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Detection of Freshness of the Fruits using Machine Learning Techniques

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***Abstract*—**Survival period of the fruits after harvest is relatively short. The main objective of this research is to measure the freshness of fruits by observing their CO_2 release, water vapor release, and O_2 absorption after harvesting for the papaya and watermelon. They were categorized into the three groups (500g-1kg, 1kg-1.5kg, 1.5kg-2kg) and tested in 4 selected days including the harvested day, three days after harvest, a week after, and two weeks after to observe the changes in these three factors (CO_2, O_2, and humidity). A CO_2 sensor, an O_2 sensor, and a humidity sensor was set up to detect the changes. The collected data was used to train the machine learning model (Keras Sequential Model). After entering the type of the fruit, weight, the difference of oxygen, and water vapor concentration after 45 minutes, as inputs for the model, the model will predict the freshness of the fruit as a percentage. The Accuracy of the developed model was considered to be 0.989. The results of the analysis implied that the rate of O_2 absorption gradually increases after harvesting and the water vapor release gradually decreases. It is suggested to use higher sensitivity sensors to obtain accurate results.

***Keywords*—**Freshness, Fruits, Machine learning, Sensors

I. INTRODUCTION

Fruits and vegetables have been a significant part of the meals that humans take daily. Since the incidence of diseases has increased in modern times, people have become more curious and cautious about natural and organic products: especially fruits and vegetables. Among them, people pay more attention to the freshness of the fruits they eat. Thus, it implies the need to identify the quality of fruits since it has proved to affect human health.

Significantly, the quality of the fruits depends on the freshness of the fruits. The fruits that have not been processed in any manner are considered fresh fruits. They are full of essential vitamins, minerals, antioxidants, fibre, and other nutrients which can improve human health and they are considered essential to maintaining good health. Fresh fruits have many advantages to the human body such as providing 10-20 times more fiber intake without really trying. Many fresh fruits contain essential fibres that are specially required to maintain body health. Consuming less sugar and salt causes to improve personal health and consuming a fruit instead of other types of cooked food support to get more energy and feel full faster. They provide essential nutrients for and support to gain energy and are also beneficial in increasing the immunity of the body. Other than that, many studies have implied the importance of having a balanced diet and its impact on reducing diseases like cancer and similar chronic diseases. Apart from that, fruits also can provide important antioxidants to the human body including flavonoids. According to the specialists, these types of fruits contain nutrients, vitamins (Vitamin B, C, K) and minerals (Calcium, Potassium, Magnesium), and dietary fibre. They support the supply of all-important health benefits to humans and therefore are recommended to be consumed in general. Also, they are a major source of complex carbohydrates, antioxidants, and anti-carcinogenic substances which are important to human health.

A. *Reasons for loss of freshness of fruits*

The major reason for this is the damage that is caused to the cell walls of the fruits after several days of harvesting. This causes the fruits to spoil faster. Some major factors contribute to the fruits spoil such as air, moisture, light, and microbial growth. They also contribute to increase the deterioration of the cell wall of the fruit. It is accepted generally that the microbial influence is the major reason for the fruits to get damaged easily. Microbes such as bacteria, yeast, and mold require water and nutrients essentially for their existence. Fruits contain 90 percent of these essential elements that facilitate microbial actions and cause the fruits to crack and spoil very quickly. In addition to these factors, oxygen supply also plays a crucial role in the above process. Required amount of oxygen concentration also enables microbes to be active and survive for a period of time. Another important fact is that these misro-organisms cause to destroy the essential nutrients that are contained in fruits. When the fruits are damaged, it activates an enzyme that is contained naturally in the fruits and it increases the speed of rotting. The process gets much quicker when they are exposed to light since their outer layers begin to deteriorate. This process is commonly known as photodegradation, which causes discoloration, loss of flavor, and nutrients from the fruits. The fruits can be identified as decaying when they show discolorations, blemishes, slimy patches, unpleasant odor or taste. Temperature is also a determinant for the food spoilage. Extreme temperatures (either hot or cold) can impact on the spoilage of fruits. If fresh fruits are frozen, it causes them to freeze the plant cells and convert them into ice-crystals making cell walls to expand and creating discolorations, slimy texture, and appearance.

B. How human health is affected by contaminated fruits

Eating contaminated fruits can cause various diseases. Many different disease-causing microbes or pathogens can contaminate fruits. Thus, they can affect human health also. Water, soil, manure, wildlife or birds, contaminants, and food can be contaminated when used or prepared by the consumer. Vomiting, diarrhea, abdominal cramps, nausea, fever, joint/backaches, and fatigue are some diseases caused by having not fresh fruits. Everyone is at risk of foodborne illness from contaminating fruits or not being fresh, but some people are at higher risk. People who are suffering from diseases such as AIDS, cancer, kidney issues or other types of chronic diseases are at high risk. Senior people are also at risk of above-mentioned illnesses. Additionally, people who have been diagnosed with autoimmune disorders such as lupus, and similar disorders and the people who have had medication for immune-suppressing are also considered to be at risk. Apart from them, the new born or unborn babies, children under 5 years, and pregnant women together with people who have been addicted to or having a bad medical history related to drugs and alcohol are also at high risk.

C. Observation of sticker on fruits (PLU code)

PLU stands for Price Look-Up. These codes can be observed as a small sticker commonly in the fresh produce that have been kept for sale in the market. The sticker indicates a code and the code stands for a standardization of the fruits depending on their quality and production criteria. In Sri Lanka, these stickers can be seen commonly among the fruits that are imported from other countries. They can also be seen in the fruits that are available in the supermarkets. These codes are primarily assigned by the International Federation for Produce Standards (IFPS). There is a common attribute in all these codes that they start with number 3 or 4. Another important aspect is that regardless of the production country or the country where it is sold, the codes are similar for each type of fruit all around the world. However, if the code is a four-digit number, this implies that the fruit has been produced conventionally. If it contains five digits beginning with number 8, that implies the fruit has been made with genetic modifications whereas if the number begins with 9, it indicates that the fruit is grown organically and is best suitable for consumption.

Many research has been conducted to detect the freshness of fruits using different methodologies. Liu *et al*. (2020) studied a volatile organic compounds gas sensor based on quartz crystal microbalance for fruit freshness detection. Using gas sensors based on Quartz Crystal Microbalance (QCM) technique to test the freshness of the fruits has been outlined depending on several factors. They are the history of development, working principles, choice and application of sensitive materials and volatile organic compounds detection of fruits. This technique has been able to attract many scholars in the field due to its accurate prediction of the freshness of the fruits, their maturity, and the period of time that they have been kept on the shelves. Additionally, it is low cost, has high consolidation levels, and has easy access to sensing characteristics by changing the sensitive membrane material. The technique has been tested upon the fruits including bananas, apples, and mangoes by studying the features of the VOC gas released in the ripening stage of these fruits. The changes in the gas concentration in the alcohol, esters, and alkenes are the major components that have been studied. However, some defects in the system have been identified and it has been difficult to overcome the challenges in the use of the technique. The accuracy of the measurements and the level of performance of the QCM sensors is highly expected to get the accurate results. According to the study done by Kammar *et al*. (2015), content of fruit is an important quality factor to detect the freshness of the fruit. Moisture Content of fruits has an effective influence on the density of fruit. Checking the moisture content of fruits is obvious and higher the moisture contents in the fruit gives better in the quality of fruit. Moisture content of all varieties of fruit has 80-95% of its whole weight. They estimate the freshness of a variety of fruits with an electrical based approach. In the proposed system, freshness can be detected by electrical methods with the use of power supply, LED, fruit and wires to connect it. This work detects the moisture content present in the fruit with voltages applied in the electrical circuit. In turn, it shows the freshness of fruit within days. As a result, all values of the fruit from day1 to day 28 are observed. Voltage values are recorded by an electrical approach. Verify the LED glow (ON state) by applying the voltages from 0-12 Voltages to detect current flowing through the fruit apple. It means that if LED gets ON then current flowing through the fruit by potentially applying then it shows moisture content present in the fruit indirectly to analyze the freshness of the fruits within days. Kemiklioglu *et al*. (2018) developed a freshness sensor which specifically measures the ion composition of the fruits. With the improved awareness of people regarding health and consuming fresh produce or organic nutrition, this has become an effective mechanism. This thought has caused them to doubt the freshness of the fruits that are being consumed by them. The problem caused by the uncertainty of freshness of fruits and vegetables can be overcome by this new and creative freshness sensor without any chemical treatment which could damage the nutritional value of samples. They showed that according to ion concentration change, the freshness of the fruits and vegetables can be determined. According to performed measurements, they prove that by using this sensor freshness of fruits and vegetables can be determined according to change in their ion concentration. In order to reduce the damage done to the sample, used electrode scales could be lowered at new models. (Kemiklioglu Ozen, 2018). Cho *et al*. (1990) conducted similar research, a magnet console for an NMR-based sensor to detect fruit ripeness was designed through an interactive graphics simulation with a two-dimensional finite element model (FEM). The NMR technique is a fair method to test the sugar level contained in the fruits causing minimum harm to the fruit. The ripeness of the fruits is measured by considering the level of sweetness of the fruits. The NMR is designed together with an interactive graphic stimulator with a 2-dimensional Finite Element Model (FEM). As the magnetic source, a permanent magnet had been used. The simulated finite element magnetic fields were verified by comparison with magnetic fields measured in an experimental magnet console. The agreement between predictions and measurements was good with an error of 4.7%. Pole surface plates and shimming frames were used to improve the homogeneity of the magnetic fields around the air gap center where the fruit would be located. System performed reliably at a sustained harvesting rate of approximately 1.4 ha/day (3.4 acre/day), while indicating that a rate of 2 ha/day (5 acre/day) should be easily achievable. The system is operated by two workers and reduces conventional labor requirements by approximately 80-85%.

Meng *et al*. (2014) conducted research on constructing a model to test the freshness of the fruits by the use of Carbon Dioxide and Oxygen sensors. Further, it could also measure the safety of fresh produce by concerning the analytical signals about their transformations at different stages. This technique is mostly concerned with the packaging methods. The concept of Intelligent Packaging has been evolving in the fresh food production and it has gained a lot of interest among the agriculture and food industries. This technique allows to keep fresh produce clean and protected from the physical and chemical changes that occur due to various reasons. Appropriate packaging methods influenced by intelligent packaging has the potential to preserve food for a longer period of time and it is a fair method to improve the shelf life of such products in addition to the major functionality of the technique. In this study, different sensors have been used to test the carbon dioxide and oxygen gas concentration and release of the suits and have examined the ways on how they can be appropriately utilized in food production industries and agricultural activities for packaging and quality monitoring. Significantly, this study has given the emphasis on the analytical signals and their transformation since they are crucial factors when determining the freshness of the food products with regard to packaging. "Intelligent packaging components are not limited to radio frequency identification (RFID) sensors, time-temperature indicators, ripeness indicators, and biosensors " (Meng *et al*., 2014). Other devices such as carbon dioxide and oxygen gas sensors, and nano biosensors can also be used to monitor the freshness of the products using real time data. This study clearly depicts the possibility of using and applying carbon dioxide and oxygen gas sensors in testing the freshness of the food products. This can be applied in industrial and agricultural food packaging to maintain the freshness of the products.

According to the study of Neethirajan *et al*. (2008) the researchers have explored how to use the Carbon Dioxide sensors accurately in the process of food preservation. They have identified the functionalities of these sensors including the process of detection, sensor development process, sensing mechanisms and their features. Apart from them, they have significantly focused on how CO_2 sensors can be effectively and accurately used in food packaging in the industries and agricultural processes in future practices. At present, sensors are basically used in process control, quality monitoring, and safety assessment of fruits and fresh produce. These CO_2 sensors are gaining demand in the fields of mass food production and food storage since they have the ability to monitor and detect the incipient spoilage by assessing the carbon dioxide levels in the respective packaging and storage structures. This study also denotes the characteristics of effective gas sensors as the reversibility, accuracy, repeatability, reliability, and long-lasting nature. Apart from those basic features, they should also be capable of being handled by non-technical users, and should be able to gather required data automatically. At present, Nano enabled and microelectronics-based CO_2 gas sensors have become the new trend in the market and studies are being conducted to make it more accurate and successful. The study suggests that in future, these sensors will be wireless, and will have the ability to generate real time data through real time processing with high accuracy to study the freshness of the food products.

Santonico *et al*. (2017) proposed a multisensory system based on electrochemical sensors acting via a liquid medium and controlled by a dedicated low-noise electronic interface equipped with an elaboration unit able in extracting/storing a committed model for oxygen and carbon dioxide detection. According to the authors, the sensors which are used for carbon dioxide and oxygen monitoring are important in many fields including biomedicine, industries, and environmental research. It is required for these sensors to be easily operational, with an improved response rate and should also have an incredible amount of sensitivity. The predictive model shows a good reproducibility in terms of measurements and a reduced root mean square error in validation. The Root Mean Square Errors in cross validation are around 2% for both O_2 and CO_2, which does represent a promising performance both for IAQ (Indoor Air Quality) and breath analysis applications. The results of the study conveyed the reliability of the device and how it is applicable in many fields. Besides, each application asks for a specific release with different specifications in terms of size, power consumption, and user interface and this appears rather possible by the proposed sensor system. Valentino *et al*. (2020) conducted research under the topic of “A Design of Deep Learning Experimentation for Fruit Freshness Detection”. Here they proposed a design of computer vision-based technique using deep learning with the Convolutional Neural Network (CNN) model to detect fruit freshness. According to researcher’s computer vision-based techniques and algorithmic approaches have been widely proposed in recent decades. Fruit has a period where the fruit is said to be fresh fruit. During this time many fruit supply companies publish the fruit as unfit for consumption and lack the accuracy of the fruit sorting process when obtained from the orchard and include other fruits in unsuitable packaging. In this research Fruits are classified as Fresh and Rotten by collecting, separating, and then labelled. This dataset includes 10,901 images of three types of fruits with six classes of fresh fruit and rotten fruit. After they collect data, they preprocess data by cropping, resizing the data as needed. After that, designing a model that is planned to be used and a list of specified parameters such as the level of learning and the number of training epochs. For the testing process data trained with the CNN model. The main objective of this research is to predict the freshness of a fruit as accurately as possible within a defined time period. In order to accomplish the main objective, specific objectives must first be fulfilled. This research predicts the freshness of fruit based on CO_2 release, O_2 consumption, and water vapor release based on the weight of the fruit. In addition, another objective of this research is to obtain freshness without observing the appearance of the fruit and to obtain the freshness of the fruit without harming the fruit.

Therefore, as a first step to make a circuit device that can measure these three factors. This circuit device should include an O_2 sensor, a CO_2 sensor, and a humidity sensor. The Arduino module was used to read the sensor data. In addition to that web technologies such as PHP and HTML, and IoT were used to control data intake with Arduino module. After developing the device, the next objective is to measure the time taken to release a significant amount of CO_2, water vapor, and the time taken to consume a significant amount of O_2 based on fruit weight. The next objective is to measure the CO_2 release level, O_2 consumption level, and water vapor release variation of fruits within a measured period of time. These values should be taken on harvest day, three days later, one week later, and two weeks later. Then these data should be stored in a database separately.

After achieving all the required data, the next objective needs to develop a model to predict the freshness of the fruit. This process is done using TensorFlow machine learning software.As the last objective, show the freshness of fruit as accurately as possible using previously obtained predicted data.

II. Methodology

Fresh fruits and vegetables continue to “breathe” after they are picked. Which means that they still have the ability to survive and improve. This process absorbs O_2 from the atmosphere and releases Carbon Dioxide and water vapor. This research is based on studying about this process. This research examines CO_2 and water vapor release, and O_2 consumption of fruits after they are harvested according to their weight. Two fruits were selected to conduct this research namely watermelon, and papaya. This research is conducted in four major stages as:

1) Develop a device that can measure CO_2 and water vapor release and O_2 consumption.
2) Measure CO_2 and water vapor release, and O_2 consumption of fruits after they are harvested, according to their weight.
3) Develop a Machine Learning (ML) model to predict the freshness of fruits using collected data.
4) Display freshness of fruit as accurately as possible with the results of the model.

The flow of the research is shown in Figure 1.

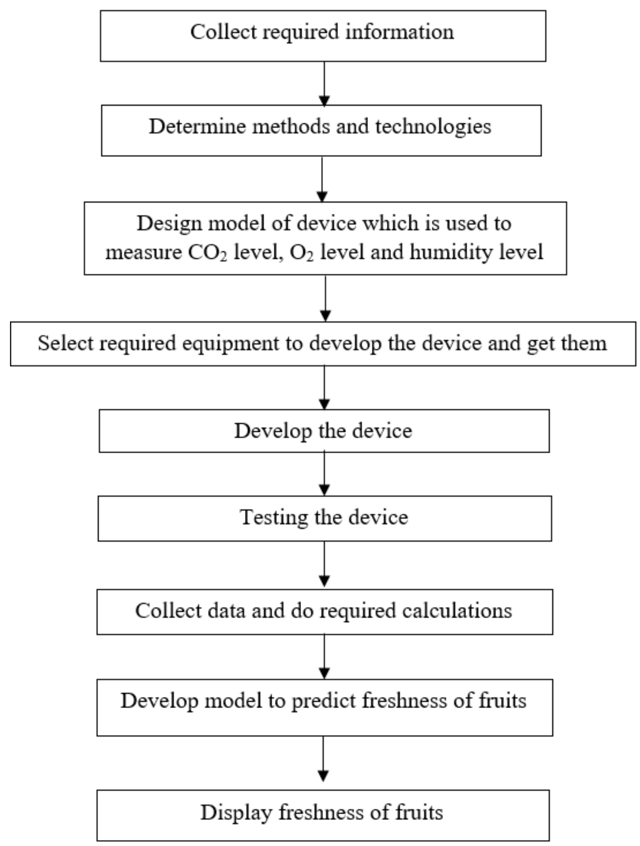

Figure 1: The flow of research Methodology

Table 1 shows required Technologies, Hardware and Software.

A circuit was implemented to measure CO_2 and water vapor release and O_2 consumption as depicted in Figure 2.

Table I: Required Technology, Hardware and Software

Technologies	Hardware	Software
Sensors	ESP8266 NodeMCU Microcontroller	Arduino sketch
Arduino	O2 Sensor (ME2-O2 -20)	XAMPP Server
IoT	CO2 Sensor (MQ-135 Gas sensor)	TensorFlow
Web technologies (PHP, HTML)	Humidity Sensor (DHT11)	
Database (MySQL)	Breadboard	
Machine learning (Python and Tensorflow)	Jumper cables	

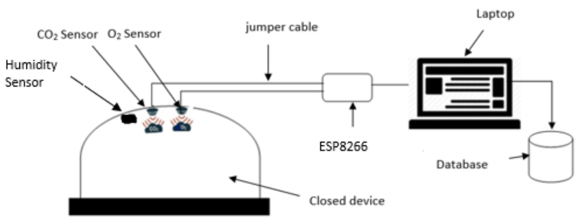

Figure 2: Collecting Sensors' data

A. Device Validation

Device validation is conducted to ensure that the sensors are working properly after implementing the device. This process was based on the actual percentage of O_2 in the environment, CO_2 (PPM), and humidity level. The average O_2 concentration of the environment is 20.9%. The test result denoted the O_2 concentration to be 20.8%, 20.9%, 20.9%, 21%, 20.9% during the 5 tests that were conducted using the oxygen sensor. The outdoor concentration of CO_2 is about 400ppm or higher than 400ppm in areas with high traffic or industrial activity. The test results obtained for CO_2 denoted the values as 486ppm, 425ppm, 456ppm, 397ppm, 463ppm on 5 tests. The general outdoor humidity level is considered to be a percentage value between 30% and 60%. The test result indicated it to be 55.53%,54.00%, 55.23%, 55.47%, and 55.96% during the five tests that were done using the humidity sensor. This implies that the results obtained by the sensor tests have been similar to the general expected values of the three elements (Figure 2).

B. Data collection through the circuit

In order to obtain the results of the study 60 papayas and 50 watermelons were used as the sample. Fruit weights also contribute to improving the accuracy of the results obtained through the tests. Therefore, depending on the weight of the fruits, they are grouped into three categories as 500g – 1kg, 1kg - 1.5kg, and 1.5kg – 2kg. In Addition to that, data was collected in four ways namely harvested day, three days after harvesting, a week later, and two weeks later.

These fruits were separately placed inside the experiment chamber to observe the amount of CO_2 release, water vapor release, and O_2 consumption. The test date was stored in the database together with the weights of the fruits and other related information. The O_2 and humidity levels were obtained as a percentage value. The CO_2 release amount was obtained as a Parts Per Million (PPM) value. Above experiment was repeatedly done to find the differences. The difference of the values between the fruits immediately after placing the fruit inside the device and after the defined period of time were calculated.

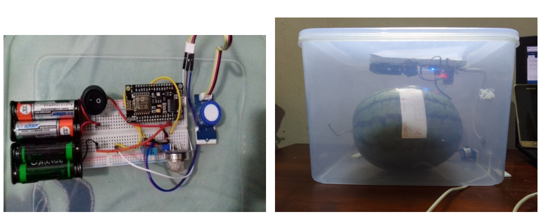

Figure 3: Implementation of device

C. Model Development

The TensorFlow application was used to develop the model. TensorFlow is known as an end-to-end open-source platform and a software library for ML. The Keras provide a high level API under TensorFlow which has a high productivity interface for solving ML problems. Therefore, in this research, Keras was used to define the model and preprocessing layers as a bridge to map columns into the CSV (Comma-Separated Values) format. Data of this format was used to train the model. The model design plan is shown in Figure 4.

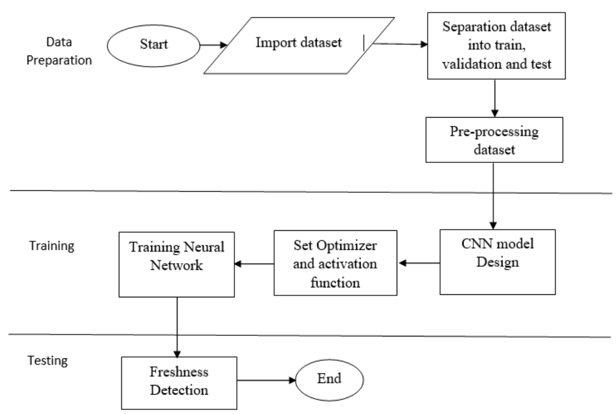

Figure 4: Model design plan

D. Data Set Description

Description of data set used for this experiment shown in Table 2 (numeric and categorical columns) was used to predict whether the fruit is fresh or not. The collected dataset was processed in three stages as validation, training, and testing. Figure 5 shows how the data is separated between these three groups. Data sets of these three separated groups was used to implement the model. Then the ML program was written to build the model.

Table II: Description of data set

Column	Description	Feature Type	Data Type
Fruit type	Type of fruit	Categorical	Object
Weight	Weight of fruit	Numerical	Object
O2	O2 absorption	Numerical	Float
Humidity	Water vapor release	Numerical	Float
Freshness	Freshness of fruit	Categorical	Int

```
RangeIndex: 460 entries, 0 to 459
Data columns (total 5 columns):
 #   Column      Non-Null Count  Dtype
---  ------      --------------  -----
 0   Fruit_Type  460 non-null    object
 1   Weight      460 non-null    object
 2   O2          460 non-null    float64
 3   Humidity    460 non-null    float64
 4   Freshness   460 non-null    int64
dtypes: float64(2), int64(1), object(2)
memory usage: 18.1+ KB
None
294 train examples
74 validation examples
92 test examples
```

Figure 5: Dataset

III. Results and Discussion

Post-harvest fresh fruits respiration can be affected by temperature, gas composition, wounding, and pest attacks. The variety of the fruit will also determine how long it can be stored and under which conditions they will retain their freshness. Therefore, it is very important to measure the level of O_2, CO_2 and water vapor. Respiration process of any fruit continues even after they are harvested. It is well known that respiration is the process where living things inhale O_2 to breakdown Carbohydrates. CO_2 is one of the end products

Table III: Sample dataset used for model development

Fruit_Type	Weight	O2	Humidity	Freshness
Papaya	500-1000	0.0099	6.13	1
Papaya	500-1000	0.0098	6.4	1
Papaya	500-1000	0.0095	6.78	1
Papaya	500-1000	0.009	6.46	1
Papaya	500-1000	0.0091	6.35	1
Papaya	500-1000	0.0095	6.11	1
Papaya	500-1000	0.0098	6.26	1
Papaya	500-1000	0.0099	6.27	1
Papaya	500-1000	0.0098	6.87	1
Papaya	500-1000	0.0096	6.13	1
Papaya	500-1000	0.0098	6.45	1
Papaya	500-1000	0.0094	6.4	1
Papaya	500-1000	0.0098	6.57	1
Papaya	500-1000	0.0091	6.11	1
Papaya	500-1000	0.0092	6.72	1
Papaya	500-1000	0.0099	6.07	1
Papaya	500-1000	0.0099	6.24	1
Papaya	500-1000	0.0098	6.48	1
Papaya	500-1000	0.0096	6.6	1
Papaya	500-1000	0.0091	6.51	1
Papaya	500-1000	0.0139	5.4	1
Papaya	500-1000	0.0128	5.22	1

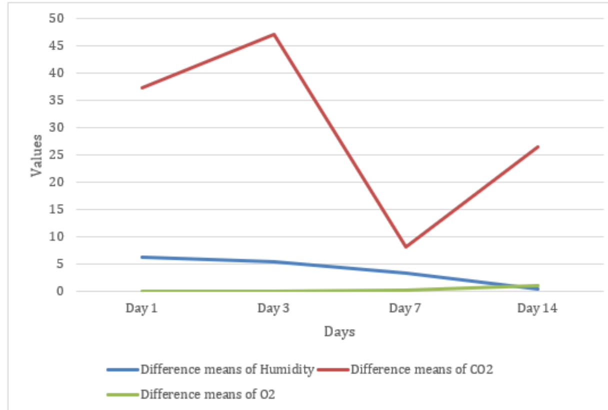

Figure 6: Factor changes analysis for Papaya 500g-1kg

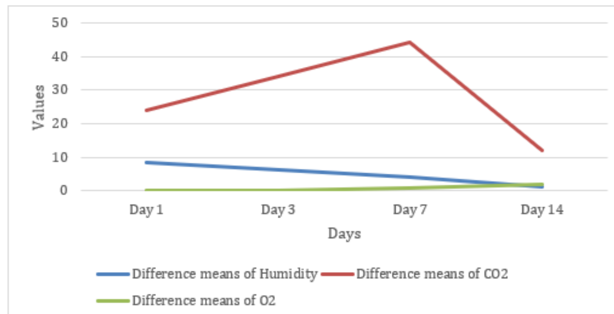

Figure 7: Factor changes analysis for Papaya 1kg - 1.5kg

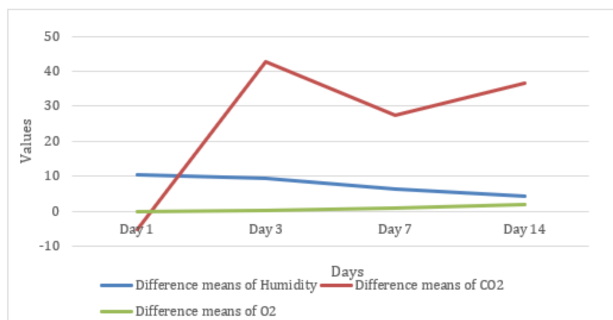

Figure 8: Factor changes analysis for Papaya 1.5kg-2kg

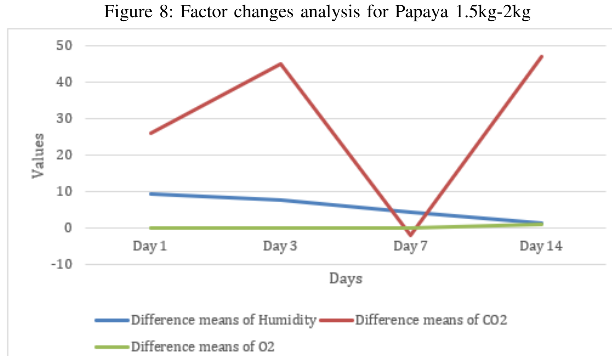

Figure 9: Factor changes analysis for Watermelon 500g-1kg

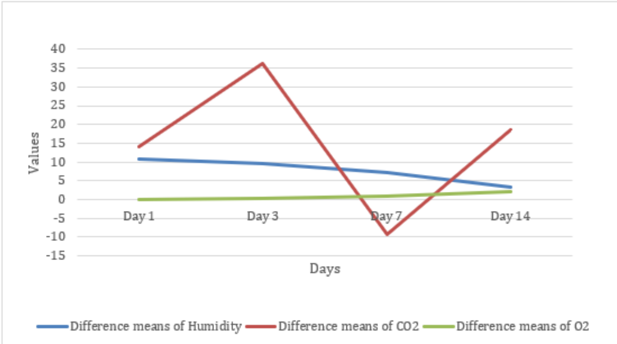

Figure 10: Factor changes analysis for Watermelon 1kg - 1.5kg

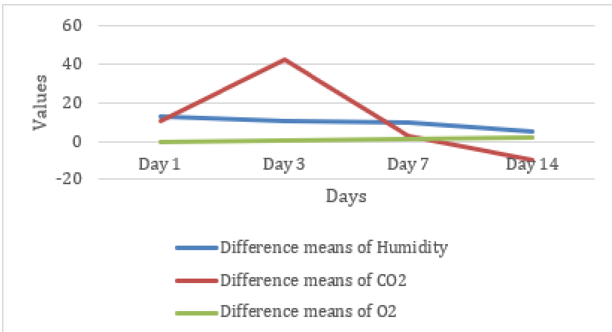

Figure 11: Factor changes analysis for Watermelon 1.5kg-2kg

of respiration along with water vapor and heat. Therefore, this study focused on measuring the O_2, CO_2 and the level of water vapor in the environment where the fruits are placed.

The developed model was used to evaluate the accuracy of the model for selected fruits. The collected data clearly showed the O_2 absorption and the release of water vapor of the selected fruits. However, it was observed that there is an error in the CO_2 release measurements which is shown in 9th column in Table 4, because a low sensitivity sensor was used for this study. As a result, some calculation errors were encountered. Therefore, in some instances, minus values were also obtained. Thus, it was unable to get an idea about the actual CO_2 release of fruits. The changes that were observed after placing the fruits for 45 minutes inside the developed device for papaya (1kg -1.5kg) are mentioned in Table 4 with the collected data.

According to the above table, it is noted that the differences of CO_2 release are not given specifically because the connected CO_2 sensor was not sensitive to minor changes. Therefore, the Factor Change Analysis was done to overcome the above issue. Factor Change Analysis was done for papaya fruits weighing 500g-1kg, 1kg-1.5kg and 1.5kg-2kg, and watermelon after 1, 3, 7 and 14 days of harvesting.

According to the Factor Change Analysis, the results showed a gradual increase of O_2 absorption, and a gradual decrease of water vapor release over time, with regard to all weight groups of both fruits. However, a low O_2 concentration level is determined as a factor for reducing the quality of the fruits. It is well known factor that ripening is one of the stages in the development process of any fruits and it requires high O_2 concentration. As results are shown in figure 12, different weights of both fruits against O_2 and water vapor release are not significant causes to affect the freshness of the fruits. However, it was not possible to get an idea of how CO_2 emissions change over time, due to the CO_2 measurement error.

IV. Conclusions

As the incidence of disease has increased in modern times, people have become more aware about natural and organic nutrition. Because of that, people pay more attention to the freshness of the fruits they consume. At present, a number of methods are used to detect the freshness of fruits. However, most of them are time consuming and not reliable.

Thus, this research aims to propose a project using the latest IT and sensor technology to address this type of issue as a sustainable solution. The proposed methodology in this research is to predict the freshness of the fruits by observing CO_2 release, water vapor release, and O_2 absorption of fruits after harvest. The two types of fruits, papaya and watermelon were selected from three weight groups for the data collection of this research. (500g -1kg, 1kg-1.5kg, 1.5kg-2kg). CO_2 release, water vapor release, and O_2 absorption are measured in 4 selected days including the harvested day, three days after harvest, a week after, and two weeks after to observe the changes in these three factors (CO_2, O_2, and humidity). Sensor technology has been used with Arduino to measure the differences among the above factors. In addition, web technologies such as HTML and PHP have been used. To store the collected data, a database was developed using MySQL. After the data collection, the data were analyzed to find the results. The results of the analysis showed that the O_2 consumption gradually increases over time and water vapor release gradually decreases over time. Using this criterion, the machine learning model was implemented for further analysis. 80% of the collected data was used for model training and 20% of the collected data was used for model validation. Through this model, the freshness of fruits was able to be predicted. Since Sri Lanka is a developing country, it is vitally important to do these types of low-cost research. As a result, the whole community is benefitted by the implications of the study.

References

Alam, A., Rathi, P., Beshai, H., Sarabha, G., Deen, M. (2021). Fruit Quality Monitoring with Smart Packaging. *Sensors, 21*(4), 1509. https://doi.org/10.3390/s21041509

Balali, G., Yar, D., Afua Dela, V., Adjei-Kusi, P. (2020). Microbial Contamination, an Increasing Threat to the Consumption of Fresh Fruits and Vegetables in Today's World. *International Journal of Microbiology, 2020*, 1-13. doi: 10.1155/2020/30292

Eom, K., Hyun, K., Lin, S., Kim, J. (2014). The Meat Freshness Monitoring System Using the Smart RFID Tag.

Table IV: Sample data collected (papaya -1kg -1.5kg)

Weight (g)	start humidity (%)	end humidity (%)	start co2 (ppm)	end co2 (ppm)	start o2(%)	end o2(%)	difference of humidity	difference of co2	Difference of o2
1230	75.23	83.25	455.96	420.36	21.4423	21.4212	8.02	-35.6	0.0211
1135	75.96	83.99	412.25	472.74	21.3974	21.3712	8.03	60.49	0.0262
1360	75.41	83.97	417.21	470.22	21.4412	21.4145	8.56	53.01	0.0267
1426	75.32	83.76	421.89	416.22	21.5279	21.5034	8.44	-5.67	0.0245
1364	75.21	83.31	412.36	453.22	21.4234	21.4031	8.1	40.86	0.0203
1250	75.14	83.23	415.23	433.33	21.4323	21.4029	8.09	18.1	0.0294
1490	74.41	83.36	417.29	461.36	21.4893	21.4632	8.95	44.07	0.0261
1275	75.23	83.47	418.26	456.27	21.4341	21.4047	8.24	38.01	0.0294
1150	75.21	83.23	435.23	477.95	21.4237	21.4016	8.02	42.72	0.0221
1050	74.89	83.98	419.56	465.27	21.3697	21.3417	9.09	45.71	0.028
1320	75.41	83.26	416.23	433.26	21.3694	21.3412	7.85	17.03	0.0282
1410	75.23	83.36	417.47	446.21	21.3691	21.3441	8.13	28.74	0.025
1320	75.12	83.12	449.23	450.23	21.4369	21.4112	8	1	0.0257
1420	75.23	83.36	441.23	469.36	21.3641	21.3412	8.13	28.13	0.0229
1430	75.12	83.2	441.66	478.36	21.4741	21.4513	8.08	36.7	0.0228
1350	74.23	83.12	412.23	432.23	21.3641	21.3426	8.89	20	0.0215
1270	75.21	83.47	413.23	441.79	21.4512	21.4242	8.26	28.56	0.027
1230	74.69	83.36	468.24	478.69	21.3647	21.3436	8.67	10.45	0.0211
1420	75.12	83.36	416.17	442.74	21.4341	21.4136	8.24	26.57	0.0205
1320	75.47	83.94	475.76	456.6	21.4336	21.4078	8.47	-19.16	0.0258

Table V: Factor Change analysis for Papaya

	500g-1kg			**1kg-1.5kg**			**1.5kg-2kg**		
	A	B	C	A	B	C	A	B	C
Day 1	6.3955	37.257	0.009575	8.313	23.986	0.024715	10.374	-5.099	0.05392
Day 3	5.407	47.0325	0.01255	6.2745	34.0695	0.073165	9.321	42.619	0.093755
Day 7	3.4065	8.193	0.19497	4.3325	44.133	1.011345	6.281579	27.48684	1.016232
Day 14	0.472	26.4545	1.12448	1.364737	12.06053	2.010568	10.374	-5.099	0.05392

A: Difference means of humidity B: Difference means of CO2 C: Difference means of O2

Table VI: Factor Change analysis for Watermelon

	500g-1kg			**1kg-1.5kg**			**1.5kg-2kg**		
	A	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**
Day 1	9.456	26.246	0.0128	10.867	14.0635	0.07527	13.1433	10.3785	0.05268
Day 3	7.8626	45.226	0.0236	9.7184	36.25263	0.2717	10.8835	42.298	0.32741
Day 7	4.5813	-1.999	0.1431	7.2595	-9.1595	1.05449	9.517	2.7655	1.4118
Day 14	1.3328	47.127	1.1073	3.274	18.5645	2.17324	5.1323	-9.427	2.3988

A: Difference means of humidity B: Difference means of CO2 C: Difference means of O2

```
 1/10 [==>...........................] - ETA: 0s - loss: 0.8383 - accuracy: 0.3438WARNING:tensorflow:Layers in a Sequential mod
el should only have a single input tensor, but we receive a <class 'dict'> input: {'Fruit_Type': <tf.Tensor 'ExpandDims:0' shap
e=(None, 1) dtype=string>, 'Weight': <tf.Tensor 'ExpandDims_3:0' shape=(None, 1) dtype=string>, 'O2': <tf.Tensor 'ExpandDims_2:
0' shape=(None, 1) dtype=float64>, 'Humidity': <tf.Tensor 'ExpandDims_1:0' shape=(None, 1) dtype=float64>}
Consider rewriting this model with the Functional API.
WARNING:tensorflow:Callbacks method `on_test_batch_end` is slow compared to the batch time (batch time: 0.0000s vs `on_test_bat
ch_end` time: 0.0010s). Check your callbacks.
10/10 [==============================] - 0s 25ms/step - loss: 0.6430 - accuracy: 0.4898 - val_loss: 0.5894 - val_accuracy: 0.48
65
Epoch 2/10
10/10 [==============================] - 0s 3ms/step - loss: 0.4667 - accuracy: 0.7109 - val_loss: 0.4310 - val_accuracy: 0.675
7
Epoch 3/10
10/10 [==============================] - 0s 3ms/step - loss: 0.3631 - accuracy: 0.7891 - val_loss: 0.3529 - val_accuracy: 0.716
2
Epoch 4/10
10/10 [==============================] - 0s 3ms/step - loss: 0.2813 - accuracy: 0.8061 - val_loss: 0.2731 - val_accuracy: 0.756
8
Epoch 5/10
10/10 [==============================] - 0s 3ms/step - loss: 0.2156 - accuracy: 0.8776 - val_loss: 0.2132 - val_accuracy: 0.878
4
Epoch 6/10
10/10 [==============================] - 0s 2ms/step - loss: 0.1606 - accuracy: 0.9218 - val_loss: 0.1455 - val_accuracy: 0.986
5
Epoch 7/10
10/10 [==============================] - 0s 3ms/step - loss: 0.1174 - accuracy: 0.9728 - val_loss: 0.1112 - val_accuracy: 0.986
5
Epoch 8/10
10/10 [==============================] - 0s 3ms/step - loss: 0.0843 - accuracy: 0.9864 - val_loss: 0.0772 - val_accuracy: 0.986
5
Epoch 9/10
10/10 [==============================] - 0s 2ms/step - loss: 0.0635 - accuracy: 0.9966 - val_loss: 0.0566 - val_accuracy: 1.000
0
Epoch 10/10
10/10 [==============================] - 0s 3ms/step - loss: 0.0438 - accuracy: 1.0000 - val_loss: 0.0447 - val_accuracy: 1.000
0
WARNING:tensorflow:Layers in a Sequential model should only have a single input tensor, but we receive a <class 'dict'> inpu
t: {'Fruit_Type': <tf.Tensor 'ExpandDims:0' shape=(None, 1) dtype=string>, 'Weight': <tf.Tensor 'ExpandDims_3:0' shape=(None,
1) dtype=string>, 'O2': <tf.Tensor 'ExpandDims_2:0' shape=(None, 1) dtype=float32>, 'Humidity': <tf.Tensor 'ExpandDims_1:0' s
hape=(None, 1) dtype=float32>}
Consider rewriting this model with the Functional API.
Fresh
```

Figure 12: Prediction results of the model

International Journal of Distributed Sensor Networks, 10(7), 591812. https://doi.org/10.1155/2014/591812

Gao, F., Dong, Y., Xiao, W., Yin, B., Yan, C., He, S. (2016). LED-induced fluorescence spectroscopy technique for apple freshness and quality detection. Postharvest Biology and Technology, 119, 27-32. https://doi.org/10.1016/j.postharvbio.2016.04.020

Ghanbari, K., Nejabati, F. (2019). Construction of novel nonenzymatic Xanthine biosensor based on reduced graphene oxide/polypyrrole/CdO nanocomposite for fish meat freshness detection. *Journal Of Food Measurement and Characterization, 13*(2), 1411-1422. https://doi.org/10.1007/s11694-019-00057-z

Gopal, J., Abdelhamid, H., Huang, J., Wu, H. (2016). Nondestructive detection of the freshness of fruits and vegetables using gold and silver nanoparticle mediated graphene enhanced Raman spectroscopy. Sensors and Actuators B: Chemical, 224, 413-424. doi: 10.1016/j.snb.2015.08.123

Hitanshu, Kalia, P., Garg, A., Kumar, A. (2019). Fruit quality evaluation using Machine Learning: A review. 2019 *2Nd International Conference on Intelligent Computing, Instrumentation and Control Technologies (ICICICT)*. https://doi.org/10.1109/icicict46008.2019.8993240

Jayasankar, K., Karthika, B., Jeyashree, T., Deepalakshmi, R., Karthika, G. 2018). Fruit Freshness Detection Using Raspberry PI. *International Journal of Innovative Research in Applied Sciences and Engineering, 1*(10), 202. doi: 10.29027/ijirase. v1.i10.2018.202-208

Kammar, S., Kulkarni, S., Kulkarni, U., K, R., Hegadi, R. (2015). Detection of freshness of fruits using electrical method. *International Journal of Engineering Trendsand Technology, 23*(2), 90-92. doi: 10.14445/22315381/ijett-v23p217

Kemiklioglu, E., Ozen, O. (2018). Design of a Sensor to Detect Fruit Freshness. *International Journal of Scientific and Technological Research, 4*(1).

Khaled, D., Novas, N., Gazquez, J., Garcia, R., Manzano-Agugliaro, F. (2015). Fruit and Vegetable Quality Assessment via Dielectric Sensing. *Sensors, 15*(7),15363 15397. doi: 10.3390/s150715363

Li, H., Gan, J., Yang, Q., Fu, L., Wang, Y. (2021). Colorimetric detection of food freshness based on amine-responsive dopamine polymerization on gold nanoparticles. *Talanta, 234*, 122706. https://doi.org/10.1016/j.talanta.2021.122706

Liu, K., Zhang, C. (2020). Volatile organic compounds gas sensor based on quartz crystal microbalance for fruit freshness detection: A review. *Food Chemistry, 334*, 127615. doi: 10.1016/j.foodchem.2020.127615

Magnaghi, L., Alberti, G., Milanese, C., Quadrelli, P., Biesuz, R. (2020). Naked-Eye Food Freshness Detection: Innovative Polymeric Optode for High-Protein Food Spoilage Monitoring. *ACS Food Science Technology, 1*(2), 165-175. https://doi.org/10.1021/acsfoodscitech.0c00089

Maynor, M., Nelson, T., O'Sulliva, C., Lavigne, J. (2007). A Food Freshness Sensor Using the Multistate Response from Analyte-Induced Aggregation of a Cross-Reactive Poly(thiophene). *Organic Letters, 9*(17), 3217-3220. https://doi.org/10.1021/ol071065a

Meng, X., Kim, S., Puligundla, P., Ko, S. (2014). Carbon dioxide and oxygen gas sensors-possible application for monitoring quality, freshness, and safety of agricultural and food products with emphasis on importance of analytical signals and their transformation. *Journal of The Korean Society for Applied BiologicalChemistry, 57*(6), 723-733. doi: 10.1007/s13765-014-4180-3

Navulur, S., S. C. S. Sastry, A., N. Giri Prasad, M. (2017). Agricultural Management through Wireless Sensors and Internet of Things. *International Journal of Electrical and Computer Engineering (IJECE), 7*(6), 3492. https://doi.org/10.11591/ijece.v7i6.pp3492-3499

Neethirajan, S., Jayas, D., Sadistap, S. (2008). Carbon Dioxide (CO_2) Sensors for the Agri-food Industry—A Review. *Food and Bioprocess Technology, 2*(2), 115-121. doi: 10.1007/s11947-008-0154-y

Perez de Vargas-Sansalvador, I., Erenas, M., Martínez-Olmos, A., Mirza-Montoro, F., Diamond, D., Capitan-Vallvey, L. (2020). Smartphone based meat freshness detection. *Talanta, 216*, 120985. https://doi.org/10.1016/j.talanta.2020.120985

Pongnumkul, S., Chaovalit, P., Surasvadi, N. (2015). Applications of Smartphone Based Sensors in Agriculture: *A Systematic Review of Research. Journal Of Sensors, 2015*, 1-18. https://doi.org/10.1155/2015/195308

S. I. Cho, G. W. Krutz, H. G. Gibson, K. Haghighi. (1990). Magnet console design of an NMR-based sensor to detect ripeness of fruit. Transactions of the ASAE, 33(4), 1043-1050. doi: 10.13031/2013.31436 Santonico, M., Pennazza, G., Parente, F., Grasso, S., Zompanti, A., Stornelli, V. *et al*. (2017). *A Gas Sensor Device for Oxygen and Carbon Dioxide Detection. Proceedings, 1*(4), 447. doi: 10.3390/proceedings1040447

Slavin, J., Lloyd, B. (2012). *Health Benefits of Fruits and Vegetables. Advances In Nutrition, 3*(4), 506-516. https://doi.org/10.3945/an.112.002154

Tichoniuk, M., Radomska, N., Cierpiszewski, R. (2017). The Application of Natural Dyes in Food Freshness Indicators Designed for Intelligent Packaging. *Studia Oeconomica Posnaniensia, 5*(7), 19-34. https://doi.org/10.18559/soep.2017.7.2

Ullo, S., Sinha, G. (2021). Advances in IoT and Smart Sensors for Remote Sensing and Agriculture Applications. *Remote Sensing, 13*(13), 2585. https://doi.org/10.3390/rs13132585

Valentino, F., Cenggoro, T., Pardamean, B. (2021). A Design of Deep Learning Experimentation for Fruit Freshness Detection. *IOP Conference Series: Earth and Environmental Science, 794*(1), 012110. https://doi.org/10.1088/1755-1315/794/1/012110

Vinci, G., Antonelli, M. (2002). Biogenic amines: quality index of freshness in red and white meat. *Food Control, 13*(8), 519-524. https://doi.org/10.1016/s09567135(02)00031-2

Wang, M., Gao, F., Wu, Q., Zhang, J., Xue, Y., Wan, H., Wang, P. (2018). Real-time assessment of food freshness in refrigerators based on a miniaturized electronic nose. *Analytical Methods, 10*(39), 4741-4749. https://doi.org/10.1039/c8ay01242c

Xing, M., Sun, K., Liu, Q., Pan, L., Tu, K. (2018). Development of Novel Electronic Nose Applied for Strawberry Freshness Detection during Storage. *International Journal of Food Engineering, 14*(7-8).

