FE006

Precision Test for Spectral Characteristic of On-line Vis-NIR versus At-line NIR Spectroscopy for Measuring Total Soluble Solids of Mango (*Mangifera indica* CV Nam Doc Mai)

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Abstract

Near Infrared (NIR) Spectroscopy is known as a rapid technique to evaluate the quality traits of fruits and vegetables. Precision and accuracy of the instrument is an important aspect in order to obtain results with minimum error. The main objective of this paper is to determine scanning repeatability and reproducibility of UV-VIS–NIR spectrometer (on-line) and NIR spectrometer (at-line) for measuring total soluble solids of Mango (*Mangifera indica* CV Nam Doc Mai) and its corresponding reference method using digital refractometer. Results shows that the repeatability and reproducibility of on-line scanning spectrometer is 0.01071 and 0.023393, similarly for at-line scanning spectrometer with 0.000775 and 0.008262 respectively. Maximum co-efficient of determination R^2_{MAX} of reference method is 0.967. This result could be beneficial for the development of model using on-line or at-line spectrometer.

Keywords: Precision test, Spectral characteristic, On-line, At-line, Total Soluble Solids, Mango.

1. Introduction

Mango (*Mangifera indica*) is one of the favorite fruit worldwide. It has several variety with different specifications, one of the common variety is Nam Doc Mai. This variety of mango is consumed widely and is most preferable because of its good taste and appearance. During the ripening process, the mango fruit becomes softer and there are several physiochemical changes that undergoes during different stages. There is an increase in the soluble sugars content known as total soluble solids, TSS as the ripening stage of mango increases. Total soluble solids is one of the parameters for quality assessment in mango fruit (Schmilovitch et al., 2000).

In order to evaluate the quality traits of Mango fruit Near Infrared (NIR) spectroscopy is known as a rapid and accurate technique. Many researches related to the methods for implementation of NIR spectroscopy has been successfully published and some are ongoing. There are several advantage of NIR spectroscopy compared to some traditional chemical methods like fast speed, accuracy, minimal sample preparation, no use of chemical, fast processing and result etc. Despite of these advantages, limited work has been able to publish in the field of on-line monitoring by NIR spectroscopy in industrial plant (Salguero-Chaparro et al., 2012).

Same variety of mango may have different shape, size, color, taste etc even when they are harvested at the same time. It is now important for the cultivars to know the difference among the same variety of fruits and sort them on the basis of their quality. Conventional methods for the determination of quality parameters are very time consuming and labor intensive (Huang et al., 2008). Many research has shown the robustness of the model in laboratory condition (off-line/ at-line) but online monitoring condition for quality analysis is more desirable nowadays. Despite these studies, the acquisition of spectral data from a moving sample (for instance, during an on-line process, on a conveyor belt or through a pipe), is quite complex (Andersson et al., 2005). The on-line acquisition of a spectrum from a moving sample is dependent on many different parameters such as physical nature of the material (particle size, shape, orientation and density) as well as the type and the composition of the material (Fernandez-Ahumada, 2008).

In order to develop a robust model based on online and at-line scanning the precision test of the instrument as well as the referencing laboratory is most important.

Repeatability and reproducibility are the parameters that describe the precision of scanning. The main aim of this paper is to test for scanning repeatability and reproducibility as well as reference method repeatability.

2. Materials and Methods

2.1 Sample Preparation.

For the experiment Mango cv. Nam doc mai sample were brought from Chachangsao province on June 3, 2017. From the samples 3 mango are selected for precison test in NIRS Research Centre of Agriculture Product and Food (www.nirsresearch.com), Department of Agricultural Engineering, Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang, Thailand.

2.2 At-line Scanning.

Samples were scanned by using NIR Multi-Purpose Analyzer (MPA) Spectrometer (Bruker optics, Germany) with scanning resolution of 16cm^{-1}in absorbance mode and there were 32 scans for 1 average spectrum of the sample. Before sample scanning the gold plate was scanned as a background. Wavenumber was from 12,500-4,000 nm.

2.3 On-line Scanning.

On-line scanning was done by UV-Vis-NIR Spectrometer, AvaSpec-2048 - USB2 standard fiber optic spectrometer, wavelength from 200-1160 nm with integration time of 7 ms and focal length of 2.5mm approximately depend on the fruit size. For on-line scanning, sample was placed in a conveyor belt inside a black box in which the Avaspec fibre optic was mounted from the top.

2.4 Repeatability and reproducibility of scanning test.

For repeatability test each samples were loaded and scanned 10 times in same position for both at-line and on-line process. Similarly for reproducibility samples were reloaded and rescanned for 9 times.

2.5 Reference method.

After scanning samples were brought for reference laboratory. Samples were cut into halves and total soluble solids of the sample was measured using Digital Hand-held "Pocket" Refractometer PAL-1 S/No L218454, Atago Japan.

2.6 Repeatability for reference method.

Repeatability of reference method can be defined as the standard deviation of difference between the repeat measurements. In this experiment, one slice of Mango is divided into three parts to measure total soluble solids and each part has three repeat measurements.

3. Result and Discussion

To obtain scanning repeatability and reproducibility for at-line scanning three wavelengths were selected. Wavenumber 10306 cm^{-1} (970nm) i.e band of water, 6943 cm^{-1} (1440 nm) i.e band of sucrose and 6326 cm^{-1} (1580 nm) band of starch were selected (Figure 1). Standard deviation of the absorbance value at the selected wavelength gives the repeatability and reproducibility of NIR instrument on sample. For measurement of repeatability and reproducibility for on-line scanning wavelength selected are 760 nm i.e band of water, 680 nm i.e band of chlorophyll, 913 nm i.e band of sucrose (Figure. 2).

Table 1 Repeatability and reproducibility by on-line and at-line scanning.

Scanning	Repeatability	Reproducibility
On-line	0.01071	0.023393
At-line	0.000775	0.008262

From table 1 we can observe that the repeatability and reproducibility of at-line scanning is low, 0.000775 and 0.008262. Repeatability gives the variation between the measurements of different sample by using same device under same operating condition. Reproducibility gives the dispersion of result under different condition. In this experiment reproducibility is calculated by varying the orientation of Mango during scanning. Low repeatability value means low variation between the measurements that indicate highly repeatable and precise scanning instrument. More robust model can be expected form at-line scanning instrument.

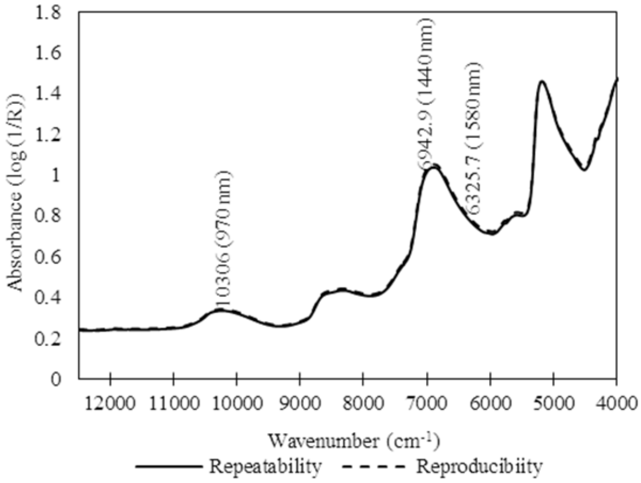

Figure.1 Average Spectra from At-line Scanning.

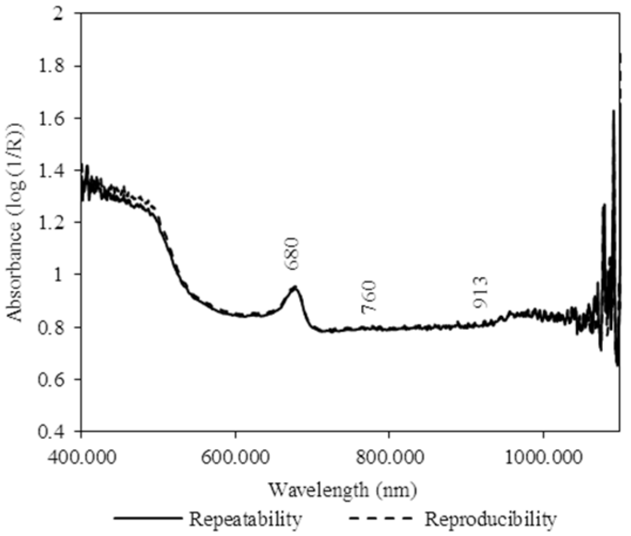

Figure2 Average Spectra from On-line Scanning.

However, there are many source of error that can occur in on-line scanning process. The surface roughness of the sample, the average distance from the sample to the optics are parameters that can also significantly influence the quality, repeatability and reproducibility of the spectra generated (Berntsson et al., 2001). In order to obtain robust models for NIR spectroscopy applications with an acceptable level of accuracy and precision, it is essential to set up the optimal operational conditions to assess the adequate online measurement (Salguero-Chaparro et al., 2012).

According to Dardenne (2010) for reference laboratory, the maximum coefficient of determination, R^2_{Max} is calculated using formula:

$$R^2_{Max} = \frac{SD_y^2 - REP^2}{SD_y^2} \qquad (1)$$

Where, SD_y is the standard deviation of the measured value of total soluble solids and REP is the repeatability of the reference data. Repeatability of regerence data is calculated (0.1403). R^2_{Max} was obtained to be 0.967 that means it is possible to develop NIR model using total soluble solids reference method. R^2_{Max} is possible only when there is no error in the spectra or model (Dardenne, 2010). It depends on the range and precision of reference data. The error from reference method was 3.3%.

4. Conclusions

From this experiment, we observed that on-line and at-line scanning instrument can be used to make a model. Compared to on-line scanning, at-line scanning gave more precise and accurate result. Precision analysis for reference laboratory indicates that good model can be developed using total soluble solids of Mango.

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