Portable near-infrared (NIR) spectrophotometers for the measurement of sucrose content in cane in the field

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Abstract In this study, the ability of two portable near-infrared (NIR) spectrophotometers to determine the sucrose content of sugarcane in the field was assessed. 400 sugarcane stalks were used to calibrate spectra from the portable ‘carry-bag’ and ‘gun-type’ NIR spectrophotometers against results from the traditional method of measurement using high-performance liquid chromatography (HPLC). The NIR spectra were analyzed using a partial least-squares regression (PLS) analysis to enable development of calibration models for each NIR instrument based on the HPLC analysis data. Correlation coefficient (r) values of 0.88 and 0.72 were obtained for the ‘carry-bag’ and ‘gun-type’ models, respectively. The standard error of calibration (SEC) values were 1.90 and 2.72%, respectively. There was no significant difference between the actual and NIR-predicted value by paired t-tests at 95% confidence interval. The portable NIR instruments offer a simple and convenient method for measuring sucrose content of sugarcane in the field.

Key words Portable, near infrared, non-destructive, sugarcane, sucrose

INTRODUCTION

Pre-harvest cane quality is normally determined by measuring Brix with a hand refractometer. The Brix value indicates the percentage of total sugar, but it does not specifically measure sucrose. It, therefore, has a low accuracy for assessing maturity and harvesting dates. Growers and millers need to know the sucrose content of sugarcane to identify high quality cane for timely harvest management. Moreover, sucrose content in cane stalks is difficult to measure in the laboratory by high-performance liquid chromatography (HPLC) (Abeydeera 1983). In particular, this instrumentation is expensive and analysis is time-consuming. Near-infrared (NIR) technology is being used to analyze quantities and qualities of products in different industries, such as rubber, polymers, paper, cosmetics, chemicals, petrochemicals and pharmaceuticals (Stuart 2004). It also saves time, reduces long-term production costs and decreases the use of chemicals that are potentially hazardous to the user and possible pollutants of the environment.

In the sugar industry, NIR is already being used to measure cane quality in different countries including Australia, South Africa and Mauritius. There are calibrations for Pol, Brix, fiber, moisture and ash (Nawi et al. 2012). Portable NIR instruments are available commercially and have been used to measure sugar content in agricultural products such as apples, mangoes, and other fruits (Temma et al. 2002; Saranwong et al. 2003; Shenk et al. 2008; Lin and Ying 2009). Portable NIR units are quick, simple and convenient for measuring sucrose content in sugarcane. This methodology requires no sample preparation or reagents, and it is a direct and non-destructive approach (Taira et al. 2013).

Since 2014, Mitr Phol Innovation Research Center together with Kasetsart University and King Mongkut’s University of Technology, Thonburi, have been studying and developing prototypes of a low-cost portable NIR instruments for measuring the sucrose content of sugarcane in the field. This study reports on the first stage of development of a portable NIR system and calibration models.
MATERIALS AND METHODS

Development of a portable NIR system

We assessed two portable NIR instrument models - a ‘carry-bag’ and a ‘gun-type’ spectrophotometer (Fig. 1) that have the capability to measure the transmittance spectrum of cane stalk samples in the 600-1100 nm and 800-1200 nm ranges, respectively.

Fig. 1. Portable NIR spectrophotometers assessed in the study included the (left) bag portable NIR and (right) gun portable NIR.

Sample analysis

We selected 400 cane stalks from fields in the Mitr Phol Phukieo sugar factory area in Thailand during the 2014/2015 harvest season. The NIR spectrum of each of these cane stalks was then measured using both instruments (Fig. 2) to enable comparison of the calibration models. Juice was then extracted from each stalk using a press machine. Sucrose in juice was measured immediately using a high-performance liquid chromatography (HPLC).

Fig. 2. Measuring sugarcane stalks with the (left) bag portable NIR and (right) gun portable NIR instruments.

Data analysis

The NIR spectra were statistically analysed using a partial least-squares regression (PLS) method to enable development of calibration model for each NIR instrument based on the HPLC analysis data.
RESULTS AND DISCUSSION

The actual sucrose (HPLC) and predicted sucrose contents using the bag and gun portable NIR instruments for the 400 sugarcane stalk samples are shown in Figures 3a,b. Correlation coefficient (r) values were 0.88 and 0.72 and the standard error of calibration (SEC) values were 1.90 and 2.72% (Table 1). There was no significant difference between the actual and NIR predicted value by paired t-test at 95% confidence interval. Hence, the predictions from the portable NIR are useful for measuring sucrose content of sugarcane in the field.

Table 1. Results for sucrose content of cane stalk samples measured with the two portable NIR instruments.

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Number of samples</th>
<th>Percent sucrose actual</th>
<th>Calibration models</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>SD</td>
<td>Min</td>
</tr>
<tr>
<td>Bag portable NIR</td>
<td>400</td>
<td>4.08</td>
<td>3.08</td>
</tr>
<tr>
<td>Gun portable NIR</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CONCLUSIONS

Our study shows that portable NIR spectrophotometers provide a simple and convenient means of measuring the sucrose content of sugarcane in the field. However, further studies are needed in order to improve calibration accuracy, and to measure indicators of cane quality such as Brix, Pol, fiber, purity, reducing sugar and commercial cane sugar (CCS).

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REFERENCES


Des spectrophotomètres portables proche-infrarouge (NIR) pour mesurer la teneur en saccharose de la canne à sucre au champ

Résumé. Dans cette étude, a été étudiée l'aptitude de deux spectrophotomètres proche-infrarouge (NIR) portables à évaluer la teneur en saccharose de la canne à sucre au champ. 400 tiges de canne à sucre ont été utilisées pour calibrer les spectres des modèles de spectrophotomètres NIR «carry-bag» et «gun-type» en comparaison de la méthode traditionnelle de mesure en chromatographie liquide haute performance (HPLC). Les spectres NIR ont été interprétés en utilisant l’analyse de régression des moindres carrés partiels (PLS) pour permettre le calibrage des modèles pour chaque instrument NIR en référence aux données d'analyse HPLC. Des valeurs du coefficient de corrélation (r) de 0.88 et 0.72 ont été respectivement obtenus pour les modèles de spectromètre ‘portable en sac à dos’ et de ‘type-pistolet’. Les erreurs type (SEC) des valeurs de calibration étaient respectivement de 1,90 et 2,72%. Il n’y avait pas de différence significative entre la valeur réelle et prédite du NIR, tests-t des échantillons appariés, à l'intervalle de confiance 95%. Les instruments NIR portables offrent une méthode simple et pratique de mesure de la teneur en saccharose de la canne à sucre au champ.

Mots-clés: Portable, proche infrarouge, non destructif, canne à sucre, saccharose

Uso de espectrofotómetros del Infrarrojo Cercano (NIR) para medir contenido de sacarosa en caña, en el campo

Resumen. En este estudio, se evalúa la habilidad de dos espectrofotómetros NIR para determinar el contenido de sacarosa en caña de azúcar, haciendo las mediciones en campo. Se utilizaron datos obtenidos de 400 tallos de caña para calibrar los espectros de un espectrofotómetro portátil "tipo cartera" y uno "tipo pistola" y se compararon con resultados obtenidos con un cromatografo liquido de alta presión (HPLC). Los espectros NIR obtenidos fueron analizados usando un análisis de regresión de cuadrados mínimos parciales (CMP) para poder desarrollar modelos de calibración para cada instrumento NIR basados en el análisis de datos del HPLC. Se obtuvieron valores de 0.88 y 0.72 de coeficiente de correlación (r) para los modelos "tipo cartera" y "tipo pistola" respectivamente. Los valores para error estándar de la calibración (EEC) fueron 1.90 y 2.72% respectivamente. No se determinó diferencia significativa entre el valor exacto y el valor obtenido con el NIR después de hacer un test t al 95% de confianza. Los equipos NIR portátiles ofrecen un método simple y conveniente para medir el contenido de sacarosa en el campo.

Palabras clave: Portátil, infrarrojo cercano, no destructivo, caña de azúcar, sacarosa