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Food Quality Estimation using NIR Spectroscopy and Mass Comparison

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Abstract— **Purchasing and eating freshly-grown fruits and vegetables is the best way to ensure no preservatives, chemicals, or dyes have been added to your food. The emerging concern for food safety has led to the increasing demand for monitoring food quality worldwide. Our project addresses a food quality estimation and informative device, a novel solution for food freshness and quality monitoring that will help customers view the availability of fresh produce in the marketplace. Near-infrared spectroscopy and calorie calculation determine the fruits and vegetables' freshness and quality assurance. We can find the calorie content easily with simple weight calculations. Calorie content information helps to accurately control the intake of calories during different meals of the day.**

***Keywords* —Spectroscopy, food, NIR, weight, quality, calorie.**

I. INTRODUCTION

India's 70% of population depends on agriculture. Agriculture supplies a very profitable economic development by providing food and raw food in the non-agricultural sectors. Agriculture needs much manual work. It consumes a lot of time and workforce to examine fruits from harvest till their growth. Also, agricultural products tend to rot after transportation due to various environmental factors. Sometimes it is difficult and time-consuming to segregate these items; hence, rotten fruits or vegetables are sold to customers through online vendors. As fruit and vegetables are not marked with an expiry date, many customers receive rotten vegetables and fruits. As a result, it impacts the customer's mindset while buying this type of goods online. In this paper, we used NIR Spectroscopic Methods and weight estimation to generate information on the freshness of produce and the calories present in a particular set.

We have divided the paper into eight sections, as described below. Section II presents the literature reviews of the research papers referred to. In section III, we discuss the application of the NIR spectroscopy methodology for formulating the freshness of produce. Sections IV and V showcase the sensors and software tools used, respectively. We describe the method to measure weight and subsequent calories and the technique to predict ripeness levels in section VI. In section VII, we describe the results derived from the analysis of logging spectroscopic data of produce over several days. It gives an insight into patterns of the spectroscopic data for different fruits and vegetables. Finally, section VIII concludes the paper by drawing over the project's final details.

II. LITERATURE REVIEW

2.1 "Determination of Food Quality by Using Spectroscopic Methods" (Advances in Agrophysical Research, 2013), Agnieszka Nawrocka and Joanna Lamorska [1]

In this chapter, the authors have described the applicability of four spectroscopic techniques, e.g., UV–VIS spectroscopy, fluorescence, infrared and Raman spectroscopy, as rapid analysis methods to determine the quality of cereals, cereals products and oils. Additionally, the physical foundations of the methods above are described.

Infrared (IR) spectroscopy is a technique based on the vibrations of the atoms of a molecule. An infrared spectrum is commonly obtained by passing infrared radiation through a sample and determining what fraction of the incident radiation is absorbed energy. The energy at which any peak in an absorption spectrum appears corresponds to the frequency of vibration of a part of a sample molecule.

Near-infrared (NIR) spectroscopy has been primarily employed in the quantitative analysis of foods. Spectroscopy has been applied to measure various foods' moisture, fat, protein, and carbohydrate content. The most significant advantage is its ability to quickly determine several components in a food sample. The precision of NIR analysis for a wide range of applications is comparable to or better than that of the chemical techniques it replaces.

Spectroscopic methods seem to be very successful at evaluating food quality. They are used for qualitative as well as quantitative analyses of food products. Furthermore, they provide information on structure-functionality relationships (e.g., secondary structure of proteins). These techniques can

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be used independently or combined with other analytical methods, such as chromatography and serve as detectors.

2.2. "Defect and Ripeness Inspection of Citrus Using NIR Transmission Spectrum" Giyoung Kim, Kangjin Lee, Kyuhong Choi, Jaeryong Son, Dongsu Choi and Sukwon Kang [2]

In this paper, the authors discuss drawing a relation between the different stages of fruit or vegetable ripening and the corresponding dataset of spectral intensity and then predicting these stages with the help of an Artificial Neural Network based on a classification model.

According to the author, the fruits change colour in the different stages of ripening depending on the four families of pigments given,

1. Chlorophyll (Green)
2. Carotenoids (yellow, red, orange)
3. Flavonoids: anthocyanins + anthoxanthins (Red, blue, purple)
4. Bealtaine (Red, yellow, purple)

These pigments are molecular structures absorbing specific wavelengths and reflecting the remainder. Unripe fruits are green because of chlorophyll in their cells. As they ripen, the chlorophyll breaks down and is replaced by orange carotenoids and red anthocyanins. These compounds are antioxidants that prevent the fruit from spoiling too quickly in the air. Then, the enzymatic browning occurs and causes discolouration - turning brown.

2.3 "Near-infrared Spectroscopy in Food Analysis" (Encyclopedia of Analytical Chemistry, 2006), Brian G. Osborne [3]

The author has described near-infrared spectroscopy in food analysis. Near-infrared (NIR) spectroscopy is based on the absorption of electromagnetic radiation. NIR spectra of foods comprise broadbands arising from overlapping absorptions corresponding mainly to overtones and combinations of vibrational modes involving C-H, O-H and N-H chemical bonds.

The concentrations of constituents such as water, protein, fat, and carbohydrate can be determined using classical absorption spectroscopy. The significant advantage of NIR is that no sample preparation is usually necessary. Hence the analysis is elementary and fast (between 15 and 90 s) and can be carried out online.

2.4 "Optical chlorophyll sensing system for banana ripening." [4]

*(Meng Li, David C. Slaughter *, James F. Thompson, Postharvest Biology and Technology 12 (1997) 273–283)*

This paper revised the existing methodology to estimate the current ripeness of fruits, such as 1. Fruit respiration rate 2. Pulp firmness 3. Pulp starch content 4. Peel colour

However, these methods are impractical in ram time; hence the paper suggested a new methodology for the Optical Chlorophyll sense system. This paper is focused on the banana fruit.

The existing method to identify bananas' ripeness uses manual peel colour inspection. However, the results were all based on a visual colour assessment of the peel, which is subjective and can have poor precision. In contrast, the peel chlorophyll content was used as the indicator of peel colour in this research.

The objectives of this research were to

• Develop an inexpensive optical chlorophyll sensing system.

• Determine the correlation between the optical chlorophyll sensing system measurement and the chlorophyll content of banana peel measured by chemical analysis.

• Determine the correlation between chlorophyll content and colour difference meter measurement and visual colour assessment.

The author used monochromatic lithium-based LED light to give a proper solution. It is used to determine reflectance at two wavelengths that best predict Chlorophyll content.

III. NIR SPECTROSCOPY

A. *Introduction*

The wavelength range of 780 nm to 2500 nm forms the NIR part of the electromagnetic spectrum. NIR, like all radiation, behaves as a wave with the properties of simple harmonic motion, which may be defined in terms of the following properties:

- Vibration frequency
  = no. of times the wave pattern is repeated in 1 s
  = angular velocity/2

- The wavelength = Velocity of light / Frequency

B. *NIR advantage*

The great advantage of the NIR is that no sample adjustment is usually required, so the analysis is elementary and quick (between 15 and 90 s). One of the strengths of NIR technology is that it allows multiple components to be measured simultaneously. It provides a built-in dilution series for a few different solubility selections containing the same chemical information. Additionally, there is a series of symmetrical vocal cords in each fundamental vibration, and a combination of each consecutive tone band is approximately the order of magnitude lower than the previous one. Finally, relatively poor absorption due to water causes high-moisture foods to be analysed. A significant limitation of NIR spectroscopy in food analysis is its reliance on less accurate reference methods.

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Near-infrared (NIR) spectroscopy has many potential advantages as an authenticity testing tool. It has already been applied to several authentication problems using a range of sample presentation and chemometric techniques. [5]

This spectroscopy technique has wide applications in agriculture with the advantages of being nondestructive, sensitive, safe, and rapid. It is suggested that large-scale data with abundant varieties can be used to build a more robust calibration model, improve the robustness and accuracy of the NIR analytical model, and overcome problems caused by confining analysis to too many uniform samples. [6]

IV. SENSORS

A. Near Infrared Sensor

This NIR sensor is one of the main components of our system. It will collate the spectral colour data for each fruit and vegetable that our system will recognise. It is a digital 6-channel spectrometer for spectral identification in near IR (NIR) light wavelengths. AS7263 consists of 6 independent optical filters whose spectral response is defined in the NIR wavelengths from approximately 600nm to 870nm with a full-width half-max (FWHM) of 20nm. We used this sensor to collect information regarding the Near Infrared values for different days during the ripening cycle. A channel was chosen for analysis according to the pattern observed for a particular grocery item. The 680 nm and 860 nm channels were commonly adopted for the study.

Fig 0: AS7263 Near Infrared Sensor

B. Weighing Load Cell Sensor

This straight bar load cell (sometimes called a strain gauge) translates up to 20 kg of pressure (force) into an electrical signal. Each load cell can measure the electrical resistance that changes in response to, and is proportional to, the strain (e.g., pressure or force) applied to the bar. With this gauge, we can judge just how heavy an object is. If an object's weight changes over time, we need to sense the presence of an object by measuring the strain or load applied to a surface. This straight bar load cell is made from an aluminium alloy and can read a capacity of 20KG of weights. It has Four lead wires which can be connected to HX711 A/D Pressure Sensor. It is easy to use with a driving voltage of 5-10V and produces the output voltage as per the force changes over it. We measured the weights of different fruits/vegetables using the sensor. Using the weight, we calculated the total calories using the calorie conversion chart issued by the US drug and fruit administration.

Fig 1: YZC-133 Weighing Load Sensor 20kg

C. Sensor casing

We designed and created a 3D Printed case for NIR Sensor. We have used Autodesk Fusion 360 Software for 3D Modelling Fusion 360 is a cloud-based 3D modelling, CAD, CAM, CAE, and PCB software platform for product design and manufacturing. This case ensured that the values recorded by the sensor were of absolute integrity and free of any errors. It was guaranteed by creating a black-coloured case with sharp edges to block light.

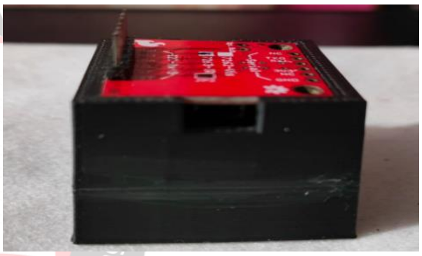

Fig 2: Sensor Casing

V. SOFTWARE

A. Python

Python is an interpreted, object-oriented, high-level programming language with dynamic semantics. Its high-level built-in data structures, combined with dynamic typing and dynamic binding, make it very attractive for Rapid Application Development and for use as a scripting or glue language to connect existing components. Python's simple, easy-to-learn syntax emphasises readability and reduces the cost of program maintenance. We used python for Raspberry Pi programming.

B. Flask Framework

Flask is a micro web framework written in Python. It is classified as a microframework because it does not require tools or libraries. It has no database abstraction layer, form validation, or other components where pre-existing third-party libraries provide standard functions. We used Flask to connect the website and the microcontroller Raspberry Pi. jinja2 is a popular template engine for Python. A web template system combines a template with a specific data source to render a dynamic web page.

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VI. METHODOLOGY

A. Methodology for counting calories

The below table shows the weight-to-calorie ratio for fruits and vegetables. This chart is obtained from the US Department of Agriculture.

Table 0: Fruit - Calorie conversion chart

Name of Fruit	Calories (per 100g)
Cucumber	15
Sapodilla	83
Lemon	29
Tomato	17
Sweet lime	43
Capsicum	26

The calorie value for each vegetable/fruit is calculated with simple proportionality according to the weight recorded by the sensor. The standard calorie value for that fruit is obtained from the US Department of Agriculture data. The website sums up the calories and displays the result. This information is used to monitor the calorie intake for diet plans and regular food consumption. It asserts control over calorie intake, an essential aspect of the sedentary lifestyle practised by several people today. Health complications like diabetes, heart palpitations, high blood pressure, depression and other pernicious diseases can be circumnavigated by understanding this simple aspect of our diet. Information is provided in this regard.

B. Methodology for ripening prediction

The NIR values are recorded by hovering the sensor completely covering the fruit surface until a range of coherent values is observed. The outliers due to human error are discarded during post-processing. Once the information on sensor values for different days is documented, we program the microcontroller to recognise each ripening stage. The sensor values are assigned a ripening stage (Day 01, Day 02 etc.). This relation is encoded for each fruit or vegetable in the roster. To test the prediction accuracy, we take a sample fruit and use the sensor over it. The program takes the sensor values as inputs. The algorithm searches for the most accurate ripening stage by comparing the input value with those recorded for analysis. If there is a crossover between these two values, that day is concluded as the current ripening level of the fruit. This information is displayed on the website for the customers to view.

Non-destructive instrument-based methods are preferred to destructive techniques. They allow the measurement and analysis of individual fruit, reduce waste, and permit repeated measures on the same item over time. A wide range of objective instruments for sensing and measuring the quality attributes of fresh produce have been reported. Among non-destructive quality assessment techniques, near-infrared (NIR) spectroscopy (NIRS) is arguably the most advanced regarding instrumentation. [7]
Pesticide residue investigation in tomatoes using NIR spectroscopy and prediction models such as PSLR and ANN underscored the use of NIR methodology for quality estimation. The non-destructive nature of the process ensures the sustained quality of produce after the completion of spectroscopy. Hence, it was chosen as the contender for the prediction of ripening levels. [8]

VII. ANALYSIS OF NIR SPECTROSCOPY RESULTS

Firstly, we recorded the NIR sensor values of each fruit/vegetable and batched them according to a specific NIR channel. We chose the NIR channel pertaining to a pattern or trend in the NIR values. If the NIR values for a channel were either rising or waxing for the fruit, that channel was considered for analysis. In contrast to the other channels with vacillating trends in the NIR values, the channels with cogent trends were informative. These waning/rising values corresponded to the different ripening stages of that fruit. These ripening stages were easily programmed with the help of information about the trend in sensor values.

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A. Analysis of tomato (680nm)

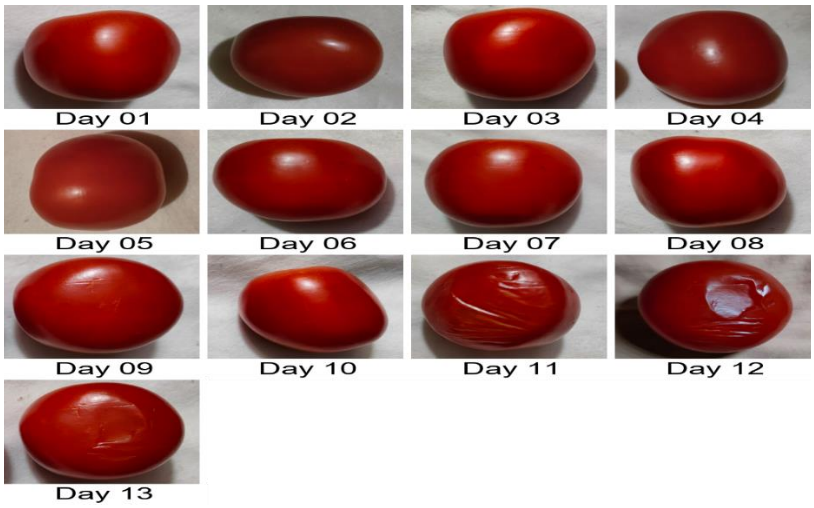

Fig 3: Discoloration of tomato

Browning or discolouration of the fruit's peel due to the breakdown of enzymes can be observed. This gradual browning is detected by NIR spectroscopy. The spectroscopy is plotted over several days to gauge a trend in the values.

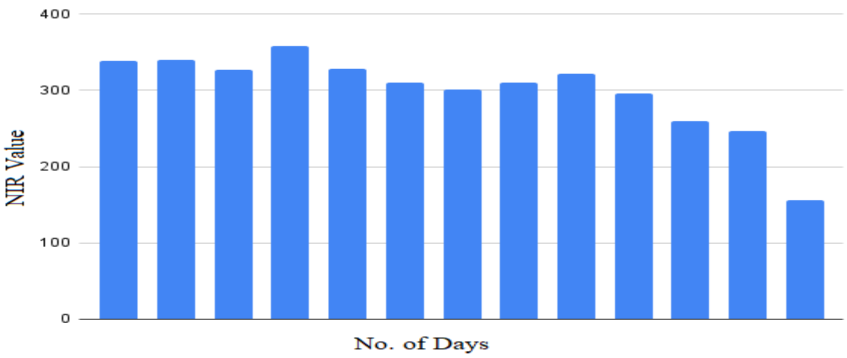

Fig 4: Graph of NIR spectroscopy value vs Number of days under observation

The 680nm channel was chosen for the observance of the tomato. The trend in the NIR values of the tomato was observed for 13 days. A clear waning trend can be seen in the graph plotted above.

B. Analysis of Sapodilla (860nm)

Fig 5: Discoloration of Sapodilla

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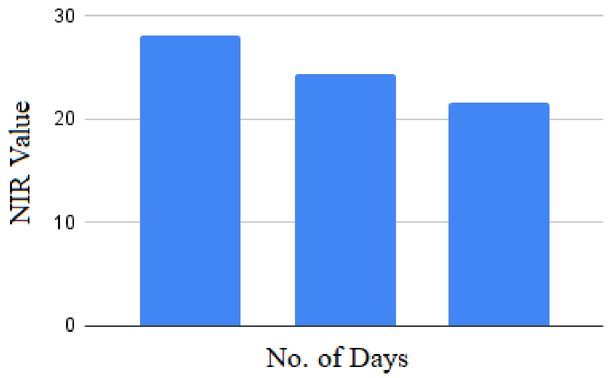

Fig 6: Graph of NIR spectroscopy value vs Number of days under observation

The 860nm channel was chosen for the observation of Sapodilla. The trend in the NIR values was observed for three days. A clear waning trend can be seen in the graph plotted above.

C. Analysis of lime (680nm)

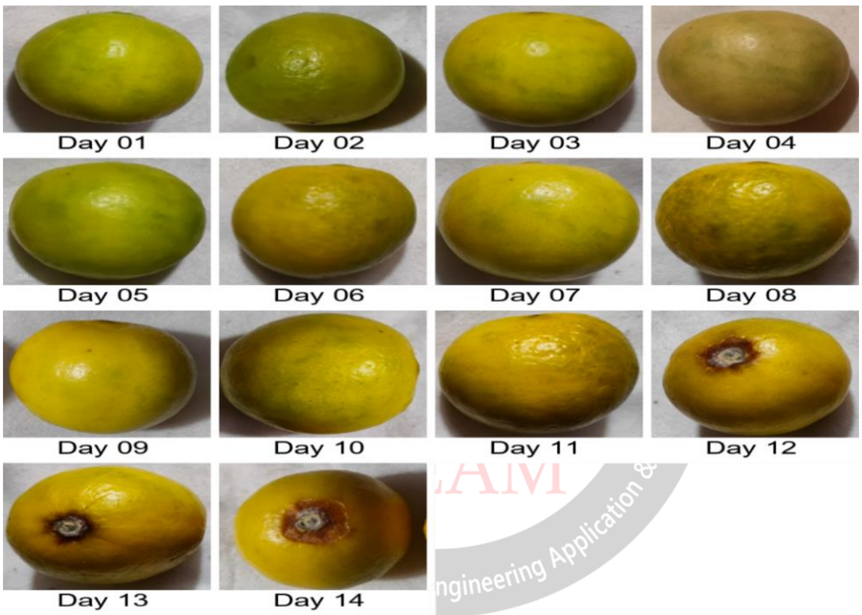

Fig 7: Discoloration of Lime

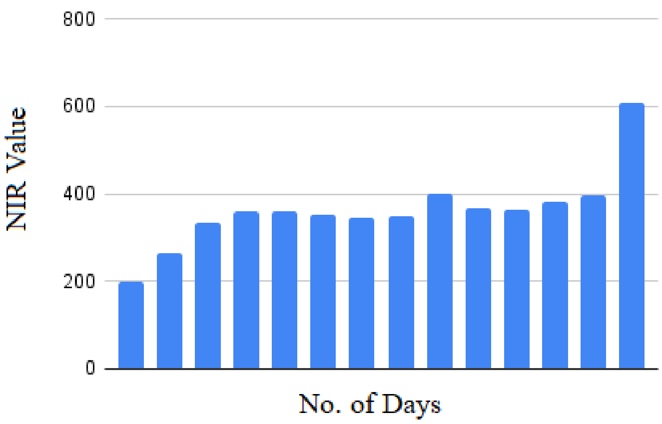

Fig 8: Graph of NIR spectroscopy value vs Number of days under observation

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The 680nm channel was chosen for the observation of Lime. The trend in the NIR values was observed for 14 days. A clear rising trend can be seen in the graph plotted above.

D. Analysis of cucumber (860nm)

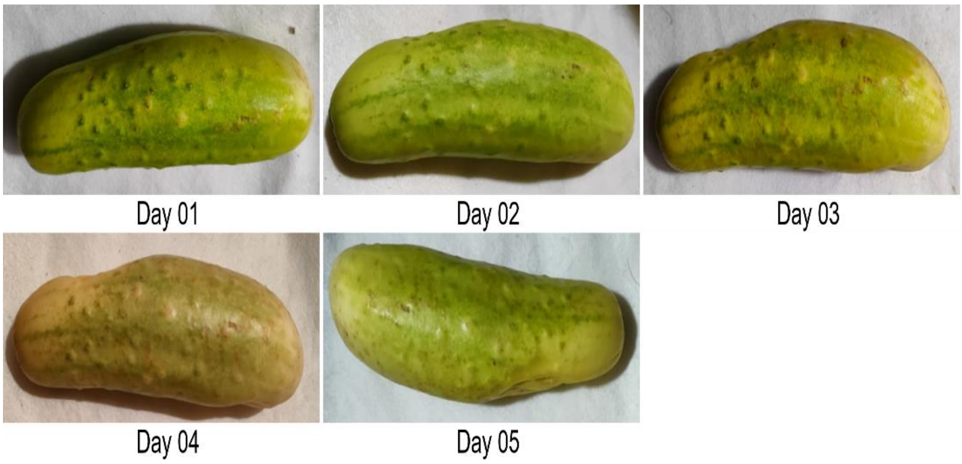

Fig 9: Discoloration of Cucumber

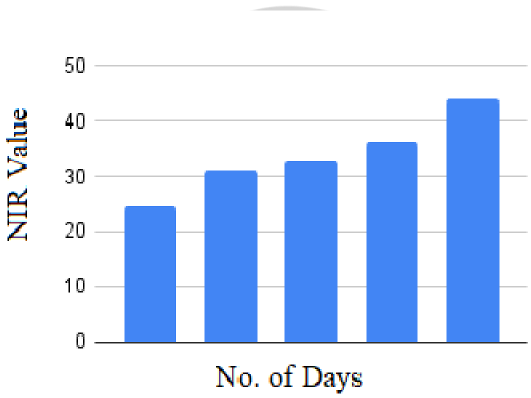

Fig 10: Graph of NIR spectroscopy value vs Number of days under observation

The 860nm channel was chosen for the observation of Lime. The trend in the NIR values was observed for five days. A clear waxing trend can be seen in the graph plotted above.

E. Analysis of sweet lime (680nm)

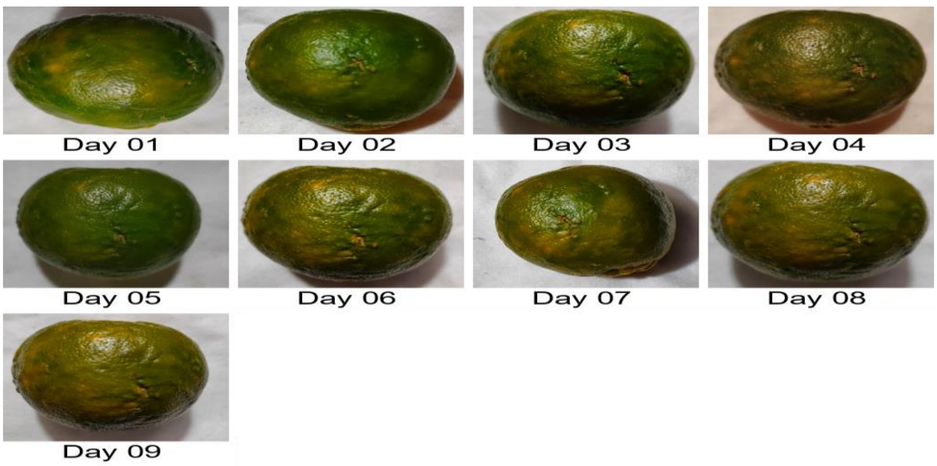

Fig 11: Discoloration of Sweet Lime

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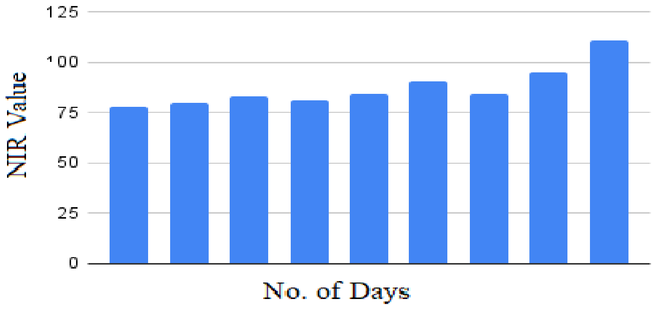

Fig 12: Graph of NIR spectroscopy value vs Number of days under observation

The 680nm channel was chosen for the observation of Sweet Lime. The trend in the NIR values was observed for nine days. A clear rising trend can be seen in the graph plotted above.

F. Analysis of capsicum (860nm)

Fig 13: Discoloration of Capsicum

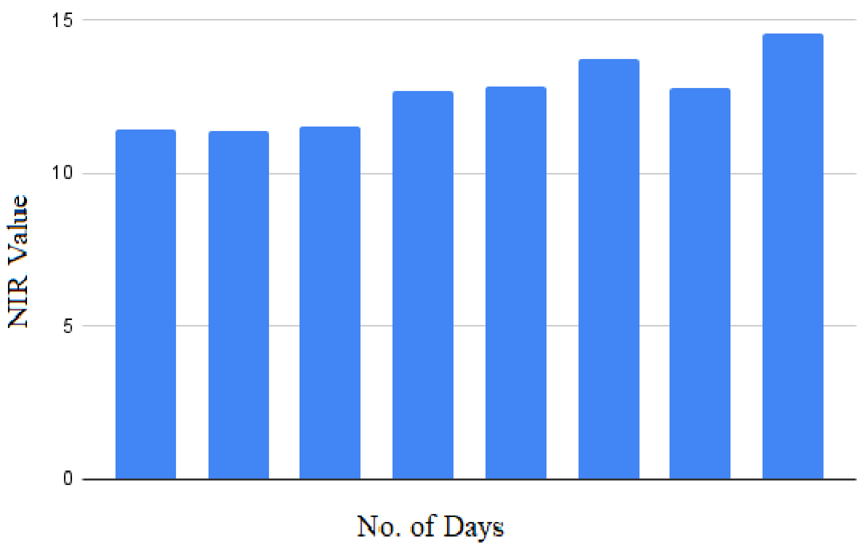

Fig 14: Graph of NIR spectroscopy value vs Number of days under observation

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The 860nm channel was chosen for the observation of Capsicum. The trend in the NIR values was observed for eight days. A clear rising trend can be seen in the graph plotted above.

Fig 15: A Web Page designed using HTML, CSS and JavaScript display weight, calories and days groceries will take to rot. This type of web page can be integrated with existing e-commerce websites.

VIII. CONCLUSION

In this paper, we identified the problem statement of the need for monitoring food quality and proposed our solution. Our project addresses the issue of transparency in online grocery shopping. Website owners often cheat their customers. Rotten groceries are delivered to their doorsteps. Sometimes, even if the food is acceptable, it may rot the next day. Purchasing high-quality and fresh groceries is essential for good health.

The customer is uninformed about the ripeness/quality of the food while grocery shopping. Also, they cannot estimate the day that the food will rot. We found that understanding the trend in sensor values helped draw a relation between different ripening levels and sensor values of the fruit. This information can be used to program the microcontroller for the different ripening stages. The programmed range of sensor values for a particular stage was accessed each time input was recorded. If the input values were in concord with the values corresponding to a specific ripening stage, that information was extracted and displayed on the website.

Additionally, we found that the standard calorie information according to the weight by the US agriculture administration can be used to estimate the calories of produce. Information on calories helps regulate intake throughout the day. This way, through our device, we facilitate the transfer of information about the calorie count and fruit and vegetable ripeness to the customer.

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