Sugarcane diagnosis using near infrared networking system

Eizo Taira, Masami Ueno and Yoshinobu Kawamitsu
University of the Ryukyus, 1 Senbaru Nishihara, Okinawa 903-0213, Japan.
E-mail: e-taira@agr.u-ryukyu.ac.jp

Introduction

Sugarcane is the major crop in Okinawa Prefecture, accounting for about 50 percent of the total area under cultivation, and more than 70 percent of farmers are engaged in its production. In order to measure the quality of sugarcane for payment, 5 kg samples are taken by a core sampler from every cane truck at the entrance to the sugar mills. Since the 2006/07 harvest year, a new measurement system was introduced into the payment system. In this new system, the sugar content is measured directly from the shredded samples using near infrared (NIR) spectroscopy instead of the conventional method using juice.[1] The new system enables the simultaneous analysis of multiple components in the sample using the measured spectrum. The spectrum is relayed via the internet to a server located in the laboratory at the University of the Ryukyus, thereby allowing the remote nutritional diagnosis of sugarcane. In this study, the possibility of the simultaneous measurement of chemical components using NIR was examined, and the networking of the quality evaluation systems in all sugar mills in Okinawa was investigated, in order to establish an effective remote diagnostic (analytical) system for sugarcane nutrition.

Materials and methods

Samples

A total of 166 test samples were obtained from sugarcane grown in the 2006/2007 harvest season. The samples were prepared as clean cane, and shredded using a cutter grinder (CG03, Jeffress Engineering. Ltd., Australia). About 100 grams of each shredded sample was used to fill the measuring cup of the NIR (InfraXact, FOSS Japan, Co. Ltd., Japan). NIR absorption was measured from 570 nm to 1848 nm in 2 nm increments in order to determine the target properties.

Chemical analysis

NIR spectrum data were collected, and each shredded sample (approximately 500 grams) was pressed using a hydraulic press with 25.5 Mpa pressure to extract the cane juice. Brix (soluble solids content) and Pol readings were immediately measured using a refractometer (RX-500FB, ATAGO Co., Ltd, Japan) and polarimeter (AP-300, ATAGO Co., Ltd, Japan), respectively. PIJ was calculated from the Pol readings and Brix values. Further, PIC was calculated from the PIJ and squeezing weight ratio.

Mineral concentrations (potassium, phosphorus, magnesium) in the extracted juice were measured using an ICPS-2000 spectroscope (Shimadzu, Kyoto, Japan).

Data analysis

Calibration equations were developed using WINISI software (FOSS Japan, Co. Ltd., Japan) for NIR spectra analysis. The NIR absorption spectra, smoothed by the moving-average method, were transformed to first derivative spectra d-log(1/R) values prior to calibration. The samples were divided into two groups for use as the prediction set and validation set. Modified partial least squares regression (MPLS) analysis was applied to the d-log(1/*R*) values of the sample set to predict the target properties (PIC, magnesium, potassium and phosphorus). Calibration equations were then tested against the validation set.

Networking system

To check and control the NIRS calibration and local systems at the 10 sugar mills currently on-line, a network system was developed using RINA software (Remote Internet Analysis, FOSS

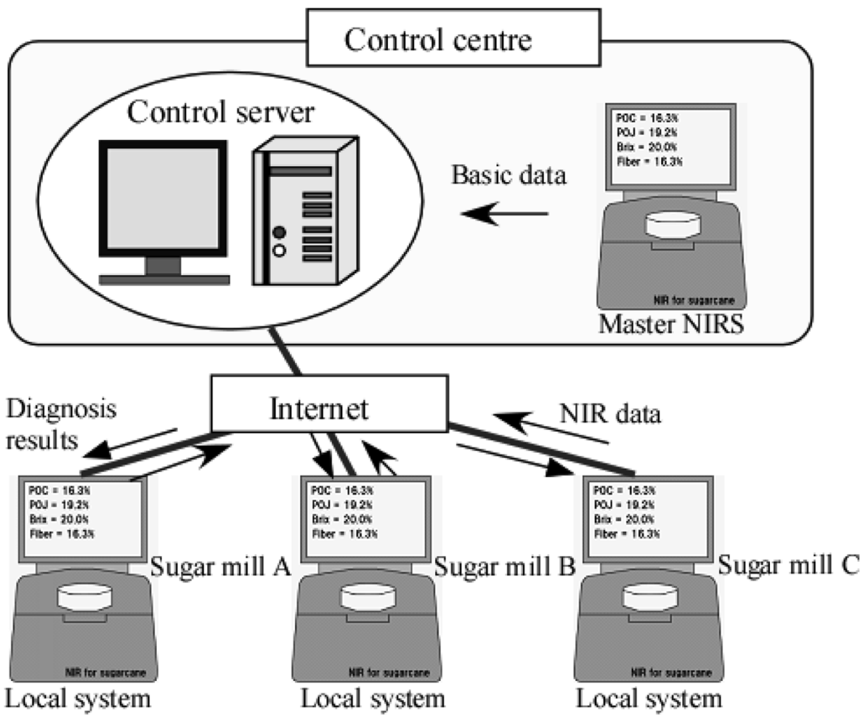

Figure 1. Outline of the networking system used in Okinawa sugar mills.

Japan, Co. Ltd, Japan). Figure 1 shows an outline of the system. This system can be extended to operate as an automatic diagnostic system using the collected spectra data.

Results and discussion

NIR calibration for a quality index

Figure 2 shows typical NIR absorption spectra from shredded cane samples.

Distinct absorption bands, due to water content, can be observed at 970 nm, 1190 nm and 1450 nm.[2] Calibration equations for PIC were developed using 86 cane samples, and validated using an additional 80 samples. Table 1 shows the calibration results for PIC against the polarimeter determinations.

The standard error of calibration (*SEC*) and standard error of prediction (*SEP*) were 0.23 and 0.23 respectively, with a correlation coefficient (*R*) between the measured and predicted values of 0.98. These results indicate the NIR system could evaluate the quality indices of shredded cane with sufficient accuracy for application to the payment system.

Figure 2. Original NIR spectra of shredded sugarcane.

Networking for effective NIR management

The local systems consist of Lab-type NIR instruments consisting of analysis software, the cutter grinder and annex apparatus. These systems were installed in ten sugar mills in Okinawa. Daily and annual checks are required to confirm accurate/normal operations. In addition, the developed PIC calibration equations should always be checked and any modifications transferred to the local systems. As the systems are distributed on eight islands, an effective monitoring and control system was thought to be necessary. Computer networking offered the best solution under such operating conditions. The control centre was located in the University of the Ryukyus, and each local system was connected to the control centre through the internet. The network monitoring system employed RINA and other software. The system works well and is simple to operate, carrying out daily checks and addressing any small problems that might arise within the local systems. The results of all measurements regarding cane quality from all local systems (including the NIR spectra) can be monitored on-line. Therefore, NIR spectra data from all sugarcane fields in Okinawa can be collected automatically.

Nutritional diagnosis

From the applications used to determine the nutritional status of sugarcane, a simple nutritional diagnostic system was developed. The results of the calibrations and validations for potassium, phosphate and magnesium are shown in Table 1.

The calibrations were applied to 100 samples. The *SEC* for potassium, phosphorus and magnesium were 503 mg kg^{-1}, 63 mg kg^{-1} and 78 mg kg^{-1}, with correlation coefficients of 0.85, 0.79 and 0.76, respectively. In the validation, the *SEP* values were 563 mg kg^{-1}, 81 mg kg^{-1} and 90 mg kg^{-1}, respectively. A previous study has shown that these components can also be measured from juice samples.[3]

In addition, the potassium content of all sugarcane samples used for the quality evaluation system in Okinawa was calculated, and the relation to sugar content was analyzed. As a result, negative correlations were confirmed in all sugar mills during the three years of this study (Table 2).

Table 1. Calibration and prediction results for PIC, Potassium, Phosphorus and Magnesium using MPLS regression.

	Calibration set			Prediction set	
	NF	R	SEC	SEP	Bias
PIC (%)	13	0.98	0.23	0.23	0.02
Potassium (mg kg^{-1})	10	0.85	503	563	26
Phosphorus (mg kg^{-1})	7	0.62	63	81	3
Magnesium (mg kg^{-1})	7	0.58	78	90	4

NF: Number of factors used in the MPLSR calibration; *R*: Correlation coefficients
SEC: Standard error of calibration; *Bias*: The average difference between the NIR and actual values; *SEP*: Bias-corrected standard error of prediction

Table 2. Correlation coefficient (r) between the PIC value and mineral content for 3 harvest seasons.

	2006/07	2007/08	2008/09
Potassium	–0.57††	–0.48††	–0.59††
Phosphorus	0.41††	0.42††	0.40††
Magnesium	–0.17	–0.06	–0.10

The measurement accuracy for phosphorus and magnesium, the values of which are used for the regulation of fertilizer application, were also adequate. These minerals are regarded as the key nutritional indices of sugarcane cultivation. These values can be simultaneously calculated together with the PIC value. Simple diagnosis is carried out based on these values and the sugar content and yield of the sugarcane. The diagnostic system can be used to guide fertilizer application and other key aspects of cultivation. Improvements through further trials are necessary for more effective and accurate diagnosis. However, this NIR networking system appears to afford a powerful tool toward the implementation of precision agriculture. As the next stage, historical trends are now being installed into the diagnostic system using GIS.

References

1. R. Sekiguchi, K. Fuchigami, S. Hara and C. Tutumi, in *NIR spectroscopy: Proceedings of the 7th International Conference,* Ed by A.M.C. Davies and P. Williams. NIR Publications, Chichester, UK, p. 632 (1996).
2. B.G. Osborne, T. Fearn and P.H. Hindle, *Practical NIR Spectroscopy with applications in Food and Beverage Analysis.* Longman Scientific & Technical, Harlow, Essex, UK, p. 30 (1993).
3. M. Ueno, Y. Kawamitsu, L. Sun, E. Taira and K. Maeda, *Sugar Cane Int.* **23,** 8 (2005).