Potential of Near-Infrared (NIR) spectroscopy technique for early detection of Insidious Fruit Rot (IFR) disease in Harumanis mango

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Abstract. Harumanis mango ‘Insidious Fruit Rot’(IFR), is one of the common issues that hampered the fruit quality and consequently lowered the premium value of Harumanis Mango. Physically and visually the affected fruit does not show any attributes that indicates the presence of IFR on any part of the fruit until it has been cut open. This paper investigates the feasibility of a non-destructive method to screen the Harumanis mango from IFR using near-infra red light and artificial neural network. A common NIR light emitting diodes of 1000nm wavelength was used as the light source to emit NIR light while a photodiode was used to measure the intensity of the reflected NIR light from Harumanis mango. Early detection of IFR were done manually by local expert using acoustic method by flicking fingers to detect any abnormality inside the fruit. Sample data on NIR Spectroscopy reflectance results of 120 samples were used to classify the presence of IFR using neural network. Mean value of NIR reflectance of RBG for Harumanis mango with an incidence of Insidious Fruit Rot are $R=0.651$, $G=0.465$ and $B=0.458$, while without IFR are $R=0.211$, $G=0.15$ and $B=0.146$. Using MATLAB’s neural network training tool, a training set regression was obtained with an accuracy value of 0.9805 for prediction of IFR, thus this value is very high in accuracy.

1. Introduction
Mango is one of the profitable agriculture products which were exported worldwide, most notably from Asian countries such as India, Indonesia, Thailand and Malaysia. Mango are a popular as nutritional tropical fruit which are now one of the most important fruits crops in subtropical and tropical area. In Peninsular Malaysia, mangoes are grown in a limited, mixed property or orchard. According to “Fruit Crops Statistics” report produced by Department of Agriculture Putrajaya, Malaysia, the area of mango orchard in Peninsular Malaysia is rising from 5772.7 hectarage in 2015 to 6048.29 hectarage in 2017. Harumanis mango is one of the most famous agricultural commodities in Perlis, Malaysia. The mango is planted in a large scale as the demand is high either by locally or
abroad. It had been included into a national agenda as a specialty fruit from Perlis [1]. Malaysia had first exported the Harumanis Mango to Japan in 2010 by merely 3.1 metric tons, however the volume was targeted to increase up to 100 metric tons by 2020. This forecast is due to a strong and popular demand based on its desirable characteristic.

One special depiction of Harumanis mango is that it is categorized as a seasonal fruit and specifically planted and grown in Perlis, Malaysia. Although there are attempts of Harumanis mango cultivation in other states in Malaysia, the volume and quality of harvest are not yet proven to date. What differentiate Harumanis Mango than other mangoes are that it is a temperamental fruit which needs a long dry season with a minimum temperature of 40° Celsius. Thus, the only state in Malaysia that has a regular period and prolonged dry weather is Perlis. A slight rain, even with occasional drizzles can affect the yield output of one season.

Although Harumanis mango have already been commercially produced over the years, local tropical fruit sector still falls short in terms of quality assessment and proper postharvest handling. Current sorting systems that are available in Jabatan Pertanian Perlis are only weight-sorter machine and manual-based sorting for the skin clearness and external defects [2]. While, in FAMA KLIA, these external parameters were evaluate using vision system. The Harumanis mango quality is monitored manually and is incredibly dependent on the human visual system. The expansion of this cultivar is reportedly hindered due to incidence of internal tissue breakdown known as ‘Insidious Fruit Rot’ (IFR). The internal quality of Harumanis Mango is greatly impaired by this disease. This incidence is categorized as a physiological disorder and it does not show any external damage even during ripe stage or harvest time. The affected fruit does not show external damage at the time of harvest or at the ripe stage but occasionally a lack of firmness in the sinus region can be detected [3]. Harumanis mango diseases become major problem and dilemma for the most farmer in Perlis due to it will affect the growth and production of quality fruit. Among major Harumanis mango familiar diseases are ‘Anthracnose (Colletotrichum Gloeosporide)’, ‘Mango Sooty mould (Meliola Mangiferae Eark)’, ‘Pink Disease (Cortitium Salmonicolor)’, ‘Stem End Rot (Botryodiplodia Theobromae)’, and ‘Insidious Fruit Rot (IFR)’ [4]. Among all these diseases, ‘Insidious Fruit Rot (IFR)’ is the hardest to detect as the physical characteristic remains unchanged even when the fruit has been affected.

The ‘Insidious Fruit Rot’(IFR) is an internal tissue breakdown categorized as a physiological disorder and does not show any external damages even during ripe stage or harvest time. It is also known as ‘Yeasty Fruit Rot’, is thought to be a physiological disorder probably identical with soft nose. The occurrence of the physiological disorder ‘soft nose’ in Kent has been associated with low calcium and high nitrogen levels in the fruit and leaves [5]. The occurrence of ‘Insidious Fruit Rot(IFR) was influenced by fruit size as research finding shows that bigger fruit was more affected by this disorder which was characterized by a tissue breakdown in the fruit. Nitrogen (N) and calcium (Ca) were found to be most consistently related to IFR. The affected fruit was found to be high in Nitrogen (N) and low in Calcium (Ca) [6]. Due to the lack of modern method in assessing internal condition and quality of Harumanis Mango, farmers tend to go for a manual and traditional method named the water displacement and floating method. This method is applied to predict the internal properties and quality of the fruit by applying the density concept [7]. Thus, a non-destructive method needs to be developed for farmers to screen the fruit from ‘Insidious Fruit Rot’(IFR) easily, fast and accurate.

Near-infrared spectroscopy is the most common analytical technique widely applied in food quality research. Moreover, its rapidity in measurements and low costs add to its large- scale application in the agri-food industries. The spectral data acquired from the instrument can be analysed by both quantitative and qualitative approaches. It can potentially be used for on line external quality monitoring as well as for multi- constituent analysis (moisture, sugar, protein, starch, etc.) for a variety of fruits [8].
2. Materials and methods

2.1 Sample selection and sensor development

A data set was made to classify defects obtained from 120 selected mango fruits, were obtained during harvest season of 2021 from FAMA, Perlis. Harumanis mango has a dark green background color when developing on the tree that turns lighter green to yellow as it ripens [3]. Naturally, the changing of skin colour occurs from dark green at the initial level, and then to green-yellowish at the final level of ripening [9]. During recent harvest, both dark green and light green skin of Harumanis mango were present as shown in figure 1.

![Figure 1](image.png)

Figure 1. Two different skin colours of Harumanis mango during harvest. Dark green on the left and light green on the right.

For this experiment, only light green colour skin Harumanis mango were selected. An early harvest mango was selected for these experiments before they were kept in a shelf storage to ripe for 5 to 7 days. This is crucial as this experiment focuses on an early detection of the disease before the mangoes reach consumers after ripening process.

These produces were obtained from local mango orchard all over Perlis. Physically, all of these samples have no defect on the skin and physical attributes, but thorough checking using traditional method of water displacement floating technique and manual acoustic method of flicking fingers to check lack of firmness at the sinus region of the mangoes were done by FAMA expert staffs. The outcome of these manual and traditional method used may indicate Harumanis mango which exhibit the occurrence of Insidious Fruit Rot (IFR) in the fruit.

Spectroscopy is a scientific discipline studying interactions of light with the matter [12]. Basic NIR spectrometer contains light source, monochromator and detector to get the spectrum of sample [13]. Light can be of different wavelengths, which are represented by the electromagnetic spectrum applied. Conventional infrared instruments usually operate in the near-, mid-, or far infrared regions, depending on the energy source and the detector used [14]. In order to predict the incidence of Insidious Fruit Rot (IFR) in Harumanis mango, a selection of near-infrared light (NIR) emitting diode (LED) were first use to estimate the best readings obtained during sampling. A 1000nm wavelength of NIR LED was chosen as the light source as the data obtained were most stable during preliminary data sampling.

To make a quantitative prediction of an Insidious Fruit Rot (IFR) disease in an intact fruit by NIR, light from the source is directed to penetrate through the flesh of the fruit and reflect back to the detector. The detector used is a photodiode sensor with a spectral responsivity up to wavelength $\lambda - 1100\text{nm}$. This range is useful for intact food due to the following facts [10]:

- Radiation can penetrate much further in fruit,
- the instrumentation has low cost, and portable enough,
- the band recognised to the third and fourth overtones of O-H and C-H stretching modes,
- lower absorbance at these wavelengths allows for transmission optics,
- water absorbance peaks are less strong.
The LED was placed in an angle between 45° to 60° to the mango surface with the distance of 15mm. The photodiode sensor is placed adjacently to the LED, with the distance of 20mm to 30mm to the mango surface. Both of these components are connected to STC12C5A60S microcontroller board. The LED will transmit NIR light to the mango and interact with the tissue inside. Next, the reflected light from the mango will be received by the photodiode sensor. To shield the fruit from ambient light, the sensor readings was done in a black box with a cable connected to a laptop to obtain sensor’s reading output. When the LED is turned ON, the photodiode sensor will take readings and show it in the serial monitor using STC-ISP programmer. The hand-held active sensor system shown in figure 2.

2.2 Data collection
Fruits were divided into three segments for data collection. Literally, the sensor was pointed to the end stem, middle and distal end as in figure 3. This step is crucial in order to segmentized and detects the most prone area. This breakdown often develops at the distal end of the fruit [5]. Each sample was divided into 3 segments, and each segment sensor gives an output of RGB values individually.

3. Results and discussion
A total of 120 samples were used for analysis and classification as tabulated in Table 1. Out of this number over 50 samples were predetermined to have been infected by Insidious Fruit Rot (IFR) disease. The notion of this predetermined sample was done by FAMA staff based on their experienced and self-taught knowledge, by means of traditional method of water displacement and checking of firmness on sinus area of Harumanis mango. While the rest of the samples were a mixed of randomly picked fruit from the same batch. Since there were 3 classes for classification, these data sets were
determined by a human expert in the notion of fruits that were with or without the incidence of IFR
diseases. 12 samples were randomly chosen for testing analysis. Thus, the total of 84 samples out of
120 samples from NIR data were for training analysis and 36 samples were used for testing analysis. It
means that 70% of total samples was for training, and 30 % was used for testing.

Table 1. Harumanis Mango Sensor Readings and Insidious Fruit Rot (IFR) results.

| Class | Number of Samples for training | Number of samples for testing | Photodiode Sensor Mean Value | IFR Result after 5 days shelf storage |
|-------|---------------------------------|------------------------------|-------------------------------|--------------------------------------|
|       |                                 |                              | R | G | B |                               |
| 1     | 28                              | 12                           | 0.651 | 0.465 | 0.458 | Yes |
| 2     | 28                              | 12                           | 0.211 | 0.15 | 0.146 | No |
| 3     | 28                              | 12                           | 0.667 | 0.469 | 0.485 | Yes |
| Total | 84                              | 36                           |                               |                                      |

Near infrared spectroscopy measurements can be collected in either transmittance, reflectance or
transfection mode. The transmittance mode allows to get information on the entire volume of the
sample crossed by the light, while the reflectance mode only from the surface of the sample [11]. This
experiment focuses mainly on the reflectance method of NIR selected wavelength on Harumanis
mango. The reflectance value of RGB were then used for analysis and comparison with the incidence
of IFR at the targeted Harumanis mango regions. Class 1 targeted area are on the distal end of the
Harumanis mango. The reflectance value of class 1 shows a mean value of R= 0.651, G= 0.465 and
B=0.458. The after-shelf storage inspection on the sample shows an incidence of insidious fruit rot
(IFR) disease in the flesh of the fruit of Class 1. Class 2 with the same targeted area of distal end have
the mean value of R = 0.211, G=0.15 and B=0.146. The after-shelf storage inspection shows no
incidence of insidious fruit rot (IFR) disease in the flesh of Class 2. While for Class 3 readings of
sensor have the mean value of R=0.667, G=0.469 and B=0.485. The after-shelf storage shows an
incidence of insidious fruit rot (IFR) disease in the flesh of the fruit of Class 3. The after-shelf storage
samples inspection was done by slicing the sample in half from sinus to peak area and the incidence of
IFR was observed in the flesh. Comparing the data value of RGB in Class 1 and Class 3, shows a
similarity in data ranges for Harumanis mango with an incidence of insidious fruit rot (IFR) diseases
in the flesh of the sample.

Neural network was used for analysis of sample training data set. 70% sample values of RGB
obtained during experiments was used as training data with the output accuracy regression of
R=0.9805 as shown in figure 4. Regression R values measure the correlation between output and
target with and R value nearing 1 means a close relationship and high accuracy of data prediction.
4. Conclusion
The design and development of a low cost NIR spectroscopy for an early detection of Insidious Fruit Rot (IFR) disease in Harumanis mango has high potential. As a non-destructive method, this design could be a great assistance for small farmers of Harumanis mango due to the cheap and easily accessible devices. The collected data can be used in neural network to determine the incidence of IFR. However, a further study in the future with multiple NIR LEDs wavelength, together with artificial neural network training can be composed with another method to validate the occurrence of IFR in an early harvest of Harumanis mango.

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