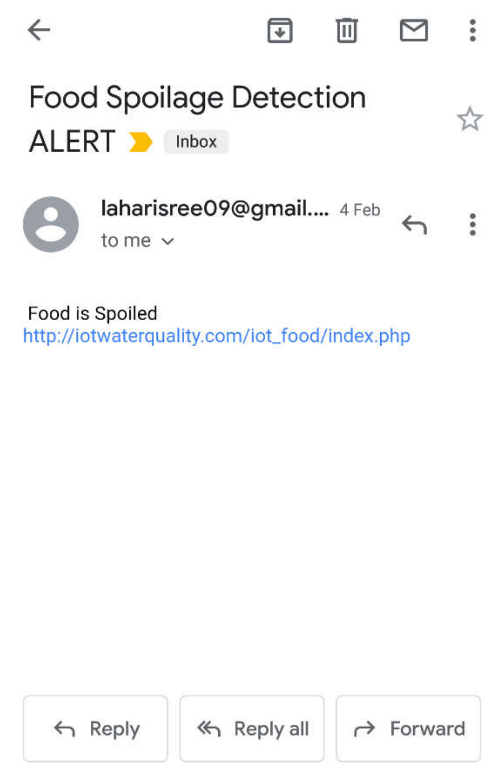


Figure 5. Output in Mail

Test Case-2: When Fresh Food is Tested

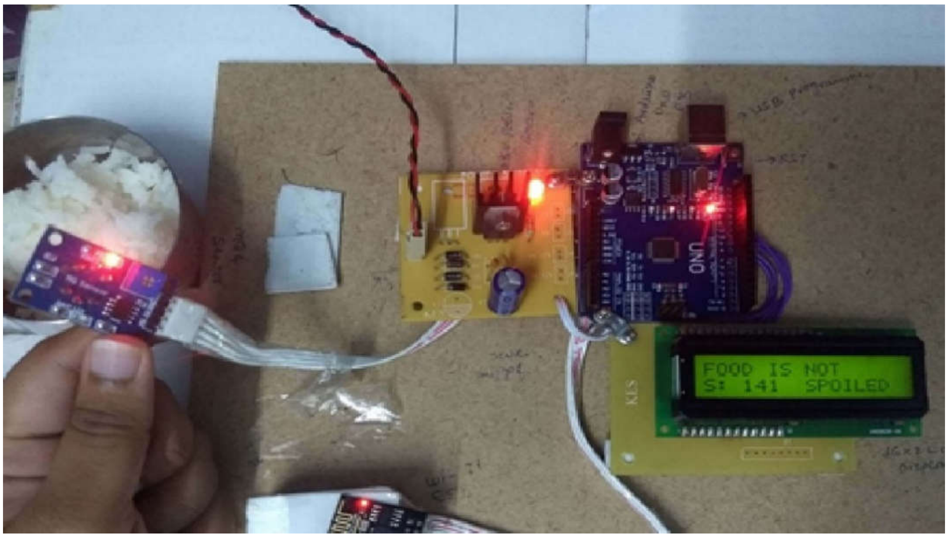


Figure 6. Output on LCD Display

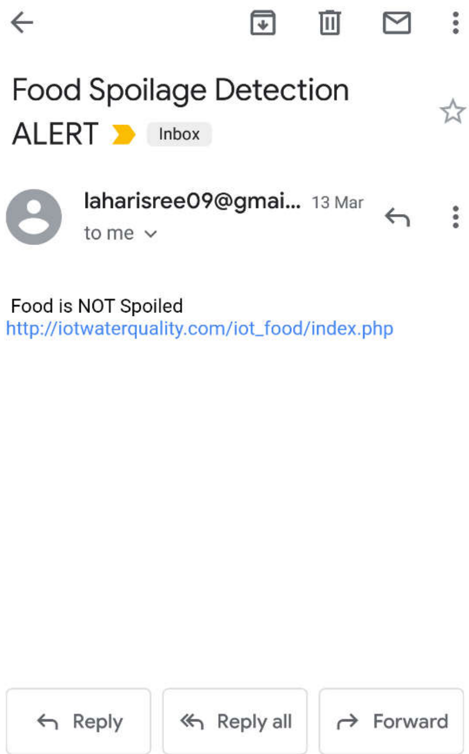


Figure 7. Output in mail

4.2 Result for Liquid Food

The system is tested on milk and water. The milk is tested in regular interval after opening carton of milk. The initial pH value of milk when tested immediately after opening the carton was 6.5. On continuous observation we found that the milk started forming clumps after 5-6 hours when it is placed at room temperature. The drinking water and the normal tap water are tested and we have observed that the pH range of drinking water was around 8 and 8.5 for one and half day and later it increased to 9. The pH value of normal tap water was greater than 8.5.

The result of the tested liquid is displayed on the LCD Widget in blynk Application, Serial Monitor and the buzzer also responds accordingly.

Test Case-1: When Stored Milk is Tested

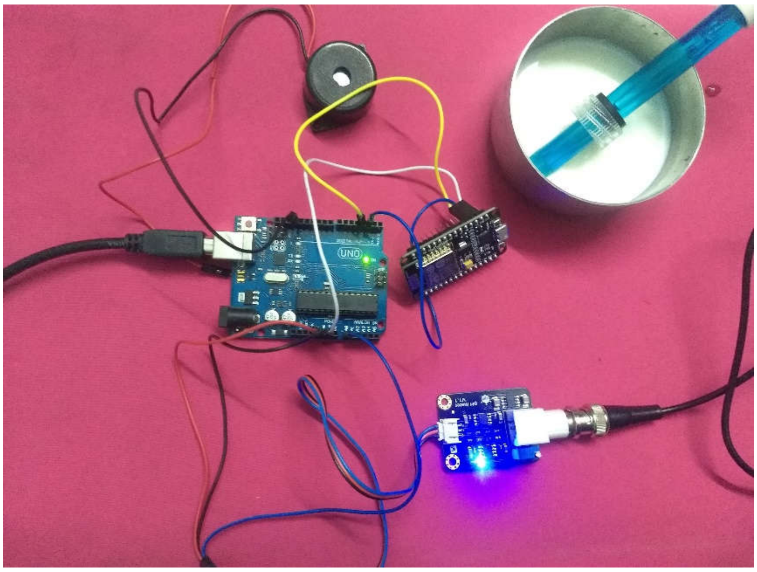
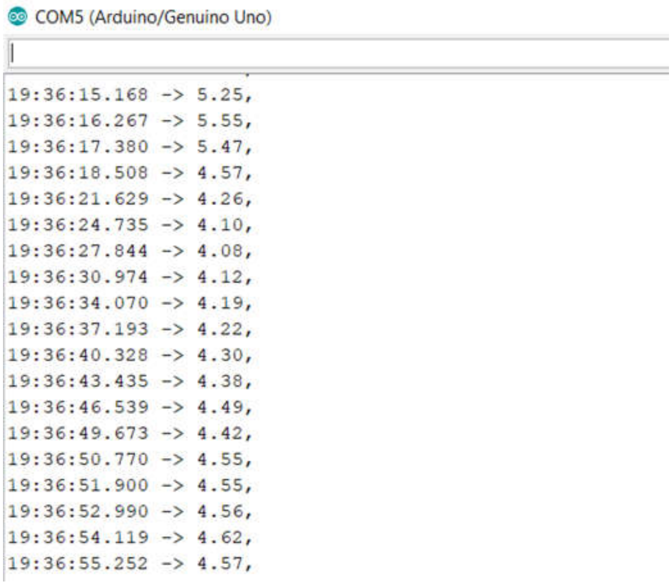


Figure 8. Testing Stored Milk

When the stored milk is tested the pH value of milk is displayed on the serial monitor and LCD widget and the buzzer rings as the milk is spoiled.



COM5 (Arduino/Genuino Uno)

```
19:36:15.168 -> 5.25,
19:36:16.267 -> 5.55,
19:36:17.380 -> 5.47,
19:36:18.508 -> 4.57,
19:36:21.629 -> 4.26,
19:36:24.735 -> 4.10,
19:36:27.844 -> 4.08,
19:36:30.974 -> 4.12,
19:36:34.070 -> 4.19,
19:36:37.193 -> 4.22,
19:36:40.328 -> 4.30,
19:36:43.435 -> 4.38,
19:36:46.539 -> 4.49,
19:36:49.673 -> 4.42,
19:36:50.770 -> 4.55,
19:36:51.900 -> 4.55,
19:36:52.990 -> 4.56,
19:36:54.119 -> 4.62,
19:36:55.252 -> 4.57,
```

Figure 9. Output on Serial Monitor

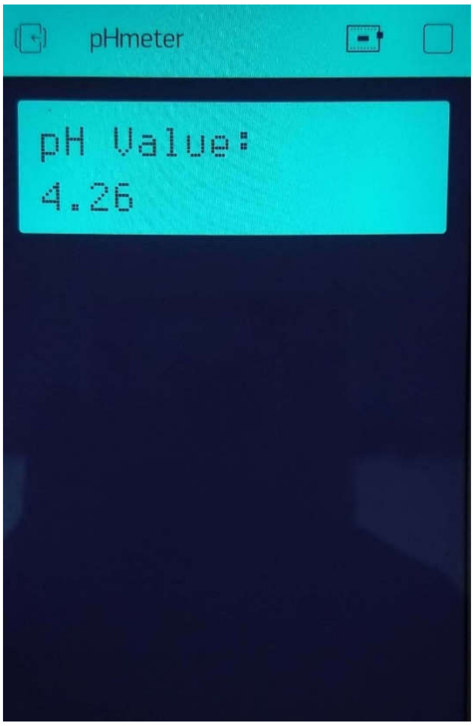


Figure 10. Output on LCD Widget in BLYNK Application

Test Case-2: When Fresh Milk is Tested

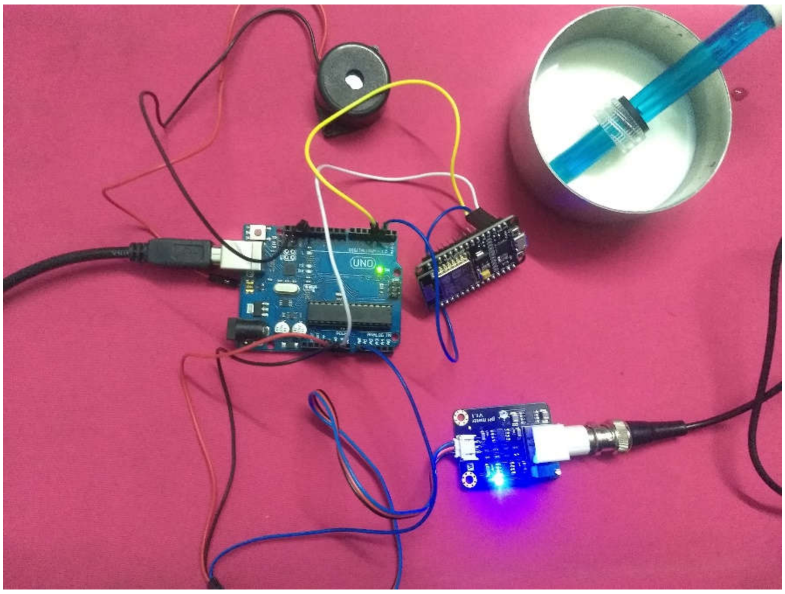


Figure 11. Testing Fresh Milk

When fresh milk is tested the pH value of milk is displayed on the serial monitor and LCD widget and the buzzer does not ring as the milk is not spoiled.

```
19:37:06.393 -> 6.63,
19:37:07.511 -> 6.66,
19:37:08.627 -> 6.65,
19:37:09.709 -> 6.65,
19:37:10.839 -> 6.65,
19:37:11.954 -> 6.65,
19:37:13.082 -> 6.65,
19:37:14.175 -> 6.66,
19:37:15.315 -> 6.67,
19:37:16.409 -> 6.67,
19:37:17.518 -> 6.67,
19:37:18.650 -> 6.68,
19:37:19.753 -> 6.68,
19:37:20.863 -> 6.69,
19:37:21.993 -> 6.70,
19:37:23.127 -> 6.70,
19:37:24.236 -> 6.70,
19:37:25.336 -> 6.72,
19:37:26.469 -> 6.72,
19:37:27.573 -> 6.72,
19:37:28.671 -> 6.73,
19:37:29.802 -> 6.73,
19:37:30.911 -> 6.74,
19:37:32.043 -> 6.75,
19:37:33.142 -> 6.67,
```

Figure 12. Output on Serial Monitor

Figure 13. Output on LCD Widget in BLYNK Application

Test Case-3: When Tap Water is Tested

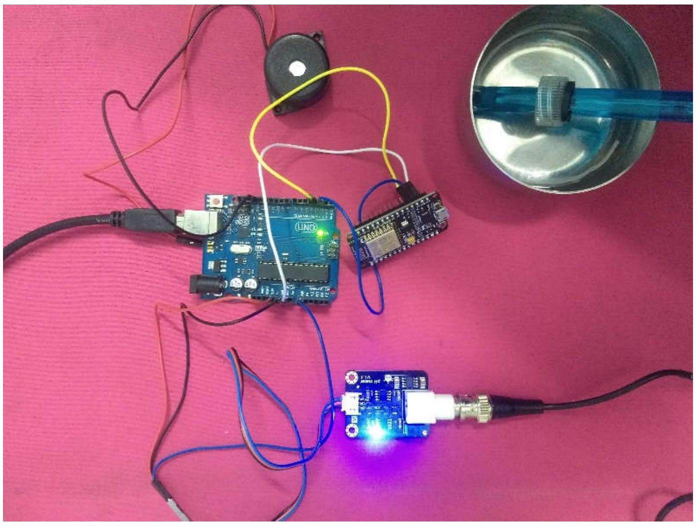


Figure 14. Testing Tap Water

When tap water is tested the pH value of water is displayed on the serial monitor and LCD widget and the buzzer rings as the water is not suitable for drinking.

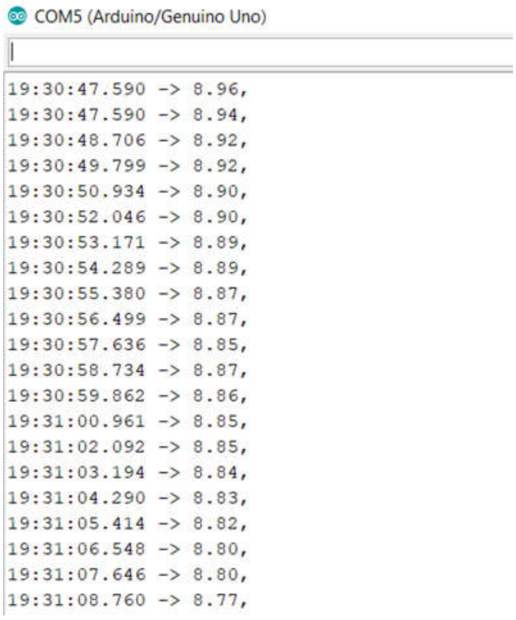


Figure 15. Output on Serial Monitor

Figure 16. Output on LCD Widget in BLYNK Application

Test Case-4: When Drinking Water is Tested

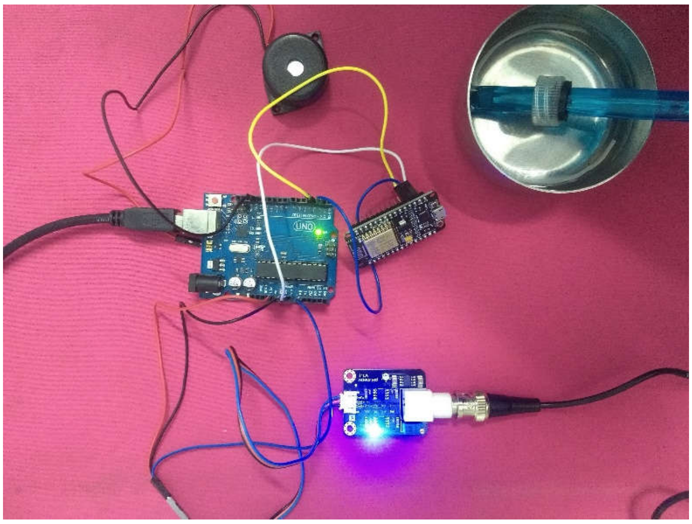


Figure 17. Testing Drinking Water

When drinking water is tested the pH value of water is displayed on the serial monitor and LCD widget and the buzzer does not ring as the water is suitable for drinking.

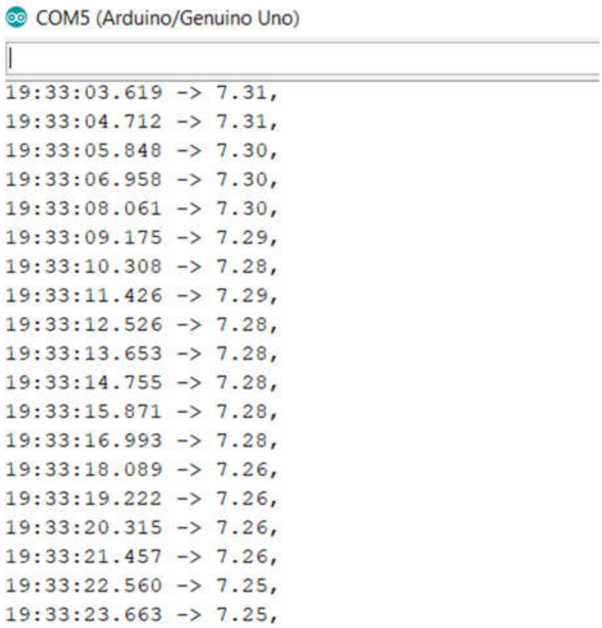


Figure 18. Output on Serial Monitor

Figure 19. Output on LCD Widget in BLYNK Application

5. Conclusion

As consumer's demand for fresh food increases, there is need to ensure the quality and safety of food. Spoilage microorganisms, including bacteria, fungi and molds play a significant role in the spoilage of food. Storage temperature, processing procedures and transportation contribute to food spoilage. Microbial succession during spoilage depends on the availability of water, high pH and storage temperature. Therefore, to prevent the spoilage of food, effective strategies and technology that can be used at processing and storage stages should be designed and utilized to limit microbial growth. In addition, early detection of spoilage microorganisms through the use of modern technologies should be attempted. There is a large literature which demonstrates the ability of e-nose to track food spoilage in very controlled environments. The primary objective to propose this system is human health. Consumption of spoiled food may be hazardous and may cause health issues to human beings. Food and water are the primary sources of living. So, monitoring food and water during transport and storage is a challenge. The proposed system provides a way for easy and quick detection of food and water spoilage.

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