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IOT SENSOR-BASED GAS DETECTION DEVICE FOR STORED FRUITS

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ABSTRACT

Fruits and vegetables spoilage detector using Arduino mega-board make use of an Arduino system which is connected to the MQ-7, MQ-2, MQ135 gas sensor and DHT11 Rh & temperature sensor. In this project, an Arduino software is installed in the PC. The spoilage detecting program is installed in the microcontroller of the Arduino. A MQ-7, MQ-2, MQ135, DHT11 Rh & temp were connected to the Arduino mega-board and also the GSM module is connected to the Arduino through which the user gets readings on the mobile or PC. When spoilage start, the fruits or vegetables come near to the sensor, it senses the gas evolved by fruits or vegetables in digital format on LCD screen by using microcontroller. Papaya starts spoiling from reading of ethylene evolved 5.9 at 36.8^{O}C temperature and 44.5% humidity. Mango starts spoiling from reading of ethylene evolved 6.3 at 36.5^{O}C temperature and 47.10% humidity. Banana starts spoiling from reading of ethylene evolved 5.2 at 40.2^{O}C temperature and 44.6% humidity. Sapota starts spoiling from reading of ethylene evolved 4.2 at 36.5^{O}C temperature and 43.9% humidity.

Key words: Arduino Mega-Board, Spoilage Detection, Gas Sensors (MQ-7, MQ-2, MQ135), Ethylene Monitoring, Fruits and Vegetables

Introduction

Fruits and vegetables account for nearly 90% of the total horticulture production in the country. India is now the second largest producer of fruits and vegetables in the world and is the leader in several horticultural crops, namely mango, banana, papaya, cashew nut, areca nut, potato, and okra (lady's finger). However, the nature of horticultural crops is such that it is not easy to make assessment of their production. These crops, especially vegetables, are grown in small plots, fields, or in the back of the houses, and they do not have single point of harvesting in most of the cases which makes their assessment difficult. Many horticultural crops have multiple pickings in a single season (Horticultural Statistics at a Glance, 2015).

Most microorganisms that are initially observed on whole fruit or vegetable surfaces are soil inhabitants, members of a very large and diverse community of microbes that collectively are responsible for maintaining a dynamic ecological balance within most agricultural systems. The even smaller subset of bacteria and fungi responsible for causing spoilage to the edible portion of the crop plant is the subject of this section. Spoilage microorganisms can be introduced to the crop on the seed itself, during crop growth in the field, during harvesting and postharvest handling, or during storage and distribution (Bhagyashree *et al.*, 2019, Janisiewicz & Korsten, 2002, Andrews & Harris, 2000).When starts spoilage and become pungent, it is most often due to the growth of spoilage microbes such as bacteria, yeasts and mould. Spoilage odors come in many flavours, depending on the type of spoilage microbe and the food being spoiled. As moulds decompose foods, they give off musty, earthy aromas similar to an old basement (Wolfe, 2014).

Ethylene is commonly known as a fruit-ripening hormone. Ethylene gas is a key regulator of the ripening process in many fruits. It regulates the ripening process in many fruits, including bananas, mango, papaya, apples, and tomatoes. Controlled exposure to ethylene can accelerate fruit ripening, making it an essential tool in the agricultural industry for managing harvest and post-harvest processes. Controlled exposure to ethylene can help uniformize ripening and provide consumers with ripe and ready-to-eat fruits.

India is the second major producer of fruits and vegetables and ranks next to Brazil and China respectively, in the world. It contributes 10 percent of world fruit production and 14 per cent of world vegetable production. Fruits and vegetables are more prone to spoilage than cereals due to their nature and composition, and this spoilage occurs at the time of harvesting, handling transportation, storage, marketing and processing resulting in waste. Efficient management of these wastes can help in preserving vital nutrients of our foods and feeds, and bringing down the cost of production of processed foods, besides minimizing pollution hazards. According to India Agricultural Research Data Book 2004, the losses in fruits and vegetables are to the tune of 30 per cent. Taking estimated production of fruits and vegetables in India at 150 million tonnes, the total waste generated comes to 50 million tonnes per annum. (Rawat, 2015). Therefore, the present study was undertaken to develop a device to detect ethylene gas during storage with an objective to develop and test the device for measurement of ethylene gas during storage of fruits and vegetables.

Materials and Methods

This work was carried out during 2021-22 in the Department of Agricultural Process Engineering,Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India. The materials required for the development of setup are Arduino Mega board, MQ7 Gas Sensor, DHT11 Relative Humidity & Temperature Sensor, MQ2 Gas Sensor, MQ135 Gas Sensor, GSM module, Smartphone, Power Bank and LCD Display Screen.

Arduino Mega Board

Arduino (Fig. 1) is open-source electronics prototyping platform based on flexible, easy-to-use

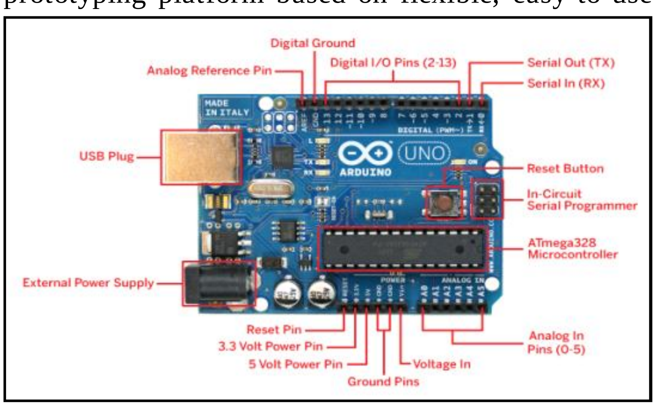

Fig. 1: Arduino Mega Board.

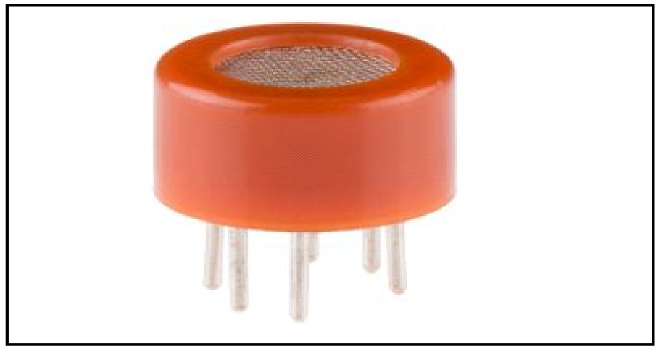

Fig. 2: MQ-7 Gas Sensor.

hardware and software. Arduino can sense the environment by receiving input from a variety of sensors and can affect its surroundings by controlling lights, motors, and other actuators.

MQ-7 Sensor

MQ-7 gas sensor (Fig. 2) module is useful for gas leakage detection (in home and industry). It is suitable for detecting Alcohol, Ethylene, Benzene, CH_4, Hexane, LPG, CO. Due to its high sensitivity and fast response time, measurements can be taken as soon as possible. The sensitivity of the sensor can be adjusted by using the potentiometer.

DHT11 Relative Humidity & Temperature Sensor

Humidity is the measure of water vapour present in the air. The level of humidity in air affects various physical, chemical and biological processes. In industrial applications, Humidity measurement determines the amount of moisture present in the gas that can be a mixture of water vapour, nitrogen, argon or pure gas

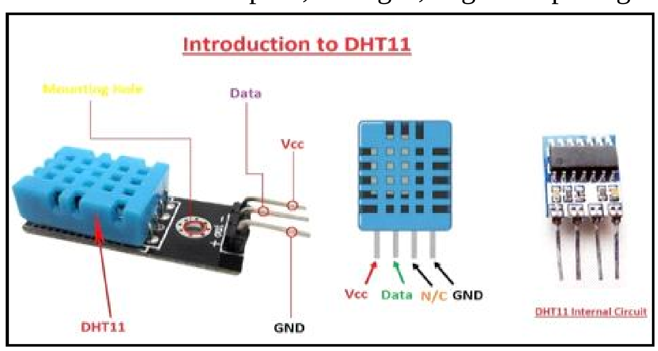

Fig. 3: DHT11 Relative Humidity & Temperature.

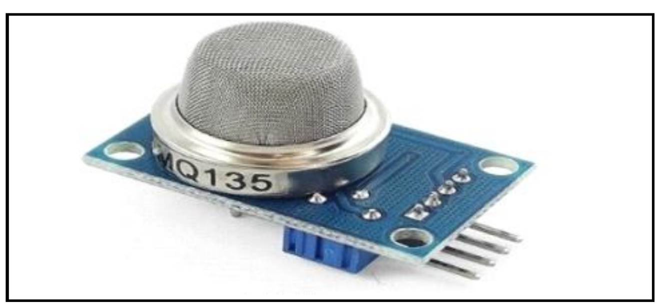

Fig. 4: MQ135 Gas Sensor.

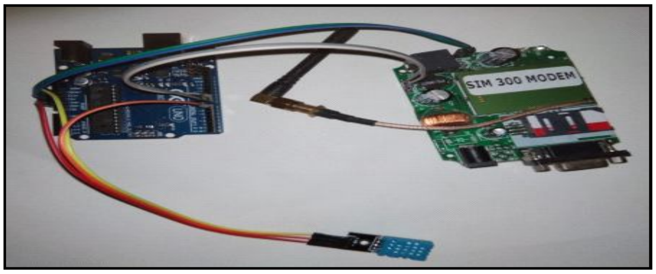

Fig. 5: GSM moduleSmartphone.

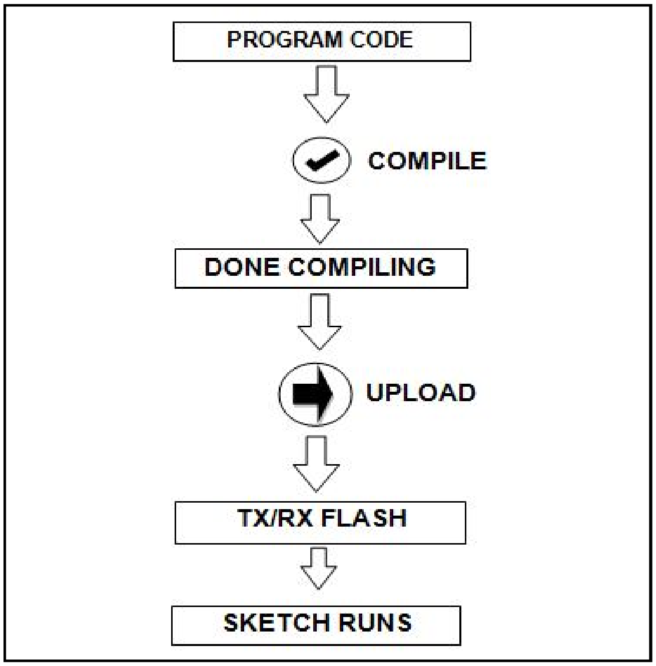

Fig. 6: Steps to run program.

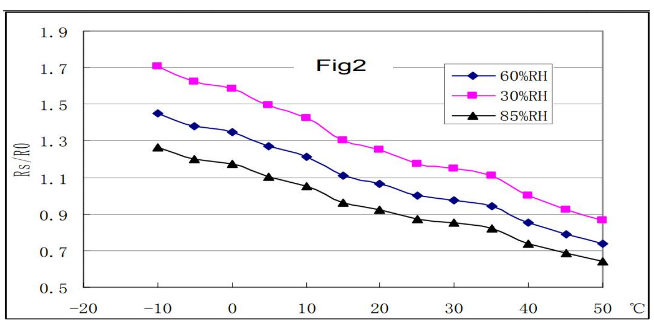

Fig. 7: Influence of Temperature/Humidity on MQ-7 Gas Sensor.

etc. DHT11 is a digital temperature and humidity sensor (Fig. 3).

MQ135 Gas Sensor

A device that is used to detect or measure the gases like ammonia, benzene, sulphur, carbon dioxide, smoke, and other harmful gases are called as an air quality gas sensor (Fig. 4).

GSM Module

A GSM modem is a wireless modem that works with a GSM wireless network. A wireless modem behaves like a dial-up modem. GSM mobile phone, a GSM modem requires a SIM card from a wireless carrier in order to operate (Fig. 5).

The spoilage readings of the fruits and vegetables get directly on the smartphone through the GSM module.

Power Bank

Spoilage Gas Detector Device is powered by a Power Bank of capacity 500maH which make it easy to use & handle during gas detection. Power banks are portable charging devices that can be used to supply the power to Arduino Board.

LCD Display Screen

An LCD display 16×2 is actually a basic and simple to use LCD module. It includes LCD glass, COB (Chip on PCB Board) LCD control board, backlight, zebra to connect LCD glass and control board and a bezel to hold everything together. 16×2 LCD display can display 16 characters per line and there are two lines. Each character has 5×8 dot matrix pixels and the cursor underneath.

Programming

In the project we have used Arduino 1.6.7 software to dump the program code in to Arduino board. The steps required to upload and run the sketch are as shown in (Fig. 6) (Bhagyashree *et al.*, 2019).

Results and Discussions

The development of a Detection Device for Ethylene

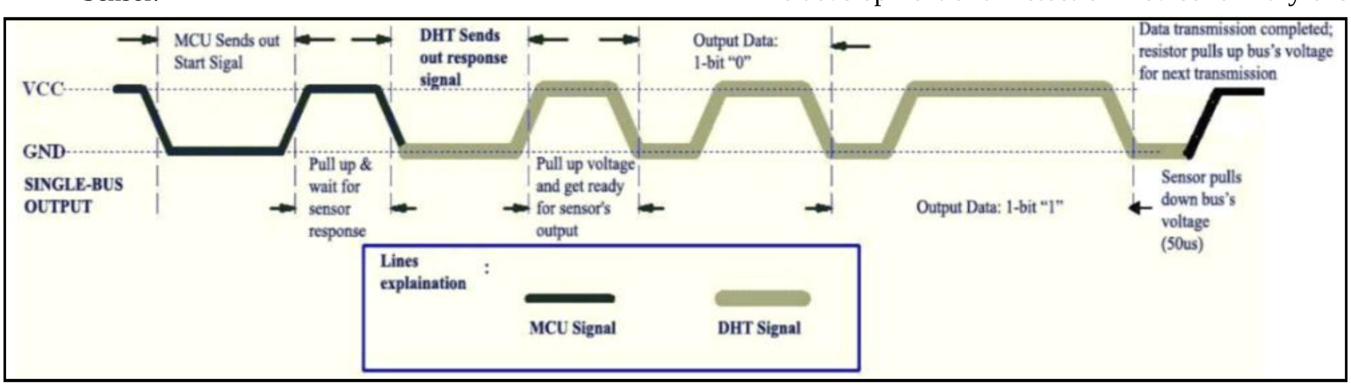

Fig. 8: Overall Communication Process.

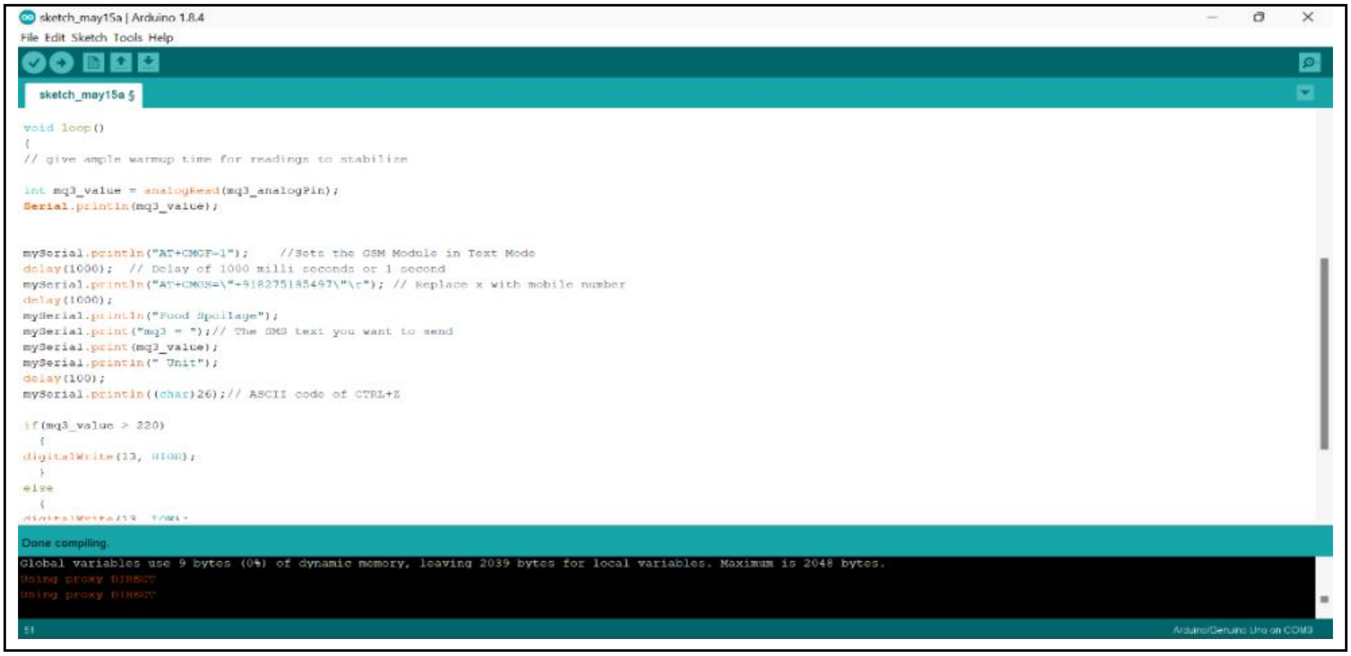

Fig. 9: Arduino Interface used for food spoilage.

Gas evolved During the Storage of Fruits and the readings of gas evolved during the ripening and spoilage of different fruits. From the observation benchmark readings of ethylene in relation with temperature, relative humidity, O_2 and CO_2 was taken for the different fruits and vegetables from which the start of spoilage takes place (Fig. 7).

Fig. 7 shows the typical temperature and humidity characteristics. Ordinate means resistance ratio of the sensor (Rs/Ro), Rs means resistance of sensor in 100ppm CO under different temp. and humidity. Ro means resistance of the sensor in environment of 100ppm CO, 20/65% RH.

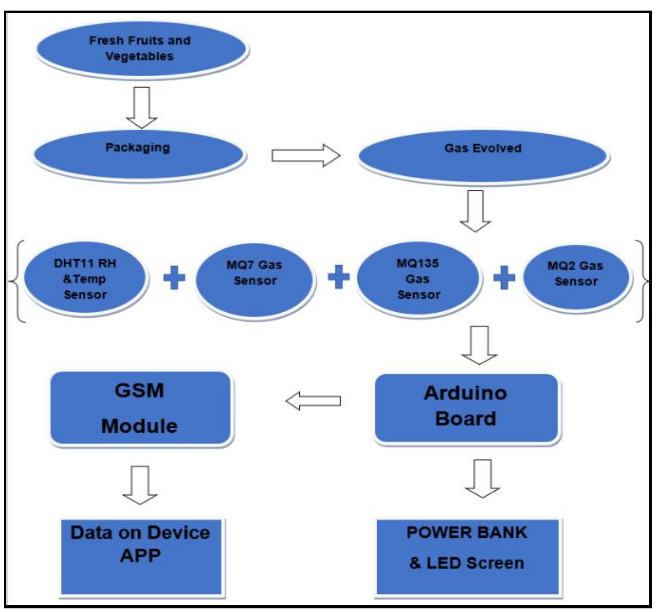

Fig. 10: Flow Chart for Experimental Setup.

DHT11 Relative Humidity & Temperature Sensor

DHT11 Temperature & Humidity Sensor features a temperature & humidity sensor complex with a calibrated digital signal output. By using the exclusive digital-signal-acquisition technique and temperature & humidity sensing technology, it ensures high reliability and excellent long-term stability.

Overall Communication Process

When MCU sends a start signal, DHT11 changes from the low-power-consumption mode to the running-mode, waiting for MCU completing the start signal. Once it is completed, DHT11 sends a response signal of 40-bit data that include the relative humidity and temperature information to MCU. Users can choose to collect (read) some data.

Setup and programme uploading

The program given in Methodology 3.10 was

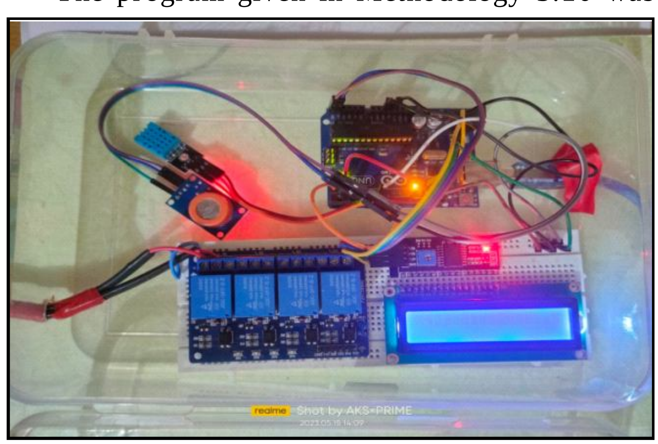

Fig. 11: Laboratory Phase of Ethylene Gas Detection Device.

Fig. 12: Compact Working Phase of Ethylene Gas Detection Device.

uploaded in Arduino software. The software program used to activate the sensors such as MQ-7, DHT11 RH & TEMP, MQ-2, MQ135 Gas sensors using a microcontroller in Arduino interphase as shown in Fig. 9. The complete experimental setup of the spoilage detection device is presented in Fig. 10.

Development of Detection Device for Ethylene Gas

Ethylene gas is an important plant hormone that regulates various physiological processes such as ripening, senescence, and abscission. Ethylene is also used in various industrial applications such as fruit preservation, welding, and plastics manufacturing. However, ethylene gas can be harmful in high concentrations, and therefore, it is important to have a reliable and accurate detection device to monitor its levels.

Here the use of different types of sensors *i.e.*, MQ7, MQ135 Gas Sensor, MQ2 Gas Sensor, DHT11 RH & TEMP which is used to detect different gases which is evolved during ripening of fruits. & Here GSM module is also used for easy access of data on smartphone.

Here Laboratory Phase of Ethylene Gas Detection Device only includes some important parts of device *i.e.*, Arduino Mega Board, MQ7, DHT11 RH & Temp Sensor, LCD Display, etc (Fig. 11).

Here Compact Working Phase of Ethylene Gas Detection Device includes all important parts of device

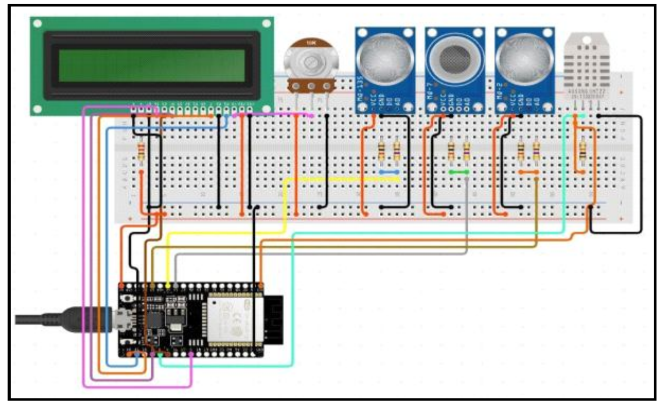

Fig. 13: Complete circuit diagram of Ethylene Gas Detection Device.

which is used for ethylene gas detection i.e., Arduino Mega Board, MQ-7, MQ135 Gas Sensor, MQ-2 Gas Sensor, DHT11 RH & Temp Sensor, GSM module, Power Bank, LCD Display Screen, etc (Fig. 13).

Readings of Spoiling of Different Fruits

The data of ethylene evolved, Temperature (p C), Humidity (%), Carbon Dioxide (CO_2), Nitrogen(N_2), Oxygen(O_2) (%) at every day on different time with the help of Ethylene Detection Device was measured & Final reading observed were presented for different fruits in Table 1 to 4.

PAPAYA

The fresh Papaya was purchased from local market and packed in corrugated box. The gas evolved such as ethylene, CO_2, O_2 & N_2 were measured using the device. Also, the data regarding temperature and RH was measured using the same device. From Table 1, it shows that the average gas evolved on day 1 were ethylene (2.95 ppm), CO_2 (0.045), N_2 (2.805) and O_2 (19.55%). The data regarding temperature and relative humidity was found in the range of 31 to 43°C and 41 to 45%. From day 2 the ethylene gas evolved was increasing from 3.4 ppm & reaches to 6.4 ppm on day 10. From Table 1, it

Table 1: Data regarding gas evolved, temperature and RH of Papaya.

Papaya							
DAY	Time	Ethylene evolved	Temperature (°C)	Humidity (%)	CO_2	N_2	O_2(%)
1	Afternoon Evening	3.0-2.9	34.2-35.6	41.0-44.5	0.05-0.04	3.10-2.51	19.6-19.5
2	Afternoon Evening	3.4-3.5	36.9-35.3	41.6-43.0	0.04-0.03	3.40-3.22	19.5-19.4
3	Afternoon Evening	3.8-4.0	34.5-33.6	42.4-44.3	0.05-0.03	3.10-2.89	19.4-19.5
4	Afternoon Evening	4.0-4.2	31.4-35.6	42.4-44.5	0.04-0.05	3.20-3.51	19.3-19.5
5	Afternoon Evening	4.6-4.8	36.7-35.8	41.6-44.3	0.06-0.05	3.40-3.51	19.6-19.4
6	Afternoon Evening	5.0-5.1	34.2-36.5	42.8-44.9	0.05-0.06	3.45-3.51	19.5-19.4
7	Afternoon Evening	5.2-5.5	37.1-39.2	43.5-44.5	0.04-0.06	3.50-3.60	19.3-19.6
8	Afternoon Evening	5.9-6.0	34.5-36.8	42.5-44.3	0.05-0.06	3.10-1.96	19.5-19.4
9	Afternoon Evening	6.0-6.2	38.0-34.6	42.8-43.6	0.05-0.06	3.60-3.97	19.6-19.4
10	Afternoon Evening	6.5-6.4	40.2-42.6	43.0-44.7	0.06-0.05	3.00-3.51	19.5-19.6

Table 2: Data regarding gas evolved, temperature and RH of Mango.

Mango							
DAY	Time	Ethylene evolved	Temperature (°C)	Humidity (%)	CO_2	N_2	O_2(%)
1	Afternoon Evening	4.0-4.1	34.2-33.6	42.23-44.52	0.03-0.04	1.82-2.50	19.6-19.3
2	Afternoon Evening	4.2-4.5	36.9-36.5	41.69-44.60	0.04-0.03	2.36-3.10	19.5-19.4
3	Afternoon Evening	4.8-4.3	34.5-33.6	40.60-43.60	0.04-0.06	1.23-2.51	19.4-19.6
4	Afternoon Evening	4.1-5.0	31.4-32.6	43.20-44.23	0.04-0.05	3.52-3.89	19.5-19.4
5	Afternoon Evening	5.2-5.4	36.7-34.5	44.00-41.50	0.04-0.05	1.05-2.50	19.6-19.4
6	Afternoon Evening	5.6-4.9	34.2-36.2	47.60-44.50	0.06-0.04	1.36-3.31	19.5-19.4
7	Afternoon Evening	5.1-4.8	37.1-35.5	41.20-44.50	0.04-0.05	2.00-3.50	19.4-19.5
8	Afternoon Evening	6.0-5.5	34.5-36.5	43.90-44.50	0.04-0.05	3.56-2.50	19.6-19.3
9	Afternoon Evening	5.9-6.0	38.0-35.9	45.30-44.50	0.06-0.05	2.15-3.50	19.6-19.4
10	Afternoon Evening	6.2-6.1	40.2-36.5	46.10-44.50	0.04-0.05	2.01-3.52	19.5-19.4
11	Afternoon Evening	6.5-6.3	41.3-38.2	45.80-44.50	0.04-0.06	3.23-2.50	19.6-19.3
12	Afternoon Evening	6.1-6.2	36.5-35.6	47.10-44.60	0.04-0.05	3.89-2.25	19.3-19.4
13	Afternoon Evening	6.5-6.7	41.9-36.5	46.90-44.56	0.03-0.05	2.25-3.51	19.5-19.4
14	Afternoon Evening	6.7-6.8	43.3-40.5	52.80-49.50	0.05-0.06	2.55-3.55	19.4-19.3

Table 3: Data regarding gas evolved, temperature and RH of Banana.

Banana							
DAY	Time	Ethylene evolved	Temperature (°C)	Humidity (%)	CO_2	N_2	O_2(%)
1	Afternoon Evening	3.0-3.1	34.2-33.5	32.40-32.80	0.04-0.05	3.10-3.11	19.6-19.4
2	Afternoon Evening	3.0-3.2	36.9-36.7	32.90-33.00	0.04-0.03	3.12-3.15	19.5-19.3
3	Afternoon Evening	3.5-3.6	34.5-35.0	33.20-33.40	0.04-0.05	3.20-3.15	19.4-19.3
4	Afternoon Evening	4.3-4.2	31.4-32.2	35.20-34.00	0.05-0.06	3.50-3.45	19.5-19.4
5	Afternoon Evening	4.0-3.9	36.7-36.8	42.00-42.20	0.05-0.03	4.12-4.15	19.6-19.4
6	Afternoon Evening	3.9-4.0	34.2-34.5	39.20-39.60	0.04-0.06	4.60-4.70	19.5-19.4
7	Afternoon Evening	4.2-4.1	37.1-37.5	40.5-39.8	0.05-0.06	4.80-4.60	19.4-19.5
8	Afternoon Evening	4.2-4.3	34.5-34.8	42.0-41.8	0.04-0.05	3.60-3.90	19.5-19.4
9	Afternoon Evening	4.9-5.0	38.0-38.2	37.2-37.8	0.06-0.04	3.40-3.10	19.6-19.4
10	Afternoon Evening	5.2-5.1	40.2-40.8	44.0-44.5	0.05-0.06	3.20-3.40	19.5-19.6
11	Afternoon Evening	5.0-4.9	41.3-41.5	43.6-42.5	0.05-0.04	4.20-4.80	19.4-19.3
12	Afternoon Evening	6.0-6.1	42.0-43.2	43.5-44.6	0.06-0.05	3.00-3.60	19.4-19.3

Table 4: Data regarding gas evolved, temperature and RH of Sapota.

Sapota							
DAY	Time	Ethylene evolved	Temperature (°C)	Humidity (%)	CO_2	N_2	O_2(%)
1	Afternoon Evening	3.0-3.2	36.7-34.5	40.60-43.60	0.04-0.05	1.36-3.31	19.4-19.3
2	Afternoon Evening	3.5-3.6	34.2-36.2	43.20-44.23	0.06-0.04	2.00-3.50	19.5-19.4
3	Afternoon Evening	4.3-4.2	37.1-35.5	44.00-41.50	0.04-0.05	3.56-2.50	19.6-19.4
4	Afternoon Evening	4.0-3.9	34.5-36.5	46.60-44.50	0.04-0.05	2.15-3.50	19.5-19.4
5	Afternoon Evening	3.9-4.0	38.0-35.9	41.20-44.50	0.06-0.05	2.01-3.52	19.4-19.5
6	Afternoon Evening	4.2-4.1	40.2-36.5	43.90-44.50	0.04-0.05	3.23-2.50	19.5-19.4
7	Afternoon Evening	4.2-4.3	41.3-38.2	45.30-44.50	0.04-0.06	3.89-2.25	19.4-19.3

shows that the minor or slight changes were observed in other gases such as CO_2, O_2 & N_2. From the Table 1, the readings of gas evolved during storage of Papaya are taken. From visual observation it was observed that the change in colour of Papaya starts from reading of ethylene evolved 3.0 ppm and the dark spots occur from reading of ethylene evolved 5.1 ppm and the full spoilage of the Papaya starts from ethylene evolved 6.40 ppm.

MANGO

From Table 2, it shows that the average gas evolved on day 1 were ethylene (4.05 ppm), CO_2 (0.035), N_2 (2.16) and O_2 (19.45%). The data regarding temperature and relative humidity was found in the range of 31 to 43°C and 40 to 49 %. From day 2 the ethylene gas evolved was increasing from 4.2 ppm & reaches to 6.8 ppm on day 14. From Table 2 it shows that the minor or slight changes were observed in other gases such as CO_2, O_2 & N_2. From the Table 2, the readings of gas evolved during storage of Mango are taken. From visual observation it was observed that the change in colour of Mango starts from reading of ethylene evolved 4.0 and the dark spots occur from reading of ethylene evolved 6.0 and the full spoilage of the Mango starts from ethylene evolved 6.80.

BANANA

From Table 3, it shows that the average gas evolved on day 1 were ethylene (3.05 ppm), CO_2 (0.045), N_2 (3.105) and O_2 (19.50%). The data regarding temperature and relative humidity was found in the range of 3 to 43°C and 32 to 45 %. From day 2 the ethylene gas evolved was increasing from 3 ppm & reaches to 6 ppm on day 12. From Table 3, it shows that the minor or slight changes were observed in other gases such as CO_2, O_2 & N_2. From the Table 3, the readings of gas evolved during storage of Banana are taken. From visual observation it was observed that the change in colour of Banana starts from reading of ethylene evolved 3.0 and the dark spots occur from reading of ethylene evolved 4.9 and the full spoilage of the Banana starts from ethylene evolved 6.1.

SAPOTA

The fresh Sapota was purchased from local market and packed in corrugated box. The gas evolved such as ethylene, CO_2, O_2 & N_2 were measured using the device. Also, the data regarding temperature and RH was measured using the same device. The data is present in Table 4 for Sapota. From Table 4, it shows that the average gas evolved on day 1 were ethylene (3.1 ppm), CO_2 (0.045), N_2 (2.335) and O_2 (19.35%). The data regarding temperature and relative humidity was found in the range of 34 to 41°C and 40 to 46%. From day 2 the ethylene gas evolved was increasing from 3 ppm & reaches to 4.3 ppm on day 7. From table 4.8 it shows that the minor or slight changes were observed in other gases such as CO_2, O_2&N_2. From the Table 4, the readings of gas evolved during storage of Sapota are taken. From visual observation it was observed that the change in colour of Sapota starts from reading of ethylene evolved 3.0 and the dark spots occur from reading of ethylene evolved 3.9 and the full spoilage of the Sapota starts from ethylene evolved 4.3.

Conclusion

Fruits spoilage detector using Arduino make use of an Arduino system which is connected to the MQ3 gas sensor. In this project, an Arduino software is installed in the PC. The spoilage detecting program is installed in the microcontroller of the Arduino. A MQ3 & other sensor is connected to the Arduino and also the GSM module is connected to the Arduino through which the user gets readings on the mobile. When spoiled fruits or vegetables come near to the sensor, it senses the gas evolved by fruits or vegetables in the graphical format which is then convert into digital format by using microcontroller. From the observation of the project, it is concluded that the spoilage of the fruits and vegetables are takes place over a particular reading. From the observation of different fruits and vegetables the reading above which the spoilage occurs are determined. Papaya starts spoiling from reading of ethylene evolved 5.9 at 36.8°C temperature and 47.10% humidity, CO_2 0.04, N_2 3.10 & O_2 19.5%. Mango starts spoiling from reading of ethylene evolved 6.3 at 36.5°C temperature and 47.10% humidity, CO_2 0.06, N_2 3.50 & O_2 19.3%. Banana starts spoiling from reading of ethylene evolved 5.2 at 40.2°C temperature and 44.6% humidity, CO_2 0.05, N_2 3.20 & O_2 19.5% and Sapota starts spoiling from reading of ethylene evolved 4.2 at 36.5°C temperature and 43.9% humidity, CO_2 0.04, N_2 3.23 & O_2 19.6%. From the above observation, it is concluded that the spoilage of selected fruits starts from 4.5 to 6.5 ppm of ethylene gas.

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