Assessment of Soluble Solids of Strawberry Fruit cv. No. 80 Using NIR Technique

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ABSTRACT

Evaluation of total soluble solids of strawberry fruit cv. No. 80 using near infrared (NIR) spectroscopy with wavelength ranging from 700 nm to 1100 nm was studied. NIRSystem6500 was used to acquire the spectrum while a total soluble solids (TSS) was measured using digital refractometer. The fruit was separated into 2 groups by percentage of red color break using the following criteria: white stage; less than 25% color break and red stage; more than 75% color break. The soluble solids content of white stage equalled to 10.02% and was significantly different from total soluble solids of red stage (10.66%). The partial least squares regression (PLSR) models for prediction TSS of strawberry showed that the calibration equations formulated by the relationship between values of spectrum and TSS could predict TSS values with the correlation coefficient; R equal to 0.81, the standard error of calibration (SEC) and the standard error of prediction (SEP) equal to 0.46 and 0.49, respectively.

Key words: Strawberry, Near infrared spectroscopy, Total soluble solids

INTRODUCTION

Many researchers have attempted to use NIR techniques to develop a nondestructive means of assessing fruit quality. In some commodities the stage of ripeness is well correlated with fruit color or sweetness. Since the initial purchase decision by consumers is often based upon appearance most commercial, sorting systems have been developed to sense the visible light characteristics associated with these attributes. Unfortunately color is not a good indicator of internal quality in strawberry fruit.

Near infrared technology is recommended for agricultural products for maturity evaluation and internal quality assessment because it is a fast, no chemicals used and it is a non-destructive technology. Many researchers used NIR spectroscopy as a nondestructive method for maturity evaluation and internal quality assessment of different kinds of agricultural products such as mangoes (Saranwong et al., 2001, 2003, 2004), apples (Liu and Ying, 2005; Liu et al., 2007), kiwifruits (Clark et al., 2004), pears (Liu and Yang, 2006) and peaches (Carlomagno et al., 2004). Besides, NIRs was applied to assess internal fruit quality by means of its chemical and physical properties. For example, the potential of interactance mode of NIRs with fiber optics was studied to estimate the soluble solid content. The spectra from 680 nm to 1235 nm were obtained by NIR spectroscopy. The calibration equation result with a correlation coefficient (R) of 0.97, standard error of calibration (SEC), standard error of prediction (SEP) and bias were obtained as 0.48 °Brix, 0.50 °Brix and 0.01 °Brix, respectively (Kawano et al., 1992, 1995). NIRs can be used to assess physiological characteristics such as apple firmness (Cho et al., 1992) and provided good results (R=0.88, SEC=2.54 N, SEP=2.85N). The measurement of titratable acidity (TA) of satsuma mandarin, the result showed that error of NIR determination was about 20% (Miyamoto et al., 1998). Likewise, Saranwong et al. (2004) successively developed the NIR calibration equations for harvest quality prediction of unripe mango (hard-green) fruit by mean of its dry matter (DM) and starch content. Thus, the aim of this research was to predict internal quality in strawberry fruit and develop calibration equation models for estimating total soluble solid content of strawberry fruit cv. No. 80 at commercially mature using near infrared spectroscopy.

MATERAILS AND METHODS

Samples

A total of 200 strawberry fruits from Royal Project Foundation, Chiang Mai province was harvested at 2 stages by percentage of color break using the following criteria: White stage; less than 25% color break and red stage: more than 75% color break (Figure 1). Then the strawberry fruits were transported to Postharvest Technology Research Institute, Chiang Mai University by refrigerated truck. Morphological characteristics of samples, including diameter, height, weight, and fruit index were determined before spectrum acquisition. The diameter and height of strawberry fruit was calculated by digital vernier. Fruit index was defined by ratio of its diameter and height. Fruit weight was measured by 2 digits using digital fine balances.

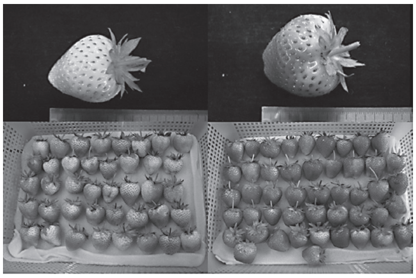


Figure 1. White and red stages of strawberry fruits.

Spectrum acquisition data

Figure 2 NIR spectrum of strawberry fruit was measured in short wavelength region from 700 to 1,100 nm at harvest date with NIRsystem 6500 spectrophotometer (Foss NIRSystem, Silver Spring, USA). All spectra were acquired raw spectrum using interactance mode with the fiber optic “interactance probe”. The NIR spectrum was obtained from both strawberry fruit’s sides by averaging 50 scans. A reference measurement of Teflon cylinder was performed at every 5 samples. The temperature of samples was controlled using a refrigerated water bath at 25°C for 10 minutes before acquisition.

Figure 2. Spectrum acquisition data of strawberry using NIRsystem 6500.

Chemical analysis

After spectra acquisition, a portion of the fruit side of each fruit which was irradiated by NIR radiation was determined for total soluble solid analysis using digital refractrometer (Atago, Japan)

Data analysis

The equation for calibration divided the data into two sets; calibration set and validation set. The Unscrambler program Version 9.8 (CAMO, Oslo, Norway®) was used for all calculations. Partial least squares regression (PLSR) was used to develop equations and determine the relationship between the spectrum and the value from chemical analysis.

RESULTS AND DISCUSSION

Morphological and TSS distributions of strawberry cv. No. 80

Morphological properties and TSS of strawberry samples cv. No. 80 red and white stages were shown in Table 1. Overviews of TSS distributions of strawberry fruits were report in Table 2. The results for physical measurement of width, length and weight showed that the average of width and length of strawberries were 35.49 and 36.31 millimeter, respectively. The averages of weight and the fruit index of the samples were 21.15 gram and 0.978, respectively. The TSS measurements of 200 samples were normal distributed around the mean value (10.34%), standard deviation (SD) was 1.05. 200 samples were divided into the calibration and prediction set (100:100). The range of TSS of the calibration set was from 12.6-6.7% while from the prediction set was 12.5-6.6%.

Table 1. The average of width, length, weight and fruit index of strawberry cv. No. 80 in each stage.

Stage	Width			Length			Weight			Fruit index	TSS (%)
	Max (mm)	Min (mm)	Mean (mm)	Max (mm)	Min (mm)	Mean (mm)	Max (g)	Min (g)	Mean (g)		
White	45.99	22.19	34.98	47.00	27.69	36.22	34.53	11.45	19.98	0.966	10.02±0.99
Red	44.00	30.00	36.01	47.00	28.55	36.41	33.52	13.85	22.32	0.989	10.66±1.00
Average	45.99	22.19	35.49	47.00	27.69	36.31	34.53	11.45	21.15	0.978	10.34

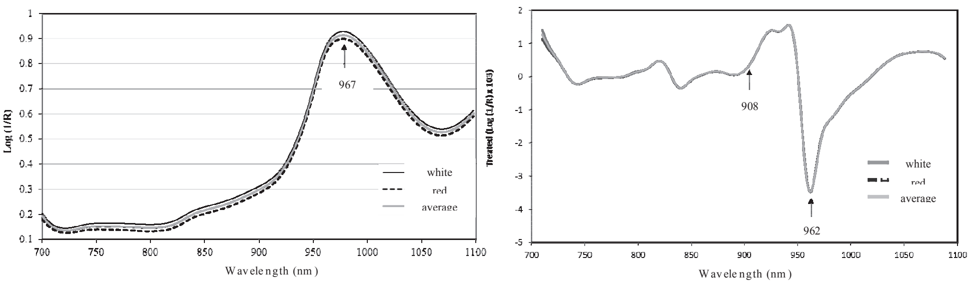
Red: More than 75% color break. White: Less than 25% color break.

Table 2. Total soluble solid content calibration and prediction set of strawberry cv. No. 80.

Sample sets	No. of samples	Max(%)	Min (%)	Mean (%)	SD
Average TSS	200	12.6	6.7	10.34	1.05
Calibration set	100	12.6	6.7	10.39	1.050
Prediction set	100	12.5	6.6	10.36	1.052

Spectra of Strawberry cv. No. 80

Figure 3 Shows the absorbance original spectra of 200 strawberry fruits (a) and 2nd derivative spectra (b). The wavelength range 700-1100 nm was used to develop the calibration model. A total soluble solids (TSS) is the organic molecule, and contains bonds C-H, O-H, C-O and C-C. Thus, it is possible to use NIR for determination of TSS in strawberry because NIR was sensitive to the concentration of organic materials. But unfortunately, TSS peak overlapped the peak of water molecules since the wavelength range 950-970 nm is the effective wavelengths of water, because the strong water absorbance bands were presented around 960 nm and 760 nm for the second and third harmonics of the fundamental O-H stretching vibration (Liu et al., 2010).



(a) (b)

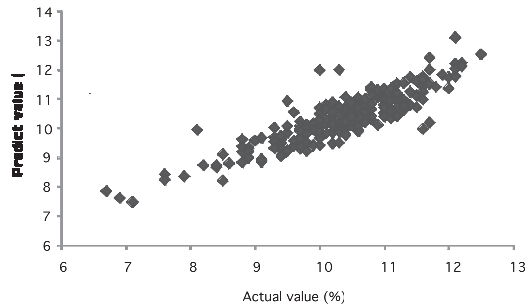
Figure 3. Means of original spectra (a) and 2nd derivative spectra (b) of stage white and red of strawberry were measured in short wavelength (700-1100 nm).

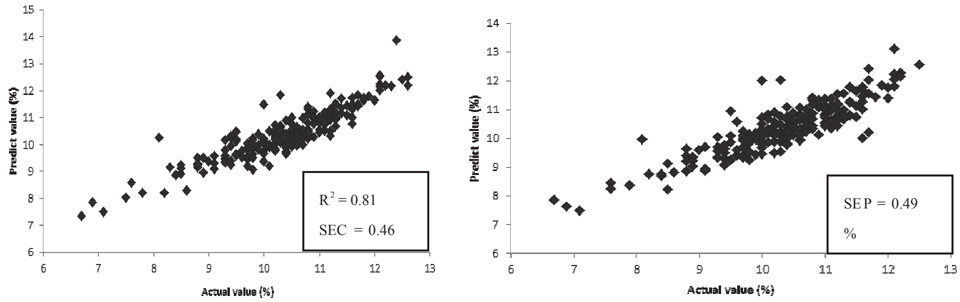
NIR determination of TSS

The relationships between the spectrum, effective wavelengths and actual value of determination the TSS were built, respectively. The spectrum data were transformed with the second derivative (10 nm averaging for left and right side) and multiplicative scatter correlation (MSC) and second derivative (10 nm averaging for left and right side) and Standard normal variation (SNV) used for develop the model (Table 3). The PLSR models with 2nd derivative pretreatment of contained TSS strawberry fruit provided the correlation of determination (R^2) of 0.813, the standard error of calibration (SEC) was 0.462% and the standard error of prediction (SEP) was 0.499% (Figure 4). The range of 850-1088 nm were the effective wavelengths, because the sugar absorbance bands were presented around 908 nm (Kawano et al., 1992; Williams and Norris, 2001).

Table 3. PLSR calibration results for TSS of strawberry fruit with spectra treated.

Method	Pretreatment	Wavelength (nm)	F	R^2	SEC	SEP	Bias
PLSR	2nd derivative	850-1088	6	0.813	0.462	0.499	0.017
PLSR	MSC+2nd derivative	850-1088	6	0.809	0.466	0.498	0.017
PLSR	SNV	850-1050	9	0.803	0.473	0.492	0.03





(a) (b)

Figure 4. Plot of actual and predicted total soluble solid of strawberry fruit in (a) calibration set and (b) prediction set.

CONCLUSION

The NIR could predict the total soluble solid content in strawberry fruit by the partial least squares regression (PLSR) models for prediction TSS of strawberry fruit in wavelength range 850-1088 nm. The best combination was PLSR model with 2nd derivative spectral pretreatment. The result showed that the correlation coefficient; R^2 was 0.813, the standard error of calibration (SEC) and the standard error of prediction (SEP) equal to 0.462 %brix and 0.49 %brix, respectively.

ACKNOWLEDGMENT

This study was supported by Royal Project Foundation, Chiang Mai province, Postharvest Technology Research Institute (Chiang Mai University) and Postharvest Technology Innovation Center.

REFERENCE

Carlomagno, G., L. Capozzo, G. Attolico, and A. Distante. 2004. Non-destructive grading of peaches by near-infrared spectrometry. Infrared Physics and Technology 46(1-2): 23-29.

Cho, R.K., K.H. Lee, and M. Iwamoto. 1992. Determination of firmness of intact apple fruits by near infrared reflectance spectroscopy. p. 71-76 In R.A Talyor (ed) Proceedings of 6th Int. Diffuse Reflectance Spectroscopy Conference Council for Near Infrared Spectroscopy, Chambersburg, PA.

Clark, C. J., V. A. McGlone, H. N. DeSilva, M. A. Manning, J. Burdon, and A.D. Mowat. 2004. Prediction of storage disorders of kiwifruit (Actinidia chinenses) based on visible–NIR spectra characteristics at harvest. Postharvest Biology and Technology 32(2): 147-158.

Kawano, S., H. Abe, and M. Iwamoto. 1995. Development of a calibration equation with tem-pearature compensation for determining the Brix value in intact peaches. Journal of Near Infrared Spectroscopy 3: 211-218.

Kawano, S., H. Watanabe, and M. Iwamoto. 1992. Determination of sugar content in intact peaches by near infrared spectroscopy with fiber optics in interactance mode. Journal of Japanese Society Horticultural Science 61(2): 445-451.

Liu, Y. D., and Y. B. Ying. 2005. Use of FT-NIR spectrometry in non-invasive measurement of internal quality of 'Fuji' apples. Postharvest Biology and Technology 37(1): 65-71.

Liu, Y. D., and Y. B. Ying. 2006. Optical system for measurement of internal pear quality using near-infrared spectroscopy. Optical Engineering 44(7): 1-5.

Liu, Y. D., Y. B.Ying, X. P. Fu, and H.S. Lu. 2007. Experiments on predicting sugar content in apples by FT-NIR Technique. Journal of Food Engineering 83(3): 986–989.

Liu, Y., X. Sun, H. Zhang, and O. Aiguo. 2010. Non-destructive measurement of soluble solid of navel orange fruit by visible-NIR spectroscopy technique with PLSR and PCA-BPNN. LWT-Food Science and Technology 43: 602-607.

Miyamoto, K., M. Kawaushi, and T. Fukuda. 1998. Classification of high acid fruits by partial least squares using the near infrared transmittance spectra of intact satsuma mandarins. Journal of Near Infrared Spectroscopy 6: 267-271.

Saranwong, S., J. Sornsrivichai, and S. Kawano. 2001. Improvement of PLS calibration for Brix value and dry matter of mango using information from MLR calibration. Journal of Near Infrared Spectroscopy 9: 287-295.

Saranwong, S., J. Sornsrivichai, and S. Kawano. 2003. Performance of a portable NIR instrument for Brix value determination of intact mango fruit. Journal of Near Infrared Spectroscopy 11: 175-181.

Saranwong, S., J. Sornsrivichai, and S. Kawano. 2004. Prediction of ripe-stage eating quality of mango fruit from its harvest quality measured Non-destructively by near infrared spectros-copy. Journal of Postharvest Biology and Technology 31: 137-145.

Williams, P., and K. Norris. 2001. Near-infrared technology in the agricultural and food industries. 2nd ed. American Association of Cereal Chemists, St. Paul.