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APPLICATION of NEAR INFRARED SPECTROSCOPY TO DETERMINE SUGARCANE QUALITY in CORE SAMPLER SYSTEM

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Abstract. Sugarcane quality was evaluated using Near Infrared (NIR) spectroscopy in two sugar factory for payment system. The samples were collected from core sampler system. The parameter of cane quality analysis were brix in cane (BIC), pol in cane (PIC) and fibre in cane (FIC). The target of this study was to develop and improve model calibration of NIR for cane quality. NIR reflectance spectra ranging from 900 – 1700 nm were collected to evaluate the sugarcane quality of shredded cane. The conventional method to determine cane quality was using Wet Disintegrator method. SX-plus software from Buchi was used as data treatment and model development. The NIR results was evaluate from high correlation coefficient (R^2), standard error calibration (SEC) and high ratio of prediction to deviation (RPD). The accuracies of NIR analysis for PIC were satisfactory with coefficient of correlation (R^2) above 0,90 both for calibration and prediction, SEC 0,528 – 0,630 and higher RPD than other parameters . The accuracies of BIC and fibre remained at unsatisfactory level with coefficient of correlation (R^2) below 0,90. The NIR instrument could be use to determine pol in cane for cane payment system purposes.

Keywords: Near Infrared spectroscopy, NIR, cane quality, pol in cane, cane payment system

1. INTRODUCTION

In Indonesia, the cane payment system is majorly considered according to cane quality (pol in cane). The sugarcane was delivered by using truck or other transportation system. The cane quality was determined individually for each truck. The new core sampler system was applied to gain cane samples. Instead of conventional method, several sugar factory was using near infrared (NIR) spectroscopy for cane quality measurement. The benefit of NIR technology was from the speed of analysis and no need chemical for analysis. The NIR was secondary method, so it must be calibrated and validated before use as cane quality determination.

The NIR technology was a method for measuring the quality in food and any materials such as maturity of mango [1], meat processing [2] and feed analysis [3]. There are several studies that have reported about cane quality determination using NIR [4,5,6]. The study were determined cane parameter using VIS/SWNIR spectroradiometer or another NIR instrument. The ability of spectroscopy method coupled with a regression program to determine several cane quality components

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by a single scanning has given this instrument in saving time and cost. Recent study by Taira [7,8,9] developed the nondestructive method for the measurement of sugar quality in shredded cane. Taira study was to developed NIR calibration equation for cane payment purposes in Japan. The Use of NIR technologies has led to a significant decrease in the costs associated with cane quality [10].

NIR for cane payment purpose has been developed in Indonesia since 2013. Several sugar factory have applied NIR to determine cane juice quality. Meanwhile, the use of NIR for shredded cane was started in East Java since 2018. Another country such as Japan [11], Kenya [12], Australia [13], and South Africa [14] also use NIR for direct analysis of cane for cane payment purposes. The main parameter for cane quality was pol in cane value. The conventional method for pol in cane determination was a complex procedure included chemical and sequence analysis. By using NIR as secondary method the determination of pol in cane value can be reduced. This work aims to find the best calibration and validation of shredded cane using NIR. The NIR spectra were obtained from the shredded cane from core sampler system.

2. MATERIAL and METHOD

Sample preparation

Data acquisition reported for calibration began from May to October 2018 in Pesantren Baru and Gempolkrep Sugar Factory (SF) . The data was collected from the core sampler system, Figure 1. The cane sample collected from randomly selected truck by the core sampler. The cane sample from truck was shredded then separated for NIR scanning and wet analysis. The weight of cane for each sampling were 5 kg.

Figure 1. Core Sampler System and Shredded Cane Sample

Chemical Analysis

Sugarcane quality analysis consists of three parameters, ie pol in cane (PIC), brix in cane (BIC) and fibre in cane (FIC). The analysis was performed in the laboratory service using Wet Disintegrator (WD) methods [15]. WD method using JEFFCO WET DISINTEGRATOR and bagasse dryer. Other supporting equipment were top a loading balance, Saccharomat Schmidt Haensch NIR W2 model for polarization readings and ABBE Refractometer NAR-1T Liquid for brix reading.

Procedure Analysis:

Weight 1000 gr (± 0.1 gr) of shredded cane, and then insert the sample into Wet Disintegrator. Add 2000 gr of water, closed wet disintegrator then run for 20 minutes. After the wet disintegrator had stopped, take the juice extract by filtering it using a rough filter. Homogenize the extract and then take

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as much as 300 ml to analyze its brix and pol contents. For moisture content analysis, weight the empty container and record the mass to the nearest 0.1 g, m_0. Add approximately 100 g (± 0.1 gr) of shredded cane to the empty container, m_1. Place the container plus shredded cane in the drying tool and dry at 110±3^{0}C for 2 hours. Weight the container plus dried shredded cane sample and record the mass to the nearest 0.1 g, m_2. The calculation as follows:

$$moisture\%cane = 100\ \frac{m1-m2}{m1-m0} \qquad (1)$$

$$pol\ in\ cane = p\ \frac{\phi+w}{\theta-b} \qquad (2)$$

Where
p = pol in cane extract from wet disintegrator
b = ^{0}brix of extract from wet disintegrator

$$\phi = 100\ \frac{\frac{x+y}{x} - \left[1+\frac{z}{100}\right]}{\left[1+\frac{z}{100}\right]} \qquad (3)$$

$$\theta = \frac{100}{1+\frac{z}{100}} \qquad (4)$$

Where
x = mass of cane
y = mass of water added
z = %brix free water (25% generally is used)
w = moisture in cane

$$fibre\%cane = 100\frac{100-w-b\left(\frac{x+y}{x}\right)}{100-b\left(1+\frac{z}{100}\right)} \qquad (5)$$

NIR Instrument and Data Analysis

An automated NIR instrument (Patria Cane Analyzer) was use for shredded cane analysis, Fig 2. The cane analyzer consist of shredder, conveyor, Buchi NIR-ONLINE system, controller and personal computer for data collection. An approximately of 5 kg shredded cane was fed into the shredder. To perform NIR measurement, the shredded cane was discharged onto the conveyor and levelled by a plate to form a uniform surface of shredded cane. The speed of the conveyor was controlled by software. Through a constant speed, the shredded cane delivered into NIR measurement. While the shredded cane travelling at the conveyor, the sample was irradiated with NIR from above. The measurement distance between the samples and detector was approximately 10 cm.

The spectra of dried shredded cane was recorded in reflectance mode from 400 – 2500 nm. The reflectance data was converted into absorbance data. The result of the wet chemical analysis was input into the software and analyzed. The SX-Plus V.30 Build 55.1510.2203 [SP1] calibration software was

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used for data processing and statistical analysis. Quantitative calibrations were developed for predicting cane quality parameters. The prediction equation was obtained using partial least square as regression method. Data preprocessing using Mahalanobis and 2nd derivative [16, 17]. Samples for validation were selected randomly by taking one of every 5 samples from the entire data. 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 relative predicted determinant, [18].

Figure 2. Automated Cane Analyzer with NIR Instrument for the evaluation of sugarcane quality

3. RESULT and DISCUSSION

The calibration equation for cane paramaters were made using 570 samples for Pesantren Baru Sugar Factory (SF) and 468 samples for Gempolkrep SF. The calibration models were formulated by applying partial least square (PLS) regression. The prediction were using 100 independent samples for each SF. In this study calibration models for cane quality were scanning using 900 – 1700 wavelength ranges. Table 1 shows the calibration and prediction result of cane quality in two SF.

The PIC paramaters showing the best result for both SF with coefficient of determination for calibration (R^2c) were 0,938 and 0,936; coefficient of determination for prediction (r^2p) 0.916 and 0.916, respectively.. Figure 3 shows the example of scatter plot of the prediction using independent samples. The RPD for PIC also higher than other parameters. RPD values is indication of model robustness. Rate of RPD values according to [19] where values above 3 represent a good models, while values below 2.3 indicate a poor calibration performance. The result from calibration and prediction sets shows that NIR was a promising method to predict cane quality. The calibration result for BIC and PIC were similar with previous work. Table 2 shows the comparison between our work and literature. The result for PIC was similar with the literature with R^2 around 0.90 – 0.96 %.

However the result for FIC still low with R^2 for both SF were 0.784 and 0.786, respectively. Their standard error also remain high above 1 % and the RPD is the lowest than other paramaters. These result also similar with the previous work where the R^2 of fiber between 0.68 – 0.90 (Table 2). The level of FIC was determined based on calculation between moisture and brix content. The sugarcane sampling from truck were accompanied by trash and other extraneous matter. These condition were made a non-uniform samples. Consequently the NIR scanning and predicted values will be at variance with the wet analysis. Since the higher variation of trash content the relationship between NIR and wet

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analysis will be poorer for the higher variation of trash content.. The variance of sugarcane homogeneity was consistent with the result of standard error estimation.

However, the cane payment system calculation only based on the PIC parameters. The calculation for sugar recovery based on the PIC and factory efficiency. Then, the share of sugar for farmers based on the sugar recovery and weight of the sugarcane from each truck. According to the result, we conclude that PIC measurement for cane payment using automated NIR system was possible. By using the NIR system also have more advantage by reducing chemical for wet analysis and enough accuracy for cane quality evaluation.

Table 1. Statistical evalution result for cane quality analysis

Parameters	Calibration				Prediction			
	Number of sample	R^2c	SEC	SECV	Number of sample	r^2p	SEP	RPD
Pesantren Baru SF								
brix in cane	570	0.885	0.776	0.826	100	0.862	0.878	2.641
pol in cane	570	0.938	0.630	0.694	100	0.916	0.672	3.381
fibre in cane	570	0.784	1.000	1.021	100	0.759	1.260	1.827
Gempolkrep SF								
brix in cane	468	0.840	0.780	0.842	100	0.872	0.880	2.672
pol in cane	468	0.936	0.524	0.612	100	0.916	0.542	3.381
fibre in cane	468	0.768	1.092	1.123	100	0.649	1.041	1.571

Note:
R^2c = coefficient correlation for calibration
SEC = standard error calibration
SECV = standard error calibration validation
r^2p = coefficient correlation for prediction
RPD = relative predictive determinant

Table 2. Comparison of statistic evaluation of NIR calibration data to literature

Parameter	Number of sample		R^2		SEP	
	our work	Literature^	our work	Literature*	our work	Literature*
brix in cane	570	173 – 11.962	0.885	0.85 – 0.95	0.878	0.247 – 0.890
pol in cane	570	180 - 12.838	0.938	0.90 – 0.96	0.672	0.237 – 0.880
fibre in cane	570	171 – 12.100	0.784	0.68 – 0.90	1.260	0.699 – 1.620

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*Source: [9,20, 21, 22, 23,24,25,26]

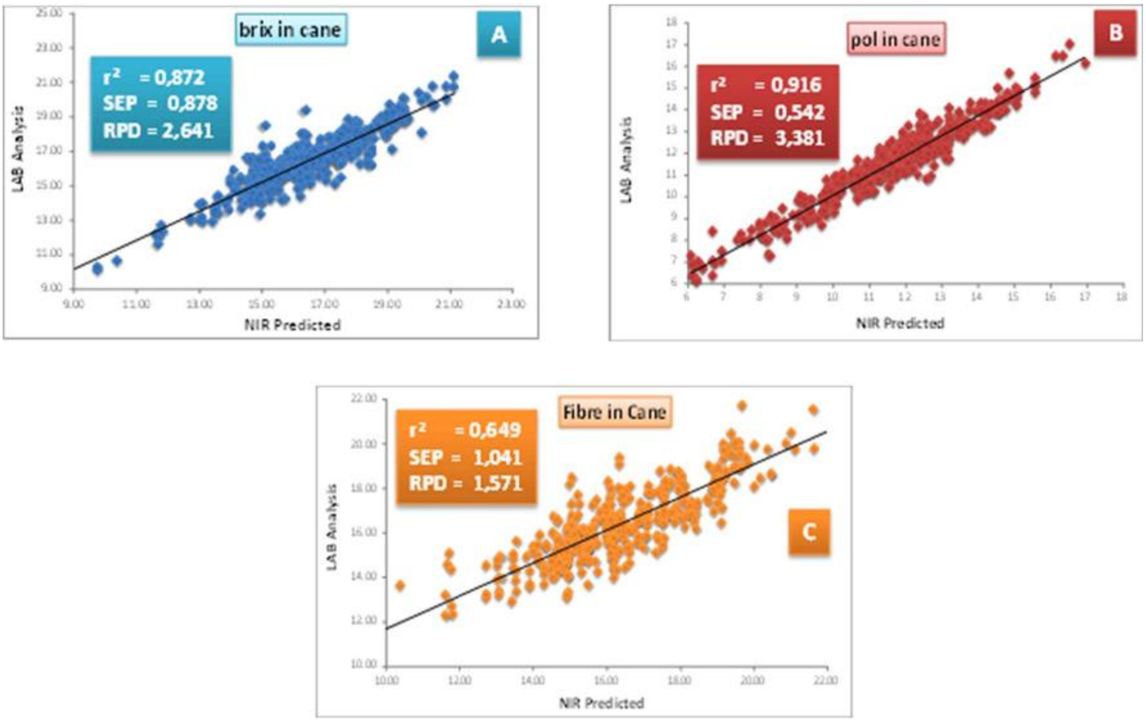

Figure 3. The NIR Predicted vs LAB Analysis for Cane Quality Parameters

4. CONCLUSION

The development of calibration equation of shredded cane quality using NIR was evaluated. An automatic cane analyzer with NIR was shown to be suitable for cane quality determination, especially pol in cane. The coefficient of correlation (R^2) for pol in cane parameter above 0,9 for tow sugar factory. These result indicate that NIR measurement system can be used to determine cane quality for cane payment system.

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