Study on application of near infrared (nir) spectroscopy for sugar cane juice analysis to replace conventional analysis methods

R Kuswurjanto¹ and Triantarti²

¹Indonesian Sugarcane Research Institute  
²Pusat Penelitian Perkebunan Gula Indonesia (P3GI)

E-mail: risvanp3gi@gmail.com

Abstract. Near infrared (NIR) spectroscopy appears as a promises method for faster analysis method in replacement of conventional analysis method. In this work, NIR was used as a replacement for conventional analysis method in sugarcane juice analysis. The cane juice samples for this study were taken from the hydraulic press juice in the core sampler system at Glenmore Sugar Factory. NIR spectroscopy equipment used was FOSS DS 2500. The partial least square regression (PLS) was used to develop calibration model. The NIR results were evaluated from correlation coefficient ($r^2$), low standard error of calibration (SEC) and high ratio of prediction to deviation (RPD). The experimental results show that for %brix analysis: $r^2 = 0.988$, SEP = 0.333, RPD = 5.441 and for %pol analysis: $r^2 = 0.986$, SEP = 0.283, and RPD = 6.125. The results have shown a good potential of NIR Spectroscopy for cane juice quality analysis as replacement of conventional analysis methods.

1. Introduction

The cane payment system for Indonesian sugar industry is based on the cane quality determination. The cane juice sample is collected from the first mill using a system which is equipped with sensor. The method for determining juice quality was using a conventional analysis method. In the recent years some of sugar factories are applied a core sampler system for cane payment. The conventional analysis method is slow and labour intensive. For high milling capacity (more than 3000 TCD), the speed of conventional analysis method is unable to analyse all samples taken from each truck. Therefore it is necessary to establish faster and reliable methods that can analyse all samples.

Near infrared spectroscopy (NIR) technology is the best solution to replace conventional analysis method. NIR applications have been evaluated for use in the sugar industry for different purposes. In plant breeding trials, NIR spectroscopic techniques were developed for quality determination of fiber in shredded cane [1, 2, 3, 4]. Online NIR systems for analysis of cane, bagasse and sugar in sugar factories have also been reported [5, 6, 7].

NIR also use as a substitute method for cane payment analysis in several countries. [8] reported the use of NIR for cane quality incentive scheme. The NIR spectroscopy was used to estimate of fibre and ash levels in cane on an individual consignment basis. NIR for direct analysis of sugarcane have been developed in Louisiana mill during milling season 2001/2002. NIR was look promising to replace the conventional method. The NIR systems are fast and can analyse large number of samples within a short
time [9]. Another country such as Australia [10], Japan [11], Kenya [12], and South Africa [13] also use NIR for direct analysis of cane for cane payment purposes. [14] reported that NIR had a promising result to analyse the first expressed juice in Ngadiredjo Sugar Factory. The objective of this study is to evaluate the performance of NIR spectroscopy for cane juice analysis (% brix and % pol) at Glenmore Sugar Factory for replacement a conventional analysis method which using purity analyser saccharomat equipment for pol analysis.

2. Methodology

2.1. Sample Preparation

Data acquisition reported for calibration began in September, 2017 and ended in October 2018. The data was collected from the core sampler system in Glenmore Sugar Factory, Figure 1. The cane sample collected from randomly selected truck by the core sampler. The cane sample from truck was shredded then extracted using hydraulic press. The juice from hydraulic press was separated for NIR analysis and conventional analysis method.

![Figure 1. Cane juice sampler from core sampler system.](image)

2.2. Conventional Analysis Method

Conventional analysis method for brix and pol referred to the ICUMSA method [15]. The brix values were obtained using refractometer method with a precision of 0.1 °brix. About 200 mL of juice samples were placed in a conical flask and 5 ml of clarifying agent was added. The contents in the flask were shaken and filtered. After rejecting the first few drops, the filtrate was carefully transferred to a 200 dm Pol tube without introducing any air bubbles. The Pol reading was taken using sacharomat/polarimeter. %pol calculation is based on polarimeter reading using following formula:

\[
pol = \frac{0.286 \times \text{pol reading}}{\text{density}}
\]  

(1)

The instrument for conventional analysis method was Schmidt Haensch Purity Analyser (PA) (figure 2).
2.3. *NIR Spectroscopy Analysis*

Samples were scanned in reflectance mode (850 – 2500 nm) using NIR FOSS DS 2500 type. Juice samples were scanned in a sample cup kit part number 60013315 with gold reflector. WinIsi version 4.10.0.15326 software was used for data processing and statistical analysis. Reflectance data were stored as log 1/R at 2 nm intervals. The mathematical treatment applied to the spectra was (1,4,4,1). The first number was the order of derivative; the second number was the gap in data points over which the derivative is calculated; the third number is the number of data points used in the first smoothing and the fourth number refers to the number of data points over which the second smoothing was applied. Model equations were developed using modified partial least square (MPLS) regression with internal cross validation and scatter correction using Standard Normal Variate (SNV) and de trend transformation [16].

The statistics used to select the best equations were: standard error of calibration (SEC), coefficient of determination of calibration ($R^2$), standard error of cross-validation (SECV), coefficient of determination for cross-validation ($r^2$) and RPD or ratio of the standard deviation of the original data (SD) to SECV [17]. The evaluation of the best method for NIR calibrations is by comparing the statistical analysis between two instrument.

3. Result and Discussion

Individual sugar recovery calculation was based on analysis of sugarcane quality. The parameters used in the analysis were the brix and pol content of cane juice. In the core sampler system, the cane juice was extracted from hydraulic press. A sugar factory with 6000 ton cane per day capacity, with hundreds of samples, the use of conventional methods for analyzing sugarcane quality is prone to human error. For this reason, the NIR instrument can be used as a secondary method.

The statistical characteristic of the cane juice samples, calibration and prediction are shown in Table 1. It was found that the range and mean values of brix and pol were almost identical in calibration and prediction data set. The data was collected during the milling season, the brix and pol values would be considered to represent the cane quality along the milling season.

| Parameter | Data Set | min  | max  | mean | standard deviation |
|-----------|----------|------|------|------|--------------------|
| brix      | calibration | 7,27 | 18,69| 13,25| 2,08               |
|           | prediction | 10,18| 18,62| 14,25| 2,04               |
| pol       | calibration | 5,14 | 14,80| 9,75 | 1,92               |
|           | prediction | 6,70 | 15,97| 10,58| 2,15               |

The calibration model was developed using the brix and pol value from 215 samples. The samples used for calibration were also used as test cases to assess the validity of the technique by the cross-
validation method, which is done by leaving out one sample at a time. The optimum number of PLS factors used in the model was eight and nine. Another set of samples were used for validation purposes. The calibration statistics are listed in table 2.

Table 2. PLS model performances of cane juice samples for both instrument.

| Parameter | Calibration Set | Prediction Set |
|-----------|-----------------|----------------|
|           | N | PLS Factor | R² | SEC | SECV | N | r² | SEP | RPD |
| brix, %   | 215 | 8 | 0.980 | 0.276 | 0.363 | 102 | 0.988 | 0.333 | 5.441 |
| pol, %    | 215 | 8 | 0.990 | 0.228 | 0.284 | 102 | 0.986 | 0.283 | 6.125 |

N = number of samples  
SEC = standard error calibration  
SECV = standard error cross validation  
SEP = standard error prediction  
RPD = ratio of prediction to deviation

The performances of calibration and prediction models were evaluated using R², SEC, SECV, SEP and RPD. Table 2 shows that both of calibration and prediction models were good with R² values being 0.980 and 0.990, respectively. The performance of the prediction set are presented by the scatter plots in figure 3 and 4, respectively. The performances of the model were evaluate using 102 independent samples in prediction set. It shows that the r² were good for both brix and pol parameters. The result of NIR prediction is consistent with the study from previous reported by [18] and [19].

Figure 3. Actual vs NIR predicted values for brix of sugarcane juice.
4. Conclusion
The result obtained in this study shows the potential use of NIRS for determining %brix and %pol of sugarcane juice quality. NIRS have a promising result to replace conventional analysis methods.

5. References
[1] Berding N, Brotherton G A, LeBrocq D G and Skinner J C 1989 Application of near infrared reflectance (NIR) spectroscopy to the analysis of sugarcane in clonal evaluation trial Proc. of the Australian Society of Sugar Cane Technologists 8-15
[2] Brotherton G A and Berding N 1989 At line analysis of mill prepared cane using near infra-red spectroscopy Proc. of the Australian Society of Sugar Cane Technologists (20) 34-42.
[3] Sanseechan P, Panduangnate L, Saenhprachat anarug K, Wongpicheek and Posom, J 2018 A portable near infrared spectrometer as non-destructive tool for rapid screening of solid density stalk in a sugarcane breeding program. Sensing and Bio Sensing Research (20) 34-40.
[4] Phuphaphud A, Saengprachatanarug K, Posom J, Maraphum K and Taira E 2019 Prediction of the fibre content of sugarcane stalk by direct scanning using visible-shortwave near infrared spectroscopy Vibrational Spectroscopy (101) 71-80.
[5] Staunton S P, Lethbridge P J, Grimley S C, Streamer R W, Rogers J and Mackintosh D.L. 1999 On line cane analysis by near infra-red spectroscopy Proc. of the Australian Society of Sugar Cane Technologists (21) 20–27.
[6] Bevin C, Staunton S, Stobie R, Kingston J and Lonergan G 2002 On-line use of near infrared spectroscopy in a sugar analysis system (SAS) Proc. of the Australian Society of Sugar Cane Technologists (24) 404-410.
[7] Staunton S P and Wardrop K 2006 Development of an online bagasse analysis system using NIR spectroscopy Proc. of the Australian Society of Sugar Cane Technologists (28) 446–453.
[8] Pope G, McDowall R, Massey W and Staunton S 2004 The Use of nir spectroscopy in a cane quality incentive scheme Proc. Australia Society of Sugarcane Technologist (26): 8 pp
[9] Madsen L, White B and Rein P 2003 Evaluation of a near infrared spectrometer for the direct analysis of sugar cane JASSCT. (23) 80-92
[10] Pollock J S, O’Hara I.M and Griffin K.G. 2007 Aligning the drivers in the value chain – a new cane payment system for Mackay Sugar Proc. of the Australian Society of Sugar Cane Technologists (29) 1–8.
[11] Taira E, Ueno M, Furukawa N, TasakiA, KomakiY, Nagaic J and Saengprachatanarug K 2013 Networking system employing near infrared spectroscopy for sugarcane payment in Japan Journal Near Infrared Spectrosc. (21) 477–483
[12] Ochola P, Apunda E O and Yewa E.O 2015 Evaluation of near infrared spectroscopy for sugarcane quality determination in western kenya Chemistry and Materials Research Vol.7 (9): 30-36
[13] Schaffler K J, Loubser L C and Bamber T 2003 On-Line analysis of quality parameters in consignments of shredded cane by near infrared spectroscopy (Nir) Proc. South Africa Sugar Technology Association (77) 51-62
[14] Kuswurjanto R and Triantarti 2015 Analisis rendemen individu menggunakan near infrared spectroscopy (NIRS) untuk mendukung peningkatan produksi gula Proc. Seminar Nasional Swasembada Pangan Politeknik Negeri Lampung 7 pp.
[15] ICUMSA Method GS 7-31 2013 The determination of pol by nir polarimetry and brix for sugarcane and factory product.
[16] Shenk J S and Westerhaus M O 1993 Analysis of agriculture and food products by near infrared reflectance spectroscopy Infrasoft International ISI.
[17] Rinnan A, Berg FVD and Engelsen SB 2009 Review of the most common pre-processing techniques for near infrared spectra Trends in Analytical Chemistry (28)1201-1222.
[18] Nawi M N, Chen G and Jensen T 2014 Prediction of sugarcane quality from juice sampling using portable spectroscopy JMES. 7 :1219 – 1226.
[19] Berding N, Brotherton GA, le Brocq DG and Skinner JC 1991 Near infrared reflectance spectroscopy for analysis of sugarcane from clonal evaluation trials: II Expressed Juice Crop Sciences 31 1024-8.

Acknowledgments
The authors would like to thanks to the staff of Indonesian Sugar Research Institute for providing the equipment and analysis. The authors would also like to thanks to the support from Glenmore sugar factory for providing the data of LAB analysis.