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Preliminary study to predict moisture content of jackfruit skin using shortwave near infrared spectroscopy

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Abstract

Moisture content of a jackfruit is one of the main attributes used by farmers to determine the maturity level of the fruit. The objective of this preliminary research was to explore the potential application of low-cost shortwave near infrared (VSWNIR) spectroscopy to non-destructively predict moisture content of jackfruit from their outer skin. A total of 870 skin portions collected from twenty-nine jackfruit samples were used in this study. After the spectral measurement, the skin portions were dried in the oven in order to measure their moisture content (%, wet basis, w.b.). Partial least square (PLS) method was used to develop both calibration and prediction models for calibrating the spectral data with the moisture content. This study found that the value of coefficient of determination (R^2) and root means square error of calibration (RMSEC) were 0.65 and 2.17, respectively. For the prediction model, the value of R^2 and root mean square error of prediction (RMSEP) were 0.64 and 2.81, respectively. These results indicated the VSWNIR spectrometer is a promising technology for non-destructively predicting moisture content of jackfruits.

1. Introduction

Jackfruit (*Artocarpus heterophyllus*) is a non-seasonal fruit which is widely planted in tropical countries such as Brazil, Thailand, Indonesia, India, Philippines and Malaysia (Madruga *et al.,* 2014). In Malaysia, approximately 5,097 ha of land were planted with jackfruit, producing about 28,042 Mt of fruit with the production values up to RM58 million (DOA, 2017). Jackfruit is a high yielding crop which bears fruit all year round with its production peak is usually between June and December (Ong *et al.,* 2006). Daud *et al.* (2017) stated that the average mass of a fruit ranged from 3.5 to 10 kg and sometimes a fruit may reach up to 25 kg. The fruit is basically round-cylindrical in shape with the dimensions of length and diameter were about 30-100 cm and 25-50 cm, respectively (Leong *et al.,* 2016).

A jackfruit maturity level can be determined by measuring several parameters of chemical composition factors such as crude fibre, colour, pH, soluble solids sugars, organic acids, moisture content and flavour changes during ripening of jackfruit (Ong *et al.,* 2006). The maturity determination is important because only the ripened fruit has good eating quality in terms of aroma, texture, sweetness, and taste and therefore is able to produce high quality of juice (Sim *et al.,* 2003). However, physicochemical property of jackfruit may vary depending on different origin regions and species sources (Zhang *et al.,* 2016). Thus, monitoring and controlling fruit maturity has become a priority issue in the jackfruit industry especially when the ripeness is perceived by customers as an important quality indicator (Sim *et al.,* 2003).

The application of spectroscopic technology for non-destructively measuring internal quality such as sugar and moisture content of fruit which could lead to maturity detection has gained tremendous interest among researchers. Several studies reported the application of near-infrared spectroscopy (NIRS) to determine the internal quality of fruit such as watermelon (Tian *et al.,* 2007) and apple (Qing *et al.,* 2007). In terms of moisture content, NIRS was successfully used to predict moisture content from sugar beet (Pan *et al.,* 2015), potato (Amjad *et al.,* 2018) and cassava (Lertworasirikul and Tipsuwan, 2008). The measurement of moisture content using NIRS is possible due to the strong absorbance of near-infrared light by water molecules.

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Recently, rapid development of a portable visible and shortwave near-infrared spectrometer (Vis/SWNIRS) with a wavelength range from 350 to 1100 nm appears promising to be employed for fruit maturity detection (Nawi *et al.*, 2013). Unfortunately, there are no reported studies have attempted to apply Vis/SWNIRS for the prediction of moisture content from jackfruit samples. Therefore, the goal of this research was to investigate the feasibility of using Vis/SWNIRS to predict moisture content from a jackfruit. The specific objective was to develop partial least square (PLS) models for predicting moisture content from the jackfruit skin samples.

2. Materials and methods

2.1 Sample preparation

A total of twenty-nine matured Jackfruit samples were purchased from a private orchard located in Rawang, Selangor. Each jackfruit sample was first weighed to obtain the mass of the fruit. Each sample was divided into five vertical portions (top, upper middle, middle, lower middle and bottom) and six horizontal portions, giving thirty portions for each fruit samples (Figure 1). In total, 870 portions were extracted from 29 jackfruit samples. Each portion was scanned on its skin surface before it was sliced into small cube and placed into an oven dryer for moisture content measurement.

Figure 1. Marking for each portion of jackfruit skin

2.2 Spectral acquisition

Spectral data of the skin from each portion was recorded using visible shortwave near infrared (VSWNIR) spectrometer (Ocean Optic HR4000, Ocean Optics Inc., Dunedin, Florida) with a wavelength ranges from 200 to 1100 nm. This high-resolution miniature fiber optic spectrometer is equipped with a charge-coupled device (CCD) detector, having an optical resolution of 0.50 nm. The spectral data of each portion was recorded three times and averaged before it was used in the development of calibration and prediction models. A scanning distance between the spectrometer and the skin surface was fixed at 1.5 cm. The spectral measurement was performed inside a black box which was illuminated by a halogen light source (Model: HL

2000, Ocean Optics Inc., Dunedin, Florida). The spectral data were collected and transformed into a computer with the application of SpectraSuite software (Ocean Optics Inc. Finland). In order to avoid a low signal-to-noise ratio, some obvious noise removed from both ends of the wavelength, considering only the wavelength regions between 500 nm and 950 nm were used for the calculations.

2.3 Moisture content measurement

After the spectral acquisition, each portion was cut into 2 cm^3 cube size. The thickness of skin samples for each portion was also measured. Then, the cube portions were put in containers and placed into a conventional oven dryer with a drying temperature of 105±2°C for 24 hours. Conventional dryer is the most economical hot air-drying technique commonly used to dry fruits and vegetables (Omolola *et al.*, 2017). Moisture content (MC) was determined using an air oven method according to the standard of Association of Official Analytical Chemists (AOAC International) (Pearson, 1976). The moisture content of samples was quantified indirectly, according to the loss of mass after drying at 105±2°C. The mass of skin samples and metal container of each portion was determined based on a wet-weight basis method (MC, %, w.b.) using the Equation (1)

$$\text{Moisture content (\%)} = \frac{W2-W3}{W2-W1} \times 100 \quad (1)$$

Where W1 is the weight of the container with the sample; W2 is the weight of the container with sample before drying; and W3 is the weight of the container with sample after drying.

2.4 Spectral data pre-treatment

Before calibration, the spectral data were pre-treated for optimal performance. The effect of several pre-treatment methods on the performance of PLS models including smoothing by moving average, multiplicative scatter correction (MSC), first and second derivatives, standard normal variate (SNV) transformation and Savitzky-Golay were investigated. In this study, a combination of Savitzky-Golay and SNV was found to yield the best performance for PLS models. These selected pre-treatment methods were implemented using the Unscrambler X 10.3 (CAMO AS, Trondheim, Norway).

2.5 Development of calibration and validation models

Before PLS models were developed, principal component analysis (PCA) was applied to extract useful information from the spectra, decrease the noise and determine the optimum number of latent variables (Wu

et al., 2008). PCA is a well-known chemometrics method used to search for directions of maximum variability in sample grouping and using them as new axes called principle components (PCs) or latent variables (LVs) that can be used as new variables, instead of the original data, in the following calculations (Nawi *et al.,* 2013). PCA was also used to detect spectral outliers that might affect model performance in each data set. PCA identified outliers from the influence plot which displays the sample residual *x*-variances against leverages. Samples with high residual variance are likely to be outliers. These identified outliers were removed before modeling by PLS regression. In this study, 5% of the data were removed for being outliers.

In this study, the development of the PLS model was achieved by full cross-validation (leave-one-out) method (Nawi *et al.,* 2013). External validation was used in this study to check the performance of the PLS models. The samples in the external validation set had not been used for the calibration development. Before calibration, samples were divided into two sets; 75% of the samples were used to develop calibration and 25% of the samples were used to validate the predictive equation (validation set).

Both PCA and PLS modelling were run using the Unscrambler X 10.3. In the end, the performance of the PLS models was evaluated by the root mean square error of calibration (*RMSEC*) and the coefficient of determination for calibration (R^2) for the calibration model. For the prediction model, the root mean square error of prediction (*RMSEP*) and the coefficient of determination for prediction (R^2) were used.

3. Results and discussion

3.1 Statistical parameter of the samples

The statistics characteristic of moisture content for jackfruit portions are presented in Table 1. From the table, it can be seen that the lowest and the highest values of moisture content recorded were 5.47 and 49.38% (w.b.), respectively. The average value of moisture content for all jackfruit samples was 16.74% (w. b). The variation in moisture content may indicate that the samples were harvested at different maturity levels. The average value of measured thickness of the skin was 2 cm.

Table 1. Statistical characteristic of moisture content for skin sample from jackfruit portions

Parameter	N	Min.	Max.	Mean
Moisture content (%, w. b.)	870	5.47	49.38	16.74

3.2 Typical spectral curves for skin samples

The effective wavelength for spectral data collected from the skin surface was from 500 nm to 950 nm. Typical spectral curves representing different lateral portions (top, upper middle, middle, lower middle, bottom) of jackfruit samples are shown in Figure 2. From the figure, it can be observed that the absorption peaks occurred around 550 nm, 680 nm and 940 nm. The absorptions can be related to the presence of carotenoids (around 500 nm), anthocyanins (550-600 nm), chlorophyll (678 nm) and water at 940 nm (Van *et al.*, 2017). Thus, it can be concluded that the peak around 940 nm was due to the reaction of chemical characteristic and water in the skin portion.
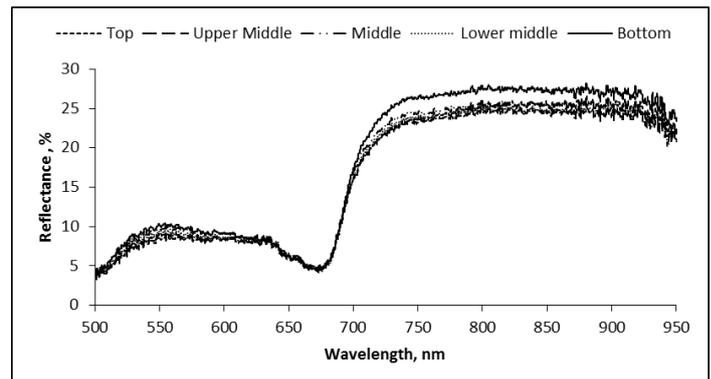

Figure 2. Reflectance spectral data for the top to bottom skin portion from 500 - 950 nm

For crop industry, the outer surface texture is an important characteristic to determine their maturity level. Fan *et al.* (2015) stated that some changes in the spectral curve represent hidden information of different components such as water, sucrose, fructose and glucose of fruit. Thus, the reflectance spectra of moisture content detected non-destructively from skin surface may be very useful to monitor crop maturity in a field.

3.3 Partial Lease Square model for moisture content and the spectral data

PLS method was used to build both calibration and prediction models to calibrate the spectral data in the range of 500–950 nm with the moisture content of jackfruit skin (Figure 3). Ten latent variables (LVs) were used in both models. The figures show that for the calibration model, the values of R^2 and RMSEC were 0.65 and 2.17, respectively. For the prediction model, the values of R^2 and RMSEP were 0.64 and 2.81, respectively. These findings indicated that the VSWNIR spectrometer is a promising technology to be used for monitoring the maturity of jackfruit. This preliminary study was unable to obtain higher R^2 values for both models probably because of the nature of the skin surface which was homogenous in terms of surface roughness and colour (Nawi *et al.*, 2014).
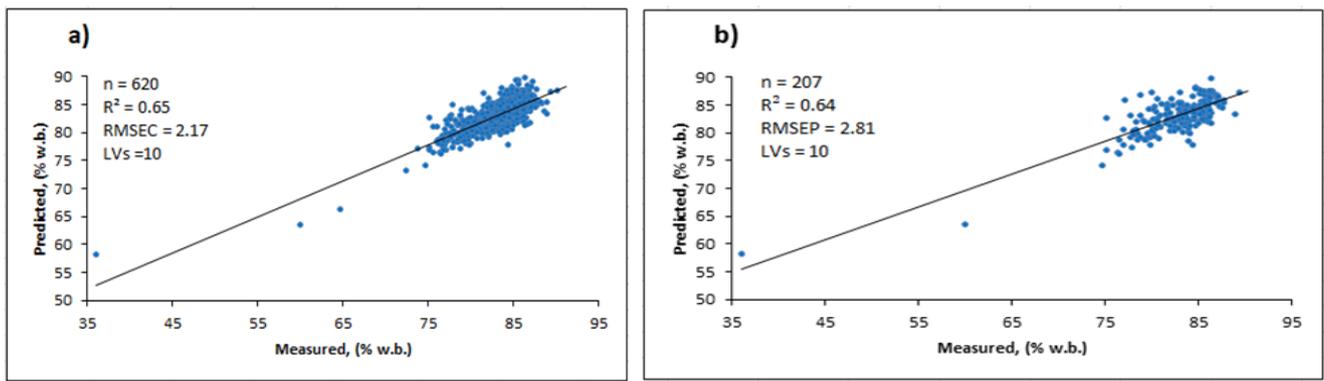
Figure 3. Scatter plots of measured vs predicted moisture content; (a) calibration model (b) prediction model

4. Conclusion

In conclusion, the VSWNIR spectroscopic technique has the potential to be used to predict moisture content from jackfruit skin. Owing to the nature of jackfruit skin which is rough and thorny, this preliminary study is considered successful and has gained an acceptable accuracy for predicting the moisture content of jackfruit with R^2 values for both calibration and prediction models were 0.65 and 0.64, respectively. The accuracy of the prediction could be increased if more jackfruit samples were used. Thus, it can be concluded that the VSWNIR spectrometer could be utilized for predicting maturity of jackfruit by scanning the moisture content from the skin surface.

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