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Hand-Held Shelf Life Decay Detector for Non-Destructive Fruits Quality Assessment

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ABSTRACT

Perishable food such as fruits have a limited shelf life and can quickly degrade if not properly stored. One method for detecting decay in these foods is the use of ethylene gas. Ethylene is a naturally occurring hormone that is released by fruits as they ripen. By measuring the levels of ethylene in the storage area, it is possible to detect when fruits and vegetables are starting to degrade. This information can then be used to act, such as removing spoiled produce and adjusting storage conditions, to extend the shelf life of the remaining products. By utilizing ethylene gas for early detection of decay, it is possible to improve food safety and reduce food waste. The project aims to utilized ethylene gas from perishable food such as fruits before decay. This project proposed portable or hand-held detection ethylene gas by including temperature and humidity. The sensor will be measuring the level of ethylene gas, temperature and humidity. Next, machine learning method; K-Nearest Neighbour(KNN) were used to evaluate the accuracy of the proposed system. This project, a hand-held decay detector for perishable food products is believed can help to prevent food waste by detecting early signs of spoilage in fruits.

Keywords: non-destructive, fruits quality assessment, ethylene gas, machine learning.

1. INTRODUCTION

Food deterioration is a major issue today because it is unhealthy for customers to ingest damaged food. Food items become unfit for ingestion as a result of a number of circumstances[1]. Food degradation is a result of variables like temperature, moisture, humidity, and light intensity [2]. The deterioration in food can caused poisoning. For this reason, it's important to check the quality or freshness of food. On a global scale, fruits and vegetables are the primary contributors to food waste, with 45% to 50% of all harvested fresh items being lost or discarded along the food supply chain. This corresponds to around 1.3 billiontonnes of food, or $680 billion USD annually in wasted fruits and vegetables [3].

Normally, the fruits evaluation can be done manually by a human; based on taste, smell and vision. However, manual detection takes a lot of time and is susceptible to human error[4]. Hence, this project aim to detecting the spoiled fruits using non-destructive method based on ethylene gas. The non-destructive methods in evaluate the fruits quality are greatly relevant for process control in food industry [7].

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For this paper, the Node MCU is connected with 3 types of sensor; MQ3[5], which is to detect efficiency of ethylene gases and DHT22 which is to check parameter temperature and humidity of fruits. By using the Node MCU Wi-Fi module, these values are transmitted to the mobile application [6] and machine learning model.

The extracted values are then used as test data or input for an machine learning model, which is subsequently compared to a trained model. In addition, this project was design to be hand-held or portable detection to monitor ethylene gas, temperature and humidity. Lastly, the user can select the image of fruit on the mobile application to check the quality of fruit and informed by the machine learning model on the present food situation.

2. METHODOLOGY

2.1 Detection of Fruits Parameter

Based on the figure 1 below show overall system flowchart for this project to monitor and analysis the dataset of ethylene gas from fruits by using machine learning. The system will showthe value of temperature and humidity of surrounding area into MIT App. This flowchart also shown the proposed flowchart represents the process of detecting decay in fruits using a hand- held detection of fruits.

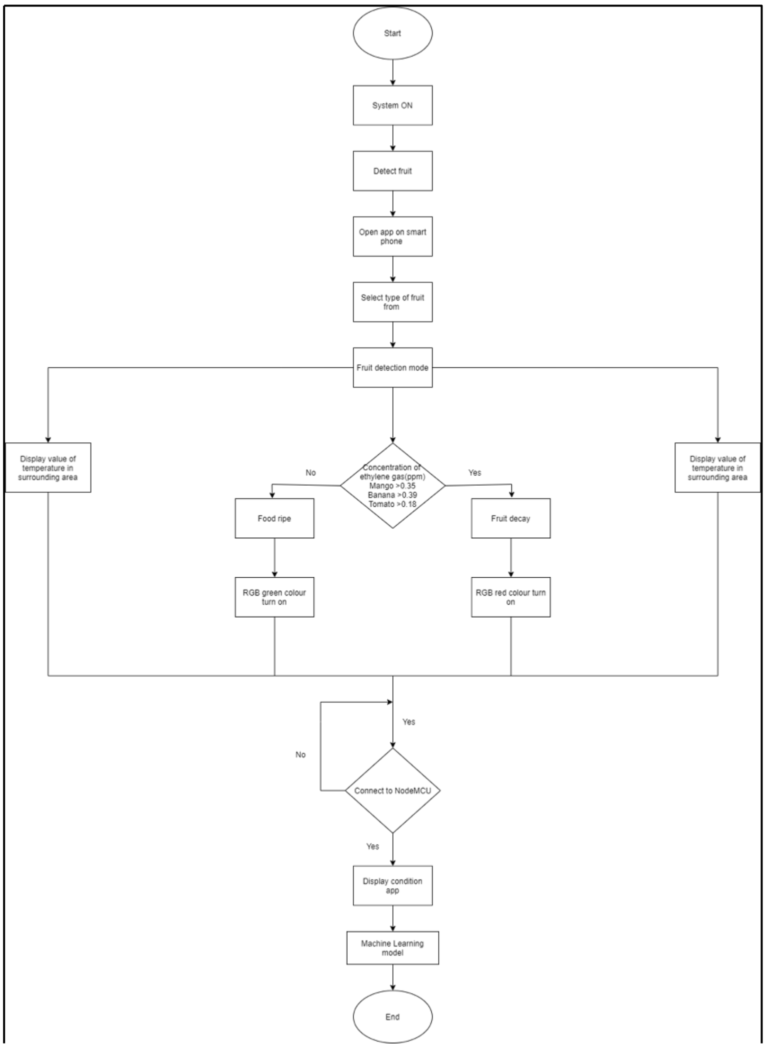

Figure 1. Main flowchart

In this detection of fruit parameter part, the system begins with collecting of fruit parameter such as ethylene gas emission level, humidity and temperature of the surrounding of the fruits itself, thus , this part of the system were assist by the MQ3 gas sensor which will be used to detect and monitored the ethylene gas production of the fruit. In addition, humidity and temperature data will be collected by the DHT22 sensor for further analysis.

For MQ3 alcohol sensor are used as the ethylene gas compound are (C2H4) and belong to the same compound structure, hence we can tune the MQ3 alcohol sensor to detect the presence of ethylene gas produce by the fruits. Application of gas sensor is widely applied in food application [8][9].

Furthermore, ethylene gas level produce by the fruits differs as the fruits began to ripe, thus ethylene gas level can be monitored, and the fruits shelf life can be determined in the analyzing process. Next, machine learning analysis is performed[11], the data collected by the sensor which is the ethylene gas level will be analysis using KNN method.

2.2 Hand-Held Conceptual Design

For hand-held conceptual design, this project was created utilizing Autodesk Inventor software, utilizing various tools such as extrude, fillet, join, and plane. The aim of the project is to develop a portable device for detecting the level of ethylene gas in parts per million, temperature, and humidity in the surrounding environment. The compact and user-friendly design allows for easy transportability. As depicted in figure 2, the project exhibits a straightforward and engaging appearance. The illustration below displays the lateral aspect of the project. According to figure 3, the MQ3 sensor and DHT11 sensor are located at the base of the device. The MQ3 sensor is employed to detect ethylene gas for this project, the cylinder in the base represents the MQ3 sensor, while the rectangle represents the DHT11 sensor. The DHT11 sensor is utilized to monitor the temperature and humidity of the surrounding environment. The top cylinder represents the RGB module which serves as the output indicator, displaying results obtained from the microcontroller through color-coding. The switch and the battery charging port type C were placed at the side of the project.

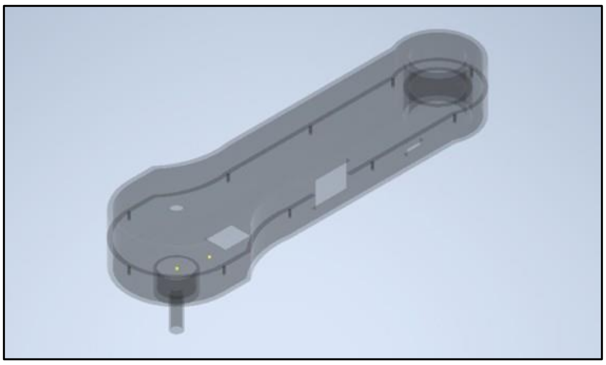

Figure 2. Front view

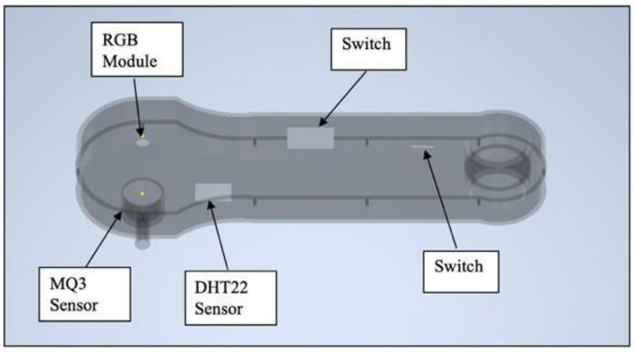

Figure 3. Side view

3. RESULTS AND DISCUSSION

3.1 Hardware and Software Development

Figure 4, the MQ3 sensor and DHT11 sensor are located at the base of the project. The top section of the project accommodates two sensors, the MQ3 sensor and the DHT11 sensor, while the MQ3 sensor was represented by a black cone acting as its protective cover.

Figure 5 below shows the left-side view of the project. The switch and the battery charging port type C were placed at the side of the project. Since the side project has a flat area, that was the ideal place to install the switch and charging port. The figure also shows that cable type C was currently charging the battery.

For software development, figure 6 displayed the levels of ethylene gas, the surrounding temperature and humidity, which will indicate the freshness of the fruit. After users select any types of fruit on the app and it will show value of ethylene gas, the surrounding temperature and humidity. This software also can show notice on screen whether the fruit is good to eat or not. If the fruit indicates a reading value less than the specified amount, the screen will turn green to indicate that the fruit is in good condition. However, if it reaches or exceeds the specified value, the screen will turn red to indicate that the fruit is spoiled or decay. Based onthe figure 7 below show, screen turn to red because the fruit is spoiled or decay while table 1 shows the notice conditions.

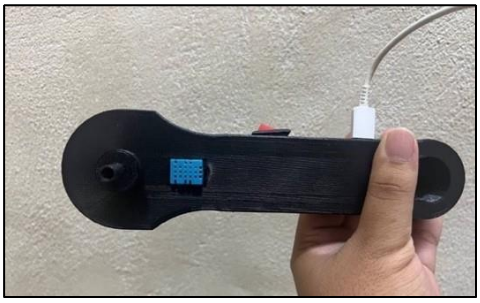

Figure 4. Bottom view

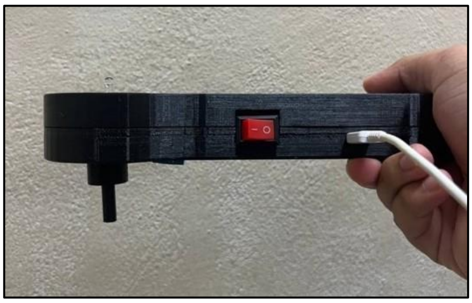

Figure 5. Left-side view

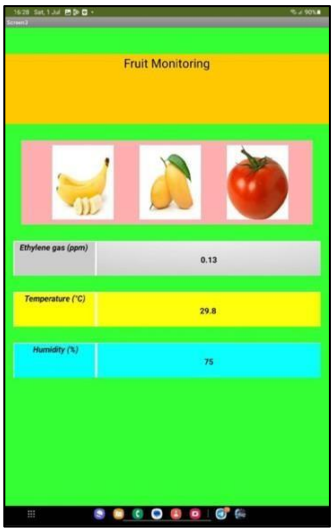

Figure 6. Fruit in ripe condition.

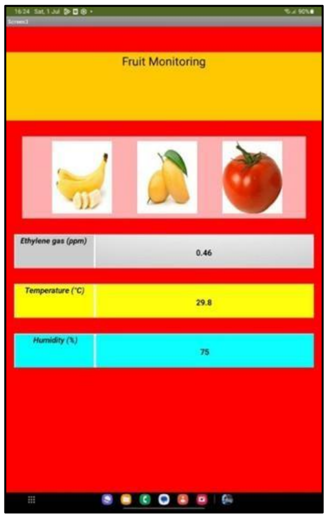

Figure 7. Fruit in decay condition

Table 1 Notice conditions

Parameter of Fruits	Unit	Notice
Mango	>0.35 ppm	Screen will turn red
Banana	<0.39 ppm	Screen will turn green
Tomato	>0.16 ppm	Screen will turn red

3.2 Analysis of Ethylene Gas Concentration

3.2.1 Ripe Condition and Decay Condition of Mango

Figure 8 below shows the conditions of the Mango in ripe state. The test has been conducted by put the mango for the sensor to obtain the data. From the chart show the trend for the ethylene data is static. The amount of ethylene gas is generally rising. The gas concentrationprogressively increases from 0.1 ppm on day one to 0.34 ppm on day seven. Given that ethylene gas production normally rises as fruit ripens, this trend suggests that the mangoes are going through the ripening process. As a signalling molecule, ethylene gas controls several physiological changes related to ripening. The ripening process can also be influenced by other elements, including temperature, humidity, and fruit maturity. Therefore, considering these other aspects, undertaking additional research, or consulting subject-matter specialists would be necessary for a thorough understanding of mango ripening stages.

However, figure 9 below shows a decay stage of mango deterioration. The test has been conducted by put the mango for the sensor to obtain the data. There is little variation in the concentration of ethylene gas from day 8 to day 10, with readings ranging from 0.35 ppm to 0.45 ppm. This could signal the beginning of decomposition, as it is a sign that the mangoes have achieved maturity or senescence. Ripening and spoilage of fruit are both hastened by increased ethylene gas levels. Since this time of year typically sees a steady release of ethylene gas, it may indicate the mango decaying stage.

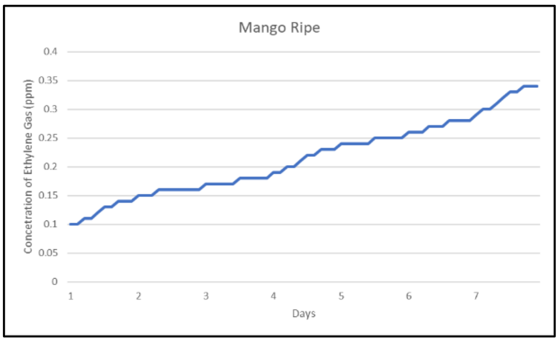

Figure 8. Ripe stage mango chart

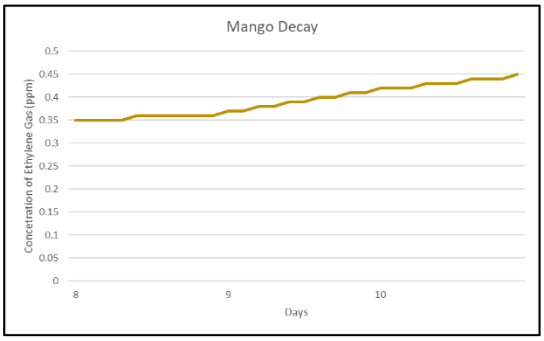

Figure 9. Decay stage mango chart

3.2.2 Ripe Condition and Decay Condition of Banana

Figure 10 below represents the conditions of a ripe banana. The test was conducted by placing the banana on the sensor to collect data. Based on the graph's data, the concentration of ethylene gas (ppm) and its relationship with days can shed light on the ripening stage of bananas. During the first three days (1-3), the concentration of ethylene gas ranges between 0.08 and 0.34 ppm. Beginning on day 4, the concentration of ethylene gas steadily rises to between 0.35 and 0.39 parts per million (ppm). The increasing concentration of ethylene gas indicates the onset of ripeness in bananas. Ethylene is a natural plant hormone that promotes fruit maturation processes, such as the development of colour, tenderness, and flavour. The increasing ethylene gas levels suggest that the bananas are enduring these physiological changes associated with maturation.

Nevertheless, figure 11 below show the banana on the decay stage. The sensor detected the high concentration of ethylene gas produce by the banana. Based on the provided data, the concentration of ethylene gas (ppm) and its correlation with days can provide insight into the decay stage of bananas. From day 6 to day 10, the ethylene gas concentration gradually increases from 0.39 to 0.61 per million (ppm). This rise in ethylene gas levels indicates that bananas are approaching the decay stage. It has been demonstrated that elevated levels of ethylene gas accelerate fruit ripening and promote degradation. The consistent increase in ethylene gas concentration during this period indicates that the bananas will likely rot. To thoroughly evaluate the decomposition stage, it is necessary to consider additional factors, such as temperature, humidity, and tangible characteristics, such as colour, texture, and signs of deterioration.

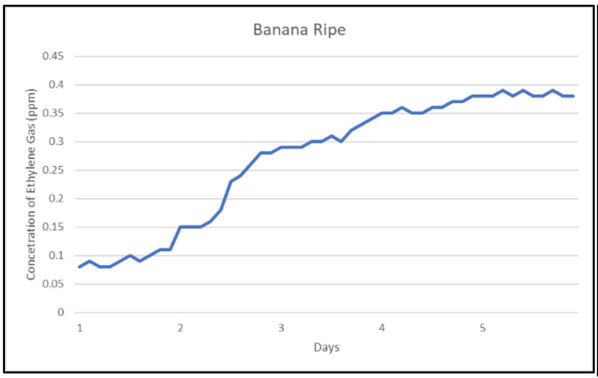

Figure 10. Ripe stage banana chart

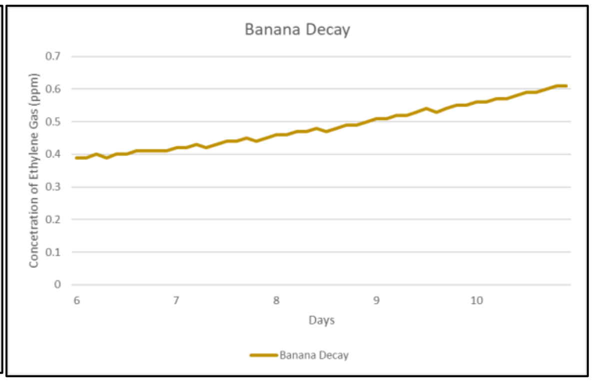

Figure 11. Decay stage banana chart

3.2.3 Ripe Condition and Decay Condition of Tomato

Figure 12 below represents the conditions of a ripe tomato. The test was conducted by placing the tomato at the sensor to collect data. The progressive increase in the concentration of ethylene gas over time is indicative of the maturation process. During the initial days 1 to 3, the concentration is relatively low, ranging between 0.04 and 0.08 ppm. This indicates that the tomatoes are currently in the early phases of maturation. For four to six days, the ethylene gas concentration reaches approximately 0.1 parts per million (ppm). This signifies the transition to a later maturation stage, during which the tomatoes continue to mature and develop their distinctive flavour and colour. For 7 to 9 days later, the ethylene gas concentration remains constant between 0.1 and 0.15 parts per million (ppm). This indicates that the tomatoes are mature, completely developed, and ready to be consumed.

However, figure 13 below show the tomato in early stage of decay condition. On Day 10, the concentration reaches a higher level, between 0.16 and 0.18 ppm. This elevated concentration indicates that the tomatoes have entered the decay stage. During the degradation stage, the increased production of ethylene gas accelerates the maturation process, resulting in the tomatoes' softening, discolouration, and rotting. The greater humidity levels and temperatures recorded in the data set contribute further to the decomposition of the tomatoes. The sustained high concentration of ethylene gas, in conjunction with the progression of the days, indicates the progression of decomposition in the tomatoes. Once tomatoes reach this stage, their quality and edibility may be compromised, and they should be discarded to prevent any potential health dangers.

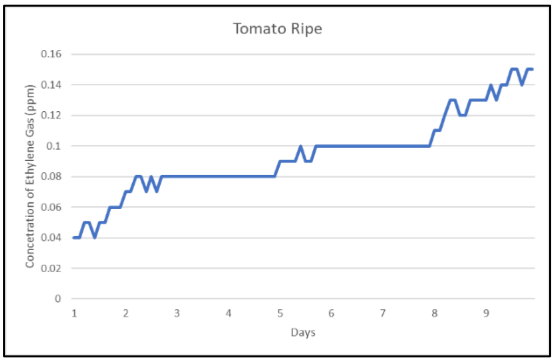

Figure 12. Ripe stage tomato chart

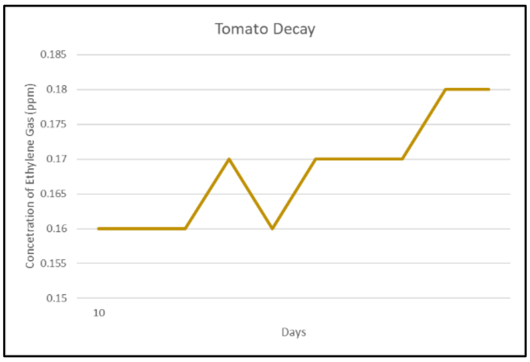

Figure 13. Decay stage tomato chart

3.3 Analysis using KNN Method

All the data combined into one data and classified into two groups: ripened and decayed fruits that have been tested: mango, banana and tomato. From the data that have been combined, the accuracy of data can be obtained by using supervised machine learning which is KNN method [10].

The KNN method with the 'n_neighbors' parameter set to three demonstrates the veracity of the data in the assertion. KNN employs the majority of the three closest neighbors to establish the class label. The image depicts how accuracy varies with different 'n_neighbors' values. The high accuracy indicates that the dataset was effectively classified using the KNN model with the 'n_neighbors' parameter set to 1. From Table 2, it shows that 83.33% of the data points were success identified by the model, as indicated by the stated accuracy. This result indicate that the success rate for KNN to classify or detecting fruit ripeness and decay based on measurements of ethylene gas sensor is quite high.

Table 2 KNN method result

	precision	recall	f1-score	support
Decay Banana	1.00	0.89	0.94	9
Decay Mango	0.90	1.00	0.95	9
Decay Tomato	0.00	0.00	0.00	2
Ripe Banana	0.60	0.43	0.50	7
Ripe Mango	0.79	0.85	0.81	13
Ripe Tomato	0.86	0.95	0.90	20
Accuracy			0.83	60
Macro avg	0.69	0.69	0.68	60
Weighted avg	0.81	0.83	0.82	60
KNN: 0.833333333333				

4. CONCLUSION

In conclusion, the construction of a portable degradation detector for perishable foods represents a significant advancement in food quality control. This study aimed to identify and detect the ripeness and decomposition phases in perishable mango, banana, and tomato using a portable and cost-effective device. The optimal parameters for assessing these fruits' maturation and decomposition stages were determined through experimentation and analysis. In this detection method, ethylene gas, a key indicator of maturation and decaying processes, played a crucial role.

Implementing the handheld decay detector satisfies the food industry's need for efficient and accessible instruments. The IoT system also successfully developed by using MIT App Inventor to monitor the data which is ethylene gas, temperature and humidity. By precisely quantifying the concentration of ethylene gas produced by the fruits, the decay detector allows for the timely identification of their ripeness and potential for decomposition. This data has the potential to substantially reduce food waste and increase consumer contentment by facilitating informed decisions about the quality and shelf life of perishable food products. The KNN result shows 83.33% of accuracy and efficiency of detecting fruit ripeness and decay based on measurements of ethylene gas. Overall, this research has implications for effective quality control in the agricultural industry, helping to reduce waste, optimize harvest time, and ensure the delivery of fresh, high-quality products to consumers.

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