Development of IoT Sensor for Pepper Adulteration Detection using Sensor Arrays

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Abstract: Adulteration is an act of degrading the quality of food by means of adding harmful substances to the nutritional food substances. As adulterants are being used more sophisticatedly, it has become difficult for consumers to detect the adulterants in food. It can happen at various stages, from production to processing, storage to transportation and conveyance. The current adulteration detection techniques are very complex, not portable for real time testing, expensive and equipment are laboratory based. Also, these techniques use destructive sensing method. To overcome the issues, this paper reports how papaya seeds which are a common adulterant present in pepper are sensed with sensor monitoring system using machine learning while also making sure the whole system is cost-effective and portable at the same time. Subsequently, to take care of the above-said issue this paper is proposed to design a low-cost portable IoT sensor for pepper adulteration detection in real-time.

Keywords: Food Adulteration, Sensor Array, IoT, Pepper, Volatile Organic Compounds.

1. Introduction

According to the annual public laboratory testing reports for the year 2017-18' in India, close to a quarter of 25% of the samples analysed were found to be misbranded/adulterated. The data shows that 99,353 food samples were analysed by the public labs in the year 2017-18 to find out how much adulteration/ misbranding is being done. These food samples were collected across almost all food categories right from loose to packaged commodities [1].

1.1. Common Techniques

In gas chromatography technique, it is possible to specifically separate the food samples and identify the components that can be vaporized without the sample being damaged. The mix of gas chromatography and mass spectrometry (GC-MS) techniques possibly decrease the time taken to analyse the sample; however, its application is enormously restricted due to the significant expensive operation and equipment.

There is an antibody-based analytical method in which the biochemical reaction between the antibody and enzyme-substrate introduced in the test produces a signal, which is envisioned as a colour shade change in the substrate. The concentration of the analyte in the sample directly relates to the intensity of the colour shade change. This technique is known as Enzyme-linked immunosorbent assay (ELISA).

Polymerase Chain Reaction is the most commonly used analytic method for food adulteration detection. which is a DNA-based technique that is greatly sensitive to the molecular formation and is ideal for natural products with intact DNA.

DNA of food materials, particularly grains, goes through physical and compound changes from oxidation responses and mechanical shearing during preparing or potentially extraction. Thus, making PCR inadequate for detecting the food adulterants in cereal flours and their products.

An instrument that detects odours and flavours that utilizes pattern-recognition systems and an array of semi-selective chemical sensors derived from mammalian olfactory sequencing for detection of adulterants in flour and similar kind of food products is known as Electronic nose.

Electronic sensing is believed to play an evolving role in testing the adulteration of food items. Although the conventional methods are still successfully pertinent, present-day techniques and hardware are encoded with refined numerical equations and computer-aided algorithms to trace particular chemical, physical, or textural properties dependent on distinguishing proof of at least one particle for a particular adulterant such as Fourier transform infrared (FTIR) spectroscopy, Near-infrared spectroscopy (NIRS), Nuclear magnetic resonance (NMR), UV-vis spectroscopy, Raman Spectroscopy and so on [2].

An array of 13 EN gas sensors were utilized to understand the variations among VOC patterns from undamaged and artificially damaged leaves of pepper plants. The SVM has demonstrated the ability to discriminate between various VOC patterns and hence was able to classify and identify appropriately the infected leaves using the EN data. Even though PCA and DFA showed a degree of discrimination with 95% accuracy in the previous analysis, SVM can achieve higher generalisation performance when compared to conventional statistical methods [3].

Usage of e-nose devices for disease-diagnostic in plant and animal hosts has been done through the invention of latest gas-sensing instrument types and disease-detection techniques with the use of sensor arrays developed and according to the need of added host types and chemical classes of VOCs closely related to individual diseases. These instruments are innovative diagnostic tools with great potential for non-invasive previous detection of numerous types of plant, animal and human diseases based on analysis of indefinite quantity VOC-metabolites derived from clinical samples [4].

Another paper shows the real-time responses of α-pinene imprinted polymer-coated AuNP sensor to three terpene vapours: α-pinene, limonene, and γ-terpinene were verified to be selective, rapid, and reversible which gives us an understanding of detectable terpene vapours. Some of the major terpene detection techniques are as follows: HPLC, GC/MS, and QCM. Also, studies that use MIP to fabricate QCM or resistant terpene sensors are being actively performed. At the terpene concentration of 500 ppm, the MOC sensor exhibited about 6.5 and 100-times higher sensitivity for α-pinene and limonene, respectively, compared to the MMC sensor [5].

The GC-MS results indicated that aphid-stressed tomato plants discharged new volatile compounds such as linalool, carveol, and nonane 2,2,4,4,6,8,8-heptamethyl and increased some terpene compounds such as caryophyllene for combating aphid attacks, and, thereby, were thought-about info-chemical biomarkers at the tomato plant-insect interaction. The changes of VOC fingerprints not only disclosed the mechanism of various sensor responses towards different tomato plant samples but also provided a baseline for further development and optimisation of the E-nose system. [6].

2. Materials and Methods

This section discusses the working mechanism of the IoT monitoring system and the development of the website. Section 3 discusses the design of front end and back end working of the website. Section 3.1 illustrates the working of a virtually simulated circuit using a gas sensor. Section 3.2 delineates the observed readings of MQ2 gas sensor with the pepper sample.

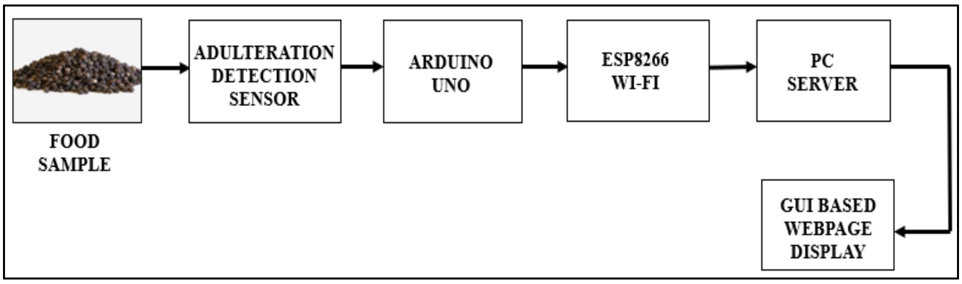

Figure 1. IoT sensor monitoring system

From Fig 1, the data sample being used is pepper and for detecting the VOCs present in pepper, gas sensors are selected due to their quick response to the odour, highly portable and as they are much cheaper. Various gas sensors have a distinctive non-selective affinity towards an assortment of Volatile Organic Compounds and consequently can be used to produce an odour signature which is distinct for each food sample depending upon their quality. MQ3, MQ135, MQ138 and TGS2602 sensors can also be employed for VOC detection.

Resistors that are connected to the sensors will act as an output load. Arduino Uno's analogue reading port has will be connected to each sensor in the sensor respectively to measure the output voltage. The 3 gas sensors are then plugged inside a sensing chamber and made sure no openings are left as open. With the help of vacuum suction, air can be sucked out thus preventing the odour from leaking into a surrounding environment which will switch ON with the help of a relay module to remove the sample odour and replace that with odourless and clean air at the sampling stage and at every sampling stage, a small amount of the pepper sample will be placed inside the sensing chamber while it is ensured that the sensing chamber is properly sealed. The pepper samples will not undergo any kind of change or chemical reaction throughout the sampling process. After voltage difference is observed for different samples, with the help of ML algorithm identification of the adulterant % in the food sample will take place and output will be displayed on the website.

Sensors employed: The role of the sensor is to detect and measure some kind of physical effect, here sensors which will help us differentiate between an adulterated and unadulterated pepper sample are considered. The sensors MQ3, MQ135, MQ138 and TGS2602 can also be employed for volatile organic compound identification.

Arduino UNO: Arduino Uno's analogue reading port has will be connected to each sensor in the sensor respectively to measure the output voltage.

WI-FI: The WI-FI module is used to give the microcontroller access to the WI-FI network and connect it to the wi-fi router for network connectivity. The Wi-Fi model used here is ESP8266.

PC server: At this point, configure the local PC server, send the information to the web and lastly close the connection. The local webserver will serve the web pages to computers that connect it. Then, the GUI displays objects that convey actions that can be taken by the user.

Table 1. Gases detected by each sensor employed

No.	Name	Sensed Gases
1	MQ3	Alcohol
2	MQ135	Benzene, Alcohol
3	MQ138	Volatile compounds (aldehydes, alcohols, ketones and aromatic compounds)
4	TGS2602	Volatile organic compounds and odorous gases

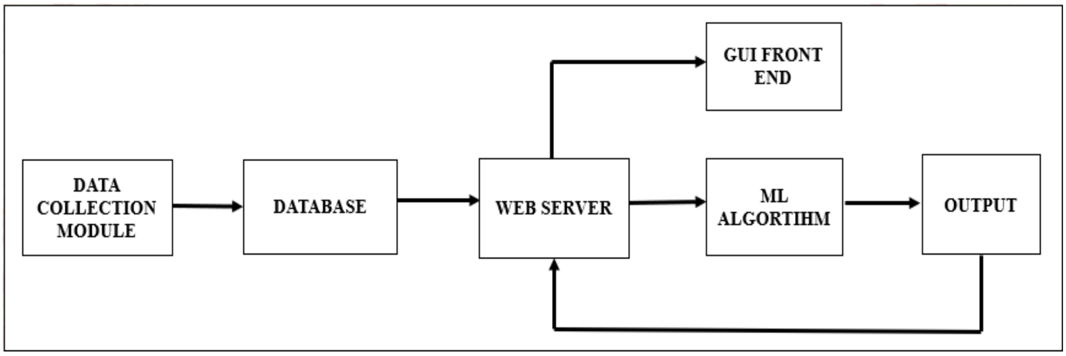

Figure 2. Data processing at server PC

Fig 2 shows that database will receive the sample information through Wi-Fi. It will collect the data and it is communicated to the database and web server. Webserver will process the data through ML algorithm.

A browser that runs only HTML, and CSS. That's the frontend. It can make calls to a backend server to get results, which it then maybe processes and displays. The backend server should respond to the frontend's requests, but the backend will need to talk to databases. The backend will receive ML algorithm as a job at the request of the user, which it should put into an ML queue. The ML algorithm once deployed will then give us the output i.e., the prediction to the database provided by us. Then the GUI front end displays objects that convey actions that can be taken.

3. Results and Discussions

This section discusses about the website design along with authentication. Website has been designed so that the data collected from real time monitoring of the sensors can be viewed from anywhere around the world. It also demonstrates the circuit simulation of a gas sensor virtually and shows the sensor reading of MQ2 sensor with pepper sample.

The navigation bar of the website consists of home, analyse, display, details, old details and methodology which when clicked will open and display the information corresponding to the respective webpage. The home button displays the main webpage of the website which gives a brief introduction to the project. Analyse webpage will display the output as adulterated food if the sample provided is adulterated or else it will display as unadulterated food. In the display webpage, which will later be used to display the spectral graph which will help us visually identify how much percentage of the adulterated sample is present in the food sample. Data regarding the details of the pepper samples along with adulterant percentage mixed and collected will be displayed in the details webpage. In the old details webpage, previous sample data details will be displayed. Block diagram for the proposed system can be viewed in the methodology webpage. Additional buttons have been provided below the brief description of the page. Project description details will be mentioned on the about webpage. To check if the system is currently running or ideal, it can be done by clicking on the current status button.

This is a customized HTML website where all the details of the project including the output will be displayed on the website. It is ensured that only registered users can log into the website. Go to the local browser and enter localhost along with the folder name in which the code file of PHP type of registration form is saved and click enter. Then Apache (*local server*) will host this PHP form on the browser and so it opens the registration form. Register with the respective credentials and then submit them as demonstrated in Figure 3 if the user is not registered. From Figure 4 login to the webpage using the previously registered credentials.

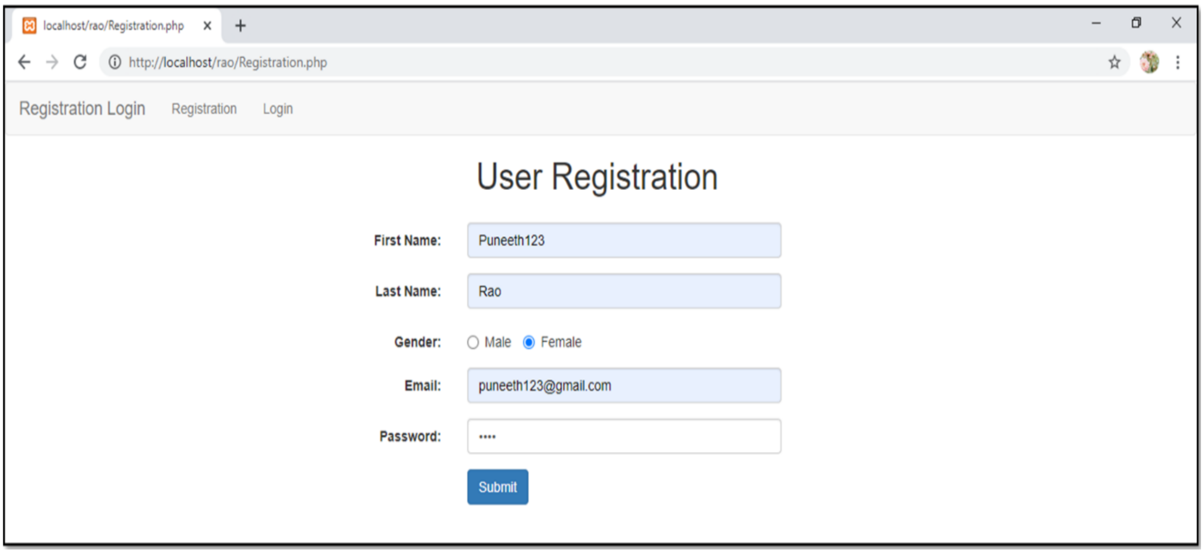

Figure 3. User registration form

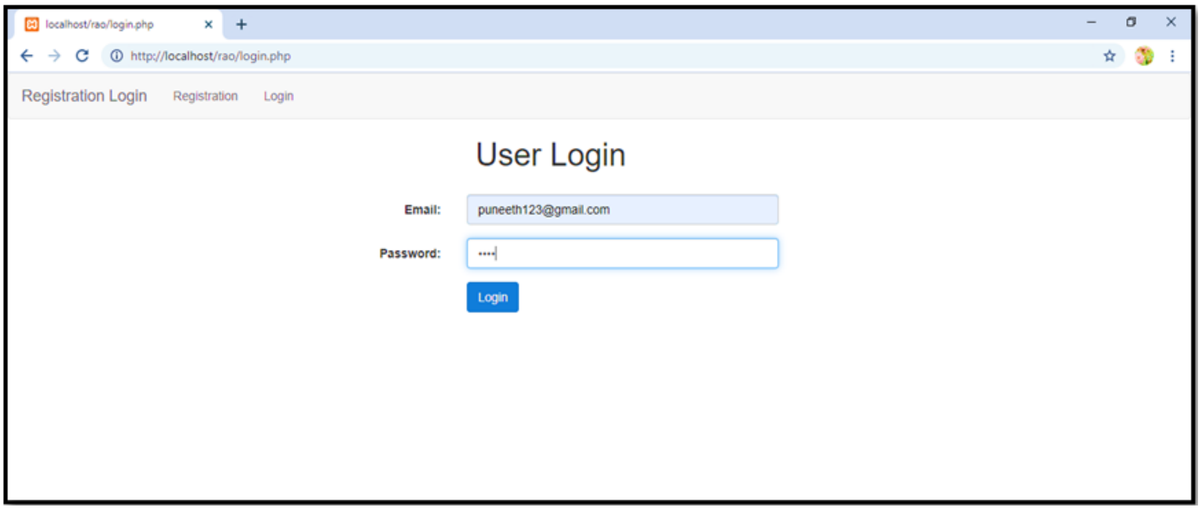

Figure 4. User login form

If either email ID or password entered is incorrect then, invalid email or password will be displayed when the user needs to go back and retype the correct credentials, only then you will be given access to proceed further. Once logged in, click on the project button and you will be taken to the project website homepage. Fig 5 displays the project website homepage with the navigation menu and other necessary buttons.

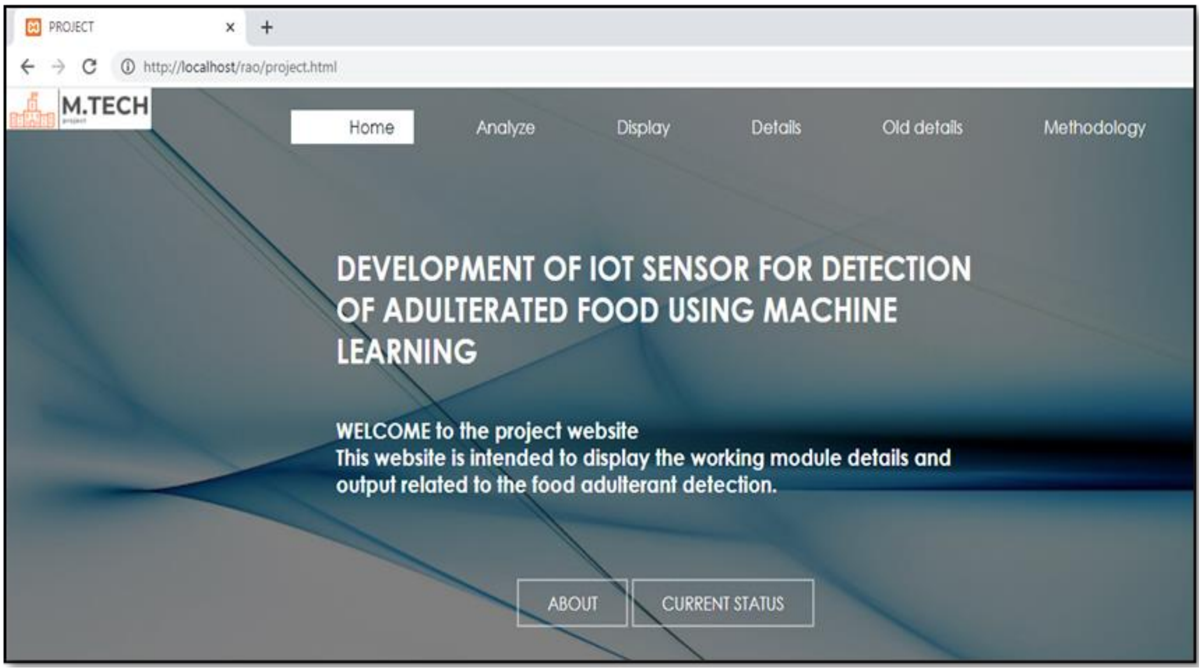

Figure 5. Homepage of the Project Website

3.1. Virtually Simulated Circuit

In this section, the simulation of a gas sensor has been shown virtually and the values before the sensor detects and after the sensor detects the smoke can be seen. From Fig 6, it can be observed that before the sensor starts working, the LCD will display “all clear” and the oscilloscope shows no wave and once the sensor detects the smoke the LCD will display “alert”, and the oscilloscope shows a square waveform indicating a change in voltage in the circuit. In this image, it can also be observed that sensor value output is displayed as 306V when the circuit is simulated without the smoke.

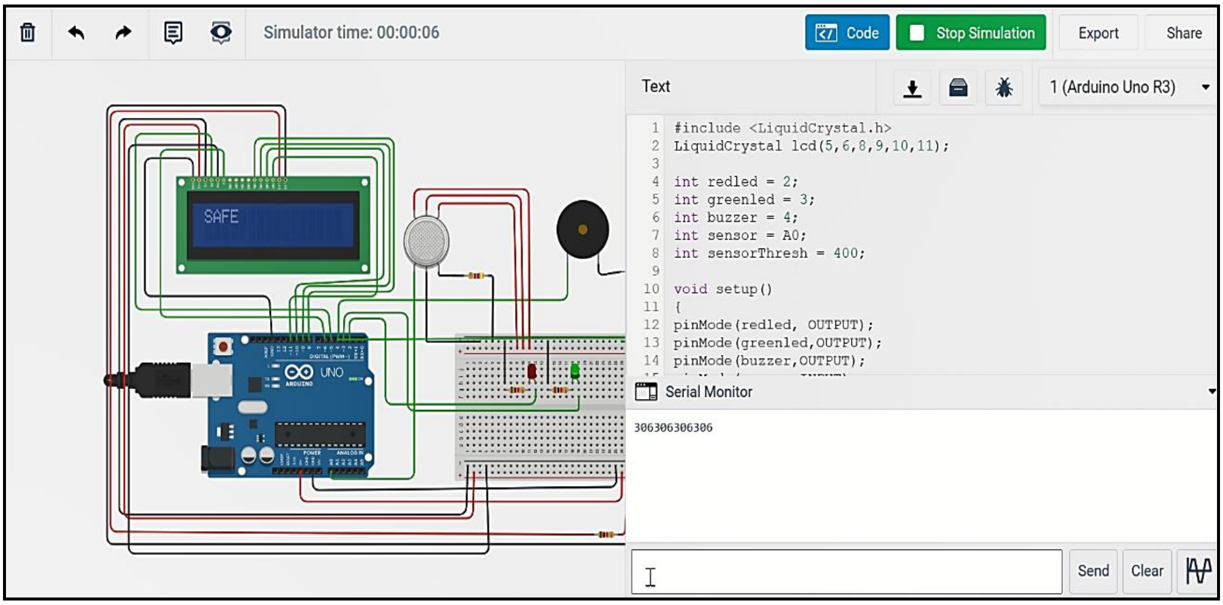

Figure 6. Sensor output values before smoke detection

From Fig 7, it can be observed that sensor value output observed is 609V-642 when the circuit is simulated with the smoke which is detected by the gas sensor, which is almost the double the previous value when the circuit is simulated with the smoke.

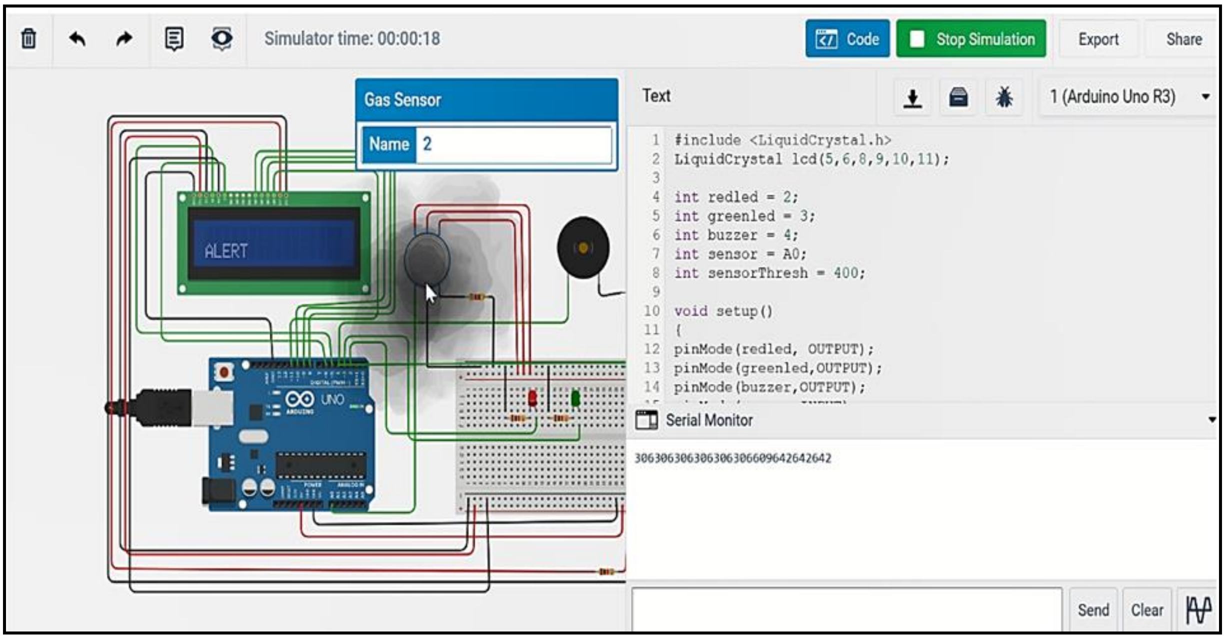

Figure 7. Sensor output values after smoke detection

3.2. Simulated Output of a Sensor

In this section the sensor readings when the pepper is placed with an MQ2 gas sensor is noted. Next, an experiment was performed using MQ2 sensor connected to the Arduino board. The Arduino Uno board was connected to the laptop, in which the Arduino Ide software was used to monitor and plot the readings. Then with the help of data streamer, the voltage change in values was saved in an excel sheet to understand if the values changed or not. Firstly, the Arduino board connected to the sensor was placed in an empty closed box and noted down the reading along with the graph. Next, the same circuit along with the pepper sample of 40gms was placed in a closed box and 180s were observed for the sensor to observe the aroma and then the reading were noted and the difference in the values with and without the pepper sample as observed.

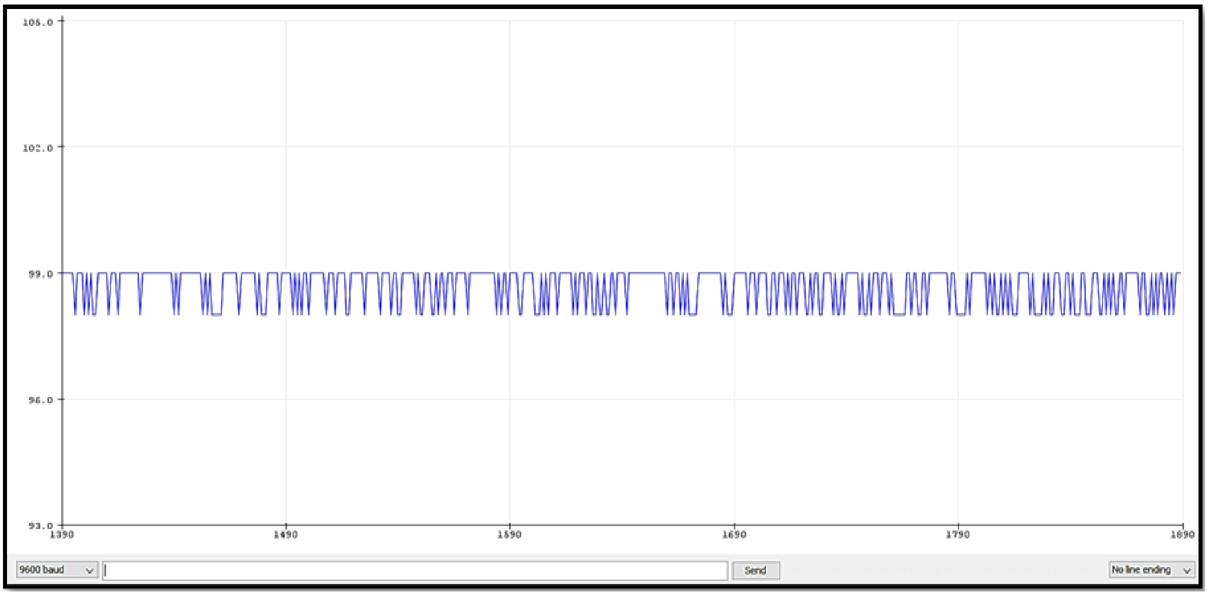

Figure 8. MQ2 reading-In a closed box

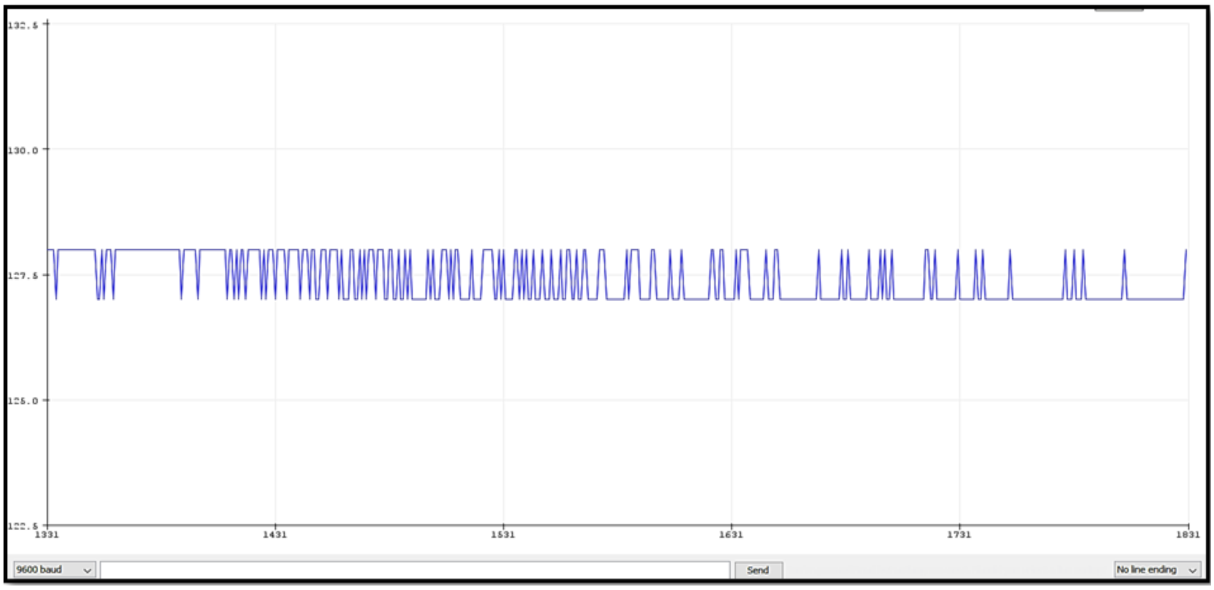

Figure 9. MQ2 reading- With pepper sample

From Fig 8, MQ2 sensor is connected the Arduino Uno the value read by the graph is 99.0V that is the MQ2 sensor reading in an empty box while from Fig 9, the value read that can be noted is 127.8V that is when the pepper sample is placed with the sensor.

4. Conclusion

New innovative solutions need to be developed for adulteration detection to ensure the food safety. This is the non-intrusive detecting method which can help us in separating the adulterants from the food sample with the help of machine learning algorithm and afterwards display the result onto the HTML site, where different insights about this project can be referred. Created customized HTML website has been designed to solely display the details and output regarding this project and simulated a virtual circuit for the working of gas sensors using Tinker cad to understand the working of a gas sensor and observed the voltage changes and as well as sensor output value changes which will be useful while constructing the circuit in a real-time environment. Noted the sensor reading for 3 different gas sensors when kept in an empty box and when kept in a pepper sample.

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