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Research Article

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Measurement of starch and soluble solid content in papaya using near infrared spectroscopy

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ABSTRACT

Starch and soluble solid content in papaya are an important parameter for measuringthe maturity of fruit after harvesting. In this work, the application of near infrared (NIR) spectroscopy in measuring starch and soluble solid content in papaya wereevaluated. Samples of papaya were harvested at 135, 131, 128, 121 and 114 days after anthesis. NIRFlex N-500 (Büchi Labortechnik AG, Flawil, Switzerland)with spectra range of 1000–2400 nm was used as spectra acquisition of papaya in reflection mode. After randomly dividing 120 spectra into calibration set and 60 spectra independent prediction set, spectra in the calibration set were subjected to a partial least square (PLS) method with preprocessing of first derivative Savitzky-Golay 9 points (dg1) and multiplicative scatter correction (msc) to establish calibration model. Validation of calibration models on the independent prediction set indicates the prediction accuracy with coefficient of correlation (R), SEC (standard error of calibration), SEP (standard error of validation set) and coefficient of variance (CV)of 0.90, 0.17%, 0.04% and 10.95 for starch content; 0.90, 0.12% and 0.12%and 4.85% for soluble solid content, respectively.The results indicated that NIR spectroscopy could be used to predict the starch and soluble solid content of papaya rapidly and nondestructively.

Keywords: NIR spectroscopy, starch, soluble solid content, papaya, nondestructive

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INTRODUCTION

As considering to market destination, papaya fruits are generally harvested at condition of hard green mature. Classification of maturity level of papaya is important in order to classifymore reliable for those papaya fruits send to local market or long distance market.Operator determines maturity level of papaya based on the visual assessment such as skin colour and shape of the fruit. This method is sometimes not reliable and depend on the experience of the operator. Classification method based on the internal qualities parameter such as starch and soluble solid content of each single fruit is expected more accurately.

Maturity level of picking date of fruits is usually chosen on the basis of the climacteric trend, germination, the operator's experience, and fruit is monitored close to the presumed date, using ripening parameters, e.g. starch content, soluble solids content, fruit flesh firmness, acidity and skin color[1]. When destructive analysis techniques are adopted, it is not possible to monitor the physiological changes on the same samples over the entire ripening period. Hence, it is important to obtain a rapid, reliable and non-destructive analytical tool as an indicator of quality

and ripeness, that can allow a more realistic measurement of the ripening stage to be obtained and which will allow the sampling to be extended to a large quantity of fruit and the same sample to be monitored during ripening[2].

Extensive researchs have been carried out on the development of non-destructive sensors [3], which have even been used jointly to better capture variations in the quality and ripening of fruit. NIR spectroscopy has proved to be useful for the measurement of quality parameters of fruit and vegetables nondestructively, including properties such as starch content and dry matter [4], soluble solids content, acidity and firmness [5], and pH[6]. This objective of this work was to evaluate the use of NIR spectroscopy in measuringstarch and soluble solid content in papaya to find the possibility the use this method to classify the maturity level of papaya based on the internal quality parameter nondestructively.

EXPERIMENTAL SECTION

Sample and data collection

The 60 samples of new local variety of papaya of IPB-9which developed by Center for Tropical Horticulture Studies – Bogor Agricultural University, were harvested from university experimental farm. Papaya fruits were harvested at 135, 131, 128, 121 and 114 days after anthesis.The weight of individual fruit ranged from 880 – 1200 g.The fruits were delivered to laboratory, where NIR spectroscopy measurements were carried out and then sent for destructive measurementfor starch and soluble solid content. All measurements were carried out in triplicate. Spectra of papaya were collected from the sample of fruits in the range of 1000–2500 nm with an increment of 5 nm using NIRFlex N-500 (Büchi Labortechnik AG, Flawil, Switzerland) at room temperature of 25°C. Spectra data were collected by measuring the diffuse reflectance of each sample in triplicate. Data collection of NIR spectra were conducted by using NIRWare 1.2 software (Büchi Labortechnik AG, Flawil, Switzerland).

Chemometricanalysis

Chemometric analysis was conducted by using NIRCal 5.2 software (Büchi Labortechnik AG, Flawil, Switzerland).The data of starch and soluble solid content were randomly split into two groups, a calibration set and a validation set in a ratio of 2:1 (120 data for the calibration set and 60 data for the validation set). The partial least square (PLS) regression model method was used to establish the relationship between starch and soluble solid content and the spectra.The peformance of PLS regression model was evaluated using parameter of coefficient of correlation (R), SEC (standard error of calibration), SEP (standard error of validation) and coefficient of variance (CV) as presented in equation 1 to 4.

$$R = \frac{\sum(x_n - \bar{x}_n)(y_n - \bar{y}_n)}{\sqrt{\sum(x_n - \bar{x}_n)^2 \sum(y_n - \bar{y}_n)^2}} \quad \text{..... (1)}$$

$$SEC\ (\%) = \sqrt{\frac{1}{N-1}\sum(x_n - y_n)^2} \text{..... (2)}$$

$$SEP\ (\%) = \sqrt{\frac{1}{N-1}\sum(x_n - y_n - \frac{1}{n}\sum(x_n - y_n))^2} \text{..... (3)}$$

$$CV\ (\%) = a\frac{SEP}{\bar{x}}\ x\ 100 \text{..... (4)}$$

Where n was the number of samples; x_n was value of reference; y_n was value of NIR prediction.

Considering the influence of a preprocessing method to the predictive models depend on the characteristics of the spectra, 2 preprocessing methods, namely first derivative Savitzky-Golay 9 points (dg1) and multiplicative scatter correction (msc) were applied to the spectra data and their function were compared with the raw data.All the data analyses were carried out with the aid of NIRCal 5.2 software (Büchi Labortechnik AG, Flawil, Switzerland).

RESULTS AND DISCUSSION

Sample spectra

Fig. 1 shows the raw spectra of papaya at different maturity level. Spectra pattern of NIR reflectance indicated that wavelength of 1215-1395 nm was CH_2, 1450 nm and 1940 nm were water, 1765 nm was CH_2 and cellulose, 1450 nm, 2461 nm, 2488 nm and 2500 nmwerestarch [7].It is shown that starch and soluble solid content in papaya were

difference among maturity levels. This indicates that there is possibility to measurestarch and soluble solid content and applied this nondestructive method to classify the maturity level of papaya.

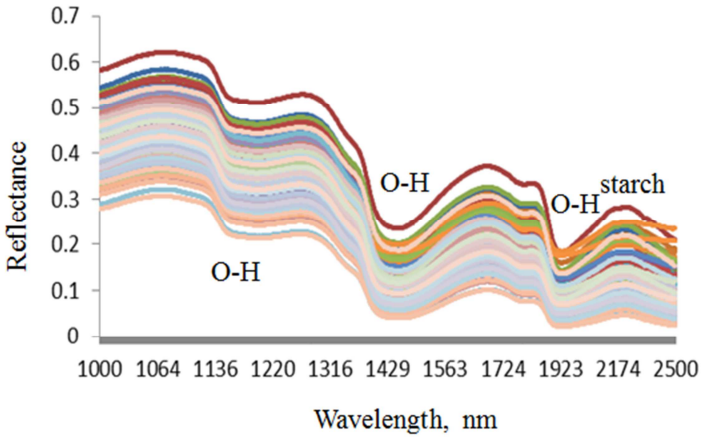

Fig. 1. Spectra of papaya at different maturity level

Sample set partition

The starch and soluble solid content of 180 samples were scatered from 0.3 to 5.31 mg/g dried weight and 3.47 to 8.9 °Brix, respectively. Table 1 showed the details of minimum, maximum, average and standard deviation for starch and soluble solid content and sample set partition for calibration and validation.

Table 1. Results of starch and soluble solid content and sample set partition

	n	Minimum	Maximum	Average	Standar Deviation
Starch (mg/g dried weight)					
Calibration	120	0.3	5.31	1.45	1.10
Validation	60	0.41	5.3	1.49	1.22
Soluble solid(°Brix)					
Calibration	120	3.47	8.9	5.47	1.47
Validation	60	3.6	8.7	5.27	1.45

Measuring model

The prediction models based on the raw and preprocessed spectra were established by PLS regression, respectively and the performance of models tested by independent validation set samples. The results were presented in Table 2. Fig.2 and 3 show distribution of data for calibration and validation for starch and soluble solid content inpapaya.For the model established fromspectra with preprocessing had best performance with 0.90 as the r value of validation of calibrationmodels for both starch and soluble solid content, respectively.

For prediction of starch content, it was reported that starch content in mango could be predicted well using NIR spectroscopy with R of 0.93[4], R^2 of 0.66 for starch content prediction in apple [8].In this work, using preprocessing of the combination of msc and dg1, the different between SEP and SECand CV were 0.01 and 10.95%. The similar result was found for apple[8]. The different SEP and SECof 0.13 and CV of 10.95% was found in mango [4]. It was consider that the number of sample has an effect on the accuracy of model. For soluble solid content, preprocessing of msc resulted R value of 0.9. Similar result of 0.91 was reported for apple [9]. The different of SEP and SEC and CV in this study were 0 and 4.85%. Similar result of 0.02 and 8% were reported for apple [8]. These findings showed thatthe combination of msc and dg1 was the optimized preprocessing method for starch content and msc for soluble solid content measurement in papaya using NIR spectroscopy.

Table 2. Results of PLS models for starch and soluble solid content

Content	Preprocessing method	R	SEC (%)	SEP (%)	CV (%)
Starch	No preprocessing	0.70	0.28	0.28	18.44
	msc, dg1	0.90	0.17	0.16	10.95
Soluble solid	No preprocessing	0.89	0.13	0.14	5.62
	msc	0.90	0.12	0.12	4.85

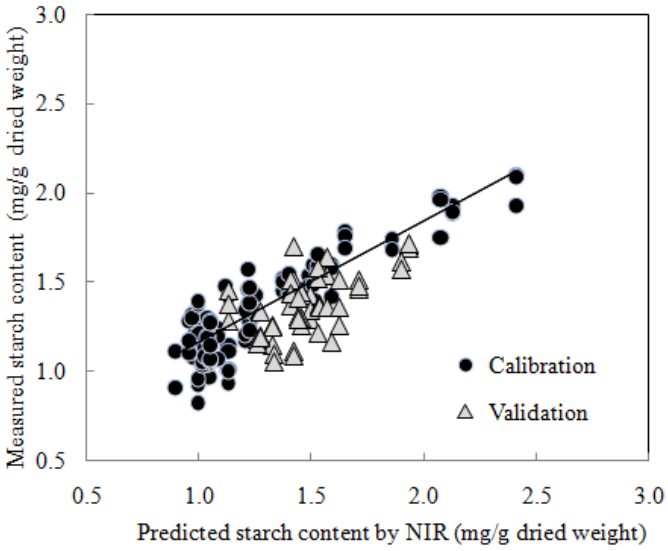

Fig.2.Distribution data of calibration and validation for starch content in papaya

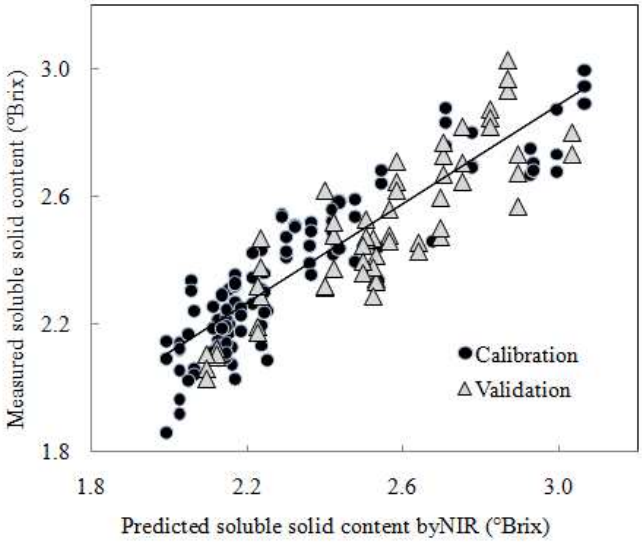

Fig.3.Distribution data of calibration and validation for soluble solid content in papaya

CONCLUSION

In this work, the PLS regression method was applied in the measurement of starch and soluble solid content in papaya using NIR spectroscopy and the effect of preprocessing methods to the model were compared. The results presented the feasibility of NIR spectrossopy in predicting the starch and soluble solid content in papaya. Validation of calibration models on the independent prediction set indicates the prediction accuracy with R, SEC, SEP and CV of 0.90, 0.17 %,0.16% and 10.95% for starch content; 0.90, 0.12%, 0.12% and 4.85% for soluble solid content, respectively. These results indicated that NIR spectroscopy can work as a nondestructive and rapid means for measuring starch and soluble solid content in papaya.

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