วารสารเกษตรนเรศวร
ISSN : 0859-3027
ISSN (Online) : 2730-356X

บทความวิจัย

การวิเคราะห์องค์ประกอบทางเคมีในยอดอ้อยแบบรวดเร็วด้วยเนียร์อินฟราเรดสเปกโตรสโคปี

สนธยา นุ่มท้วม[1]* เสาวลักษณ์ รุ่งแจ้ง[2] ชญาณิศ ศรีงาม[2] รังสรรค์ เจริญสุข[1] จุฑาพร หงส์ผาทอง[3] พัชรพล ทองคำ[4] และ ชนิกาญจน์ จันทร์มาทอง[5]

[1]ภาควิชาวิทยาศาสตร์การเกษตร คณะเกษตรศาสตร์ ทรัพยากรธรรมชาติและสิ่งแวดล้อม มหาวิทยาลัยนเรศวร พิษณุโลก 65000
[2]ภาควิชาอุตสาหกรรมเกษตร คณะเกษตรศาสตร์ ทรัพยากรธรรมชาติและสิ่งแวดล้อม มหาวิทยาลัยนเรศวร พิษณุโลก 65000
[3]สำนักงานตรวจสอบคุณภาพสินค้าปศุสัตว์ กรมปศุสัตว์ ปทุทธานี 12000
[4]กลุ่มส่งเสริมและพัฒนาการปศุสัตว์ สำนักงานปศุสัตว์จังหวัดพิจิตร พิจิตร 66000
[5]สาขาวิชาชีววิทยา คณะวิทยาศาสตร์และเทคโนโลยี มหาวิทยาลัยราชภัฏพิบูลสงคราม พิษณุโลก 65000
*Corresponding author: sonthayan@nu.ac.th

(Received January 30, 2022; Revised February 24, 2022; Accepted March 8, 2022)

บทคัดย่อ

ยอดอ้อยเป็นผลพลอยได้จากการเกษตรที่สามารถนำมาใช้เป็นอาหารหยาบสำหรับเลี้ยงสัตว์เคี้ยวเอื้องทดแทนหญ้าที่ขาดแคลนในฤดูแล้ง เพื่อนำไปสู่การเลือกใช้ที่เหมาะสมตามคุณภาพ จึงควรมีการวิเคราะห์องค์ประกอบทางเคมีของยอดอ้อยก่อนนำมาประกอบเป็นอาหารสัตว์ การศึกษาในครั้งนี้มีวัตถุประสงค์เพื่อประเมินประสิทธิภาพการวิเคราะห์คุณภาพยอดอ้อยแบบรวดเร็วด้วยเครื่องเนียร์อินฟราเรดสเปกโตรสโคปี (Near Infrared Spectroscopy: NIRS) ดำเนินการศึกษาโดยการนำตัวอย่างยอดอ้อยสดหั่นเป็นแว่นมาวัดสเปกตรัมการดูดกลืนแสง NIR ในโหมดสะท้อนกลับ ที่เลขคลื่นช่วง 9000-4000 cm-1 จากนั้นนำยอดอ้อยมาวิเคราะห์หาปริมาณวัตถุแห้ง โปรตีน เถ้า NDF ADF เซลลูโลส และลิกนินด้วยวิธีมาตรฐาน เพื่อนำมาสร้างแบบจำลองทำนายคุณภาพยอดอ้อยด้วยวิธี Partial Least Square Regression (PLSR) จากการศึกษาพบว่าแบบจำลองสำหรับทำนายปริมาณวัตถุแห้งและโปรตีนในยอดอ้อยสดมีประสิทธิภาพการทำนายดีกว่าองค์ประกอบทางเคมีอื่นๆ โดยมีค่า RPD มากกว่า 3 ในขณะที่การทำนายปริมาณองค์ประกอบที่เกี่ยวข้องกับเยื่อใยมีประสิทธิภาพการทำนายปานกลาง (RPD<3) ดังนั้นจึงมีความเป็นไปได้ในการนำเครื่องเนียร์อินฟราเรดสเปกโตรสโคปีมาใช้ในการตรวจสอบปริมาณวัตถุแห้งและโปรตีนในขณะที่ยังไม่เหมาะสมในการทำนายองค์ประกอบเยื่อใยในในยอดอ้อยสด

คำสำคัญ: ยอดอ้อย, องค์ประกอบทางเคมี, การวิเคราะห์แบบรวดเร็ว, เนียร์อินฟราเรดสเปคโตรสโกปี

NARESUAN AGRICULTURE JOURNAL
ISSN : 0859-3027
ISSN (Online) : 2730-356X

Research Article

Rapid Analysis of Chemical Composition in Sugarcane Top using Near Infrared Spectroscopy

Sonthaya Numthuam[1]*, Saowaluk Rungchang [2], Chayanid Sringarm[2] Rangsun Charoensook[1], Jutaporn Hongpathong[3], Phatcharapol Thongkum[4] and Chanikan Junmatong[5]

[1]Department of Agricultural Sciences, Faculty of Agriculture Natural Resources and Environment, Naresuan University, Phitsanulok 65000
[2]Department of Agro-Industry, Faculty of Agriculture Natural Resources and Environment, Naresuan University, Phitsanulok 65000
[3]Bureau of Quality Control of Livestock Products, Department of Livestock Development, Pathumthani, 12000
[4]Division of Livestock Extension and Development, Phichit Provicial Livestock Office, Phichit, 66000
[5]Department of Biology, Faculty of Science and Technology, Pibulsonkram Rajabhat University, Phitsanulok 65000, THAILAND
*Corresponding author: sonthayan@nu.ac.th

(Received January 30, 2022; Revised February 24, 2022; Accepted March 8, 2022)

Abstract

Sugarcane tops are crop residues and one of a major by-product of sugarcane production. They have been used as an alternative ruminant forage and a material for bioethanol synthesis. Chemical compositions inside them have a strong influence on the ethanol yield and are necessary for balancing feed ration. The objective of this study was to evaluate the possibility of near infrared (NIR) spectroscopy for a rapid determination of chemical compositions in sugarcane tops. Fresh sugarcane tops were harvested and evaluated for contents of dry matter, crude protein, ash, NDF, ADF, cellulose and lignin. The sugarcane tops were chopped and used for the NIR measurements which were performed using reflectance FT-NIR spectroscopy in the region of 9000-4000 cm^{-1}. Data analysis was performed using partial least square (PLS) regression. The performances of PLS models for predicting dry matter and crude protein were better than other chemical composition with ratio of standard deviation to standard error of validation (RPD) higher than 3, while the prediction models of fiber related component provided moderate accuracy with RPD<3. The results suggested that NIR spectroscopy had a potential to be a rapid and effective method for the determination of dry matter and crude protein in sugarcane tops, while the prediction accuracy of fiber parameters was not satisfied.

Keywords: Sugarcane top, chemical composition, Rapid analysis, Near infrared spectroscopy

Introduction

Sugarcane is one of a major economic plant in Thailand, which has been produced over 100 million tons per year for sugar production. The main by-products of sugarcane industry are sugarcane top, bagasse, and molasses (Solomon, 2011). The sugarcane tops are the first by-product of the sugar milling process that are discarded and are often burned on the field. However, they can be utilized either for feeding livestock and producing bioethanol. The green tops have been removed from the sugarcane at an arbitrary point, resulting in the variations in the chemical compositions which effects the quality of animal feed and ethanol product (Naseeven, 1988; Dodo et al., 2017; Kebede et al., 2018). Their high variations in nutritive value are also depended on soil condition, pre-harvesting methods, plant maturity and the amount of leaves (McKenzie et al., 2007; Puriya et al., 2020). For livestock production, there are many studies reported the use of sugarcane tops as feed supplements for ruminants, such as dairy cattle, beef cattle, lamb and goat (Alemzadeh & Noroozy, 2006; Mahala et al., 2013; Salinas-Chavira et al., 2013). The fresh sugarcane tops are highly palatable with good intake characteristics for livestock (Suttie, 2000). They have also been ensiled to increase the nutritive values of the cane tops and improve the livestock production performance (Alemzadeh & Noroozy, 2006; Kebede et al., 2018). For a decade, sugarcane residues have also been used as a raw material for bioenergy production, and sugarcane tops and leaves can be a renewable source to produce the bioethanol (Chandel et al., 2012; Dodo et al., 2017).

To be used as raw materials for either bioethanol or livestock feed productions, understanding chemical composition of sugarcane tops is needed. Traditionally, methods for chemical analyses are laborious, time-consuming and chemical waste. At present, however, the analyses need to be fast and affordable to help making decisions in large industries. Near infrared (NIR) spectroscopy is one of popular techniques for quality evaluation in agricultural and livestock products. The major advantages of NIR spectroscopy are a rapid, nondestructive and multicomponent analysis. It has been widely used for analyses of chemical compositions in livestock feed and forage, such as feed maize, cowpea and napier grass (Rosales et al., 2011; Baloyi et al., 2013; Maleko et la., 2019). Some studies have also reported the usefulness of NIR spectroscopy for determining chemical composition of agricultural biomass (Kelley et al., 2004; Liu et al., 2010). Therefore, in this study, we aimed to evaluate the feasibility use of NIR spectroscopy for determination of chemical composition in sugarcane tops as a less sample preparation and rapid analysis method.

Materials and methods

Sugarcane tops and sample preparation

Sugarcane tops were collected from the sugarcane farms in Phitsanulok and Kamphaeng Phet Province, Thailand. The cane tops were chopped (length of cut = 0.5 cm) for further measurement.

NIR measurement and data analysis

The NIR spectra of chopped sugarcane tops were acquired using a multi-purpose analyzer (MPA) FT-NIR spectrometer (Bruker, Bremen, Germany). The spectral acquisitions, in the region of 9000-4000 cm^{-1}, were performed in rotating-reflectance mode using a quartz cup as a sample holder at room temperature ($25\pm1^{\circ}C$) with 32 scans.

For data analysis, preprocessing of NIR spectra using the standard normal variate method was done to eliminate the spectral slope variation and scattering effects (Zaid et al., 2020). The calibration models of each chemical composition were then performed by partial least squares (PLS) regression using the OPUS program version 7.8 (Bruker, Bremen, Germany). The statistics used to develop and evaluate the equations included the correlation coefficient of the calibration (R), root mean square error of estimation (RMSEE), root mean square error of cross validation (RMSECV) and ratio of standard deviation to standard error of validation (RPD), described by Thanapase et al. (2012).

Analysis of chemical composition by reference method

After the NIR measurement, the sugarcane top samples were dried at 60°C for 36 h, ground through a 1 mm sieve screen and then kept in a desiccator until used. Dry mater (DM), crude protein (CP) and Ash were determined according to the procedures described by AOAC (2000), while acid detergent fiber (ADF), neutral detergent fiber (NDF), cellulose and lignin were determined following the procedures of Van Soest and Robertson (1991).

Results and Discussion

Total of 35 sugarcane top samples with the values of chemical compositions as shown in Table 1 were used in this study. The NIR-reflectance spectra of the cane top were shown in Figure 1. Two strong absorption bands were observed around 6924 cm^{-1} and 5238 cm^{-1} which were mainly attributed to water content of sugarcane (Kasemsumran et al., 2010; Taira et al., 2013). The scattering effect observed in the original spectra were removed by the preprocessing

Table 1. Characteristics of chemical quality of sugarcane tops used for establishment of calibration models

Quality trait	Dry matter	Crude protein	NDF	ADF	Cellulose	Lignin	Ash
Sample no.	35	35	33	34	35	35	33
Mean (%)	25.12	4.02	52.11	48.26	10.26	4.63	8.22
Minimum (%)	15.56	2.59	42.52	40.71	8.46	3.52	5.72
Maximum (%)	35.99	5.21	68.99	53.57	12.55	6.20	10.04
SD	5.17	0.85	6.38	3.38	0.98	0.85	1.21

of the standard normal variate method (Figure 1B). The PLS results for determination of chemical compositions of the cane top samples were shown in Table 2. In the calibration set, the correlation coefficients of all studied parameters were above 0.90. Among all parameters, the dry matter showed the best prediction results with the highest correlation coefficient and the RPD value (R = 0.98 and RPD = 3.56, respectively). The RPD ratios of cross-validation equations for dry matter and crude protein were larger than 3, which was the recommended minimum values by Williams and Sobering (1996). The RPD values from the NDF and ADF cross-validation equations observed in this study were quite low (<2) when compared with the previous researches that reported the prediction of NDF and ADF in forage and grasses (RDP > 3) (Yang et al., 2017). Samadi et al. (2020) suggested that predictive performance of ADF and NDF in feed might vary and could be improved depends on the method used for the spectral per-processing. However, in this study, we selected the standard normal variate method as a pre-processing method, which we believed that it could remove the scattering effect from homogeneous chopped top samples. Therefore, these low RPD values in this study might be due to the improper pre-processing method. Figure 2 shows the good correlation between the NIR-predicted values and the actual values of dry matter and protein content with correlation coefficient of validation set (r) over than 0.9. However, the slightly low accuracy (r<0.8) was observed for the prediction of fiber contents; ADF, NDF, cellulose and lignin (data not shown). These unsatisfied results is probably related to improper preprocessing method and low variation of the samples used in this study (Shetty et al., 2012; Samadi et al., 2020).

Table 2. PLS calibration and prediction results for quality traits of sugarcane tops

Quality trait	Rank	R	RMSEE	RMSECV	Bias	RPD
Dry matter	6	0.98	1.23	1.44	0.062	3.56
Crude protein	7	0.93	0.14	0.27	-0.003	3.21
NDF	9	0.95	3.88	4.14	0.138	1.98
ADF	5	0.92	1.04	1.75	-0.122	1.91
Cellulose	9	0.96	0.23	0.39	-0.027	2.51
Lignin	9	0.94	0.17	0.38	0.009	2.24
Ash	4	0.90	0.43	0.48	0.011	2.46

Rank: number of modified PLS factors used in calibration; *R*: correlation coefficient of calibration set; *RMSEC*: root mean square error of calibration; *RMSECV*: root mean square error of full-cross validation; *RPD*: ratio performance deviation

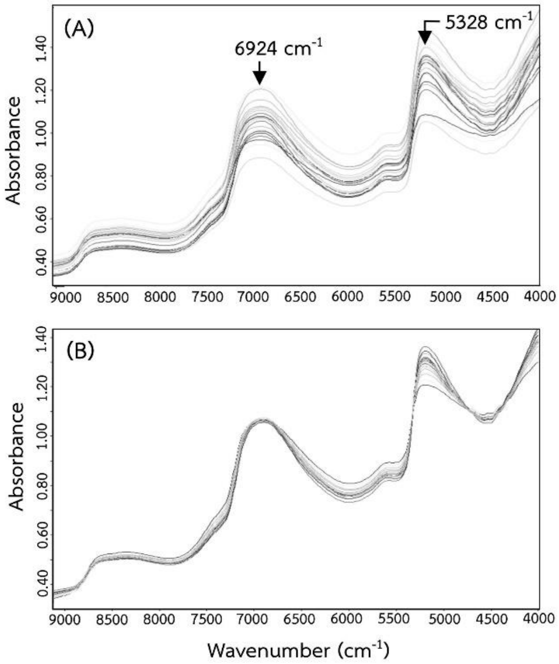

Figure 1. Original spectra of paddy rice samples (A) and the spectra after the standard normal variate preprocessing (B)

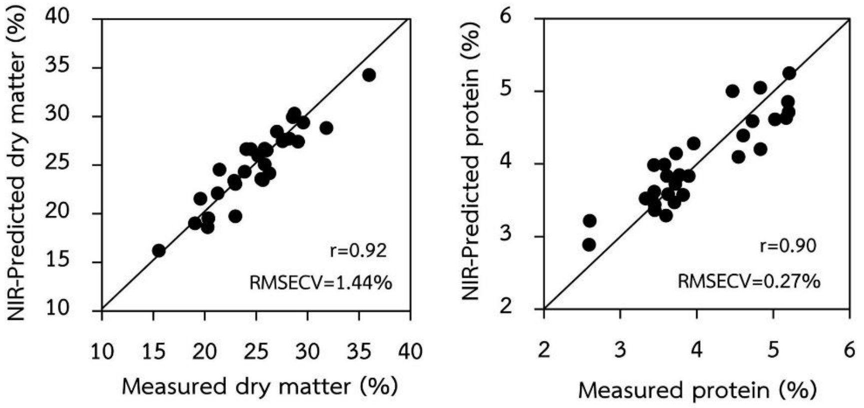

Figure 2. Scatter plots between actual and NIR-predicted chemical values in validation set

Conclusion

The study showed that NIR spectroscopy was capable for the determination of dry matter and protein content in sugarcane tops as rapid and non-destructive method. However, in this study, the unsatisfied PLS results were observed for the prediction of ash and fiber contents. The performance of NIR spectroscopy, therefore, could be improved by study the effect of preprocessing method and including the larger data set.

Acknowledgement

This research was supported by National Research Council of Thailand (Grant No. R2561B068).

References

Alemzadeh, B., & Noroozy, S. (2006). Effect of different levels of sugarcane top silage on milk production of dairy cattle. *Buffalo Bulletin*, *25*(3), 65-68.

AOAC (2000). Official methods of analysis, Association of official analytical chemists. 17th ed. Washington, USA.

Baloyi, J. J., Hamudikuw, H., Berardo, N., Ordoardi, M., & Ngongoni, N. T. (2013). Near infrared reflectance spectroscopy (NIRS) prediction of herbage quality from forage and browse legumes, and natural pasture grass grown in Zimbabwe. *African Journal of Agricultural Research*, *8*(10), 868-871.

Chandel, A. K., da Silva, S. S., Carvalho, W., & Singh, O. V. (2012). Sugarcane bagasse and leaves: foreseeable biomass of biofuel and bioproducts. *Journal of Chemical Technology and Biotechnology*, *87*(1), 11-20.

Dodo, C. M., Mamphweli, S., & Okoh, O. (2017). Bioethanol production from lignocellulosic sugarcane leaves and tops. *Journal of Energy in Southern Africa*, *28*(3), 1-11.

Kasemsumran, S., Suttiwijitpukdee, N., Prasatsrisupub, J., Thanapase, W., & Miyata, S. (2010). Quantitative determination of chemical constituents in biomass for substitute energy utilization by using near infrared spectroscopy. *Agricultural Sciences Journal*, *41*(3/1) (Suppl.), 65-68.

Kebede, G., Mengistu, A., Assefa, G., & Animut, G. (2018). Nutritional and fermentative quality of sugarcane (*Saccharum officinarum*) top ensiled with or without urea and molasses. *African Journal of Agricultural Research*, *13*(20), 1010-1017.

Kelley, S. S., Rowell, R. M., Davis, M., Jurich, C. K., & Ibach, R. (2004). Rapid analysis of the chemical composition of agricultural fibers using near infrared spectroscopy and pyrolysis molecular beam mass spectrometry. *Biomass and Bioenergy*, *27*(1), 77-88.

Liu, L., Ye, X. P., Womac, A. R., & Sokhansanj, S. (2010). Variability of biomass chemical composition and rapid analysis using FT-NIR techniques. *Carbohydrate Polymers*, *81*(4), 820-829.

Mahala, A. G., Mokhtar, A. M. S., Amasiab, E. O., & AttaElmnan, B. A. (2013). Sugarcane tops as animal feed. *International Research Journal of Agricultural Science and Soil Science*, *3*(4), 147-151.

Maleko, D., Mwilawa, A., Msalya, G., Pasape, L., & Mtei, K. (2019). Forage growth, yield and nutritional characteristics of four varieties of napier grass (*Pennisetum purpureum* Schumach) in the west Usambara highlands, Tanzania. *Scientific African*, *6*, e00214.

McKenzie, R. J. (1994). *Cane tops as cattle fodder*. Agnote-New South Wales Agriculture (Australia).

Naseeven, R., Sansoucy, R., Aarts, G., Preston, T. R., & sobre la Cana, C. D. E. (1988). Sugarcane tops as animal feed. *FAO Animal Health and Production* Paper, *72*, 106-122.

Puriya, J., Chamnanpa, W., Boodsiphum, P., & Wongtamee, A. (2020). Evaluation of potential productivity between plant cane and the first ratoon of 16 sugarcane varieties grown in the sandy soil area in Phitsanulok Province. *Naresuan Agriculture Journal*, *17*(2), e0170205.

Rosales, A., Galicia, L., Oviedo, E., Islas, C., & Palacios-Rojas, N. (2011). Near-infrared reflectance spectroscopy (NIRS) for protein, tryptophan, and lysine evaluation in quality protein maize (QPM) breeding programs. *Journal of agricultural and food chemistry*, *59*(20), 10781-10786.

Salinas-Chavira, J., Almaguer, L. J., Aguilera-Aceves, C. E., Zinn, R. A., Mellado, M., & Ruiz-Barrera, O. (2013). Effect of substitution of sorghum stover with sugarcane top silage on ruminal dry matter degradability of diets and growth performance of feedlot hair lambs. *Small Ruminant Research*, *112*(1-3), 73-77.

Samadi, S., Wajizah, S., & Munawar, A. A. (2020). Near infrared spectroscopy (NIRS) data analysis for a rapid and simultaneous prediction of feed nutritive parameters. *Data in Brief*, *29*, e105211.

Shetty, N., Gislum, R., Jensen, A. M. D., & Boelt, B. (2012). Development of NIR calibration models to assess year-to-year variation in total non-structural carbohydrates in grasses using PLSR. *Chemometrics and Intelligent Laboratory Systems*, *111*(1), 34-38.

Solomon, S. (2011). Sugarcane by-products based industries in India. *Sugar Tech*, *13*(4), 408-416.

Taira, E., Ueno, M., Furukawa, N., Tasaki, A., Komaki, Y., Nagai, J. I., & Saengprachatanarug, K. (2013). Networking system employing near infrared spectroscopy for sugarcane payment in Japan. *Journal of Near Infrared Spectroscopy*, *21*(6), 477-483.

Thanapase, W., Kasemsumran, S., & Pathaveerat, S. (2012). *Near-Infrared technology and applications in industries.* Kasetsart University Press.

Van Soest, P. V., Robertson, J. B., & Lewis, B. (1991). Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. *Journal of Dairy Science*, *74*(10), 3583-3597.

Williams, P. C., and Sobering, D. C. (1996). How do we do it: a brief summary of the methods we use in developing near infrared calibrations. *Near infrared spectroscopy*: *The Future Waves*, 185-188.

Yang, Z., Nie, G., Pan, L., Zhang, Y., Huang, L., Ma, X. & Zhang, X. (2017). Development and validation of near-infrared spectroscopy for the prediction of forage quality parameters in *Lolium multiflorum*. *Peer-reviewed Journal*, *5*(10), e3867.

Zaid, A., Abu-Khalaf, N., Mudalal, S., & Petracci, M. (2020). Differentiation between normal and white striped turkey breasts by visible/near infrared spectroscopy and multivariate data analysis. *Food Science of Animal Resources*, *40*(1), 96-105.