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Research Article

Nondestructive Prediction of Juice Recovery Yield of Pineapple Using Near Infrared Hyperspectral Imaging

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Abstract

During commercial processing of pineapples, fresh fruit selection on the basis of their quality is essential, particularly their juice content. This is to ensure high and consistent product quality, but juice level varies between individual fruit. Therefore, a non-destructive technique for predicting juice recovery yield of pineapple using near infrared hyperspectral imaging (NIR-HSI) was aimed for use in online sorting systems. Pineapples were scanned using NIR-HSI to develop a calibration model for predicting juice recovery yield of pineapple in this study. A set of 122 pineapple samples was divided into a calibration set (n = 81) and a prediction set (n= 41). Spectral pretreatments were investigated in order to obtain the best calibration model. The best model was obtained using Savitzky-Golay smoothing spectral pretreatment at the wavelength range of 935–1720 nm using partial least squares regression (PLSR). The model showed sufficient accuracy for prediction with a correlation coefficient (Rp) of 0.73 and the root mean square error of prediction (RMSEP) of 1.54%. These results indicate that NIR-HSI has the potential for use in prediction the juice recovery yield of pineapple in a non-destructive online system in pineapple processing factories.

Keywords: spectra, model, fruit, sorting

1. Introduction

Thailand is one of the important producers of pineapples in the world. Much of this production is processed into products that include canned pineapple, aseptic or frozen concentrated pineapple juice, frozen pineapple and dehydrated pineapple, and is the world's largest producer of canned pineapples [1]. The cultivar 'Smooth Cayenne' and is the most popular with more than 80% of production used in the pineapple industry, mainly because of its large fruit with its sweet and sour taste [2]. Pineapple processing factories require high consistent quality and high recovery yield and, especially for juice production, high juice content. The selection of the fresh fruit of predictable is important in terms of economics of production as well as processed product quality. The potential of using non-destructive techniques to assess the quality of fresh pineapple fruit have including of x-ray tomography to identify fruitlet core rot [3]. Fourier transform infrared spectroscopy to evaluate abiotic stress effects [4]. electrochemical impedance spectroscopy to identify and quantify fermentable sugars [5], electronic nose to evaluation shelf life [6] and Vis–NIRS to quantitative prediction nitrate level [7], Nicolai et al. [8] reported that near infrared radiation (NIR) in the range of the electromagnetic spectrum between 780-2500 nm can be used to penetrate a product. They showed that its spectral characteristics changed through wavelength dependent scattering and absorption processes and that this change depends on the chemical composition of the product, as well as on its light scattering properties which are related to its structure. Near-infrared hyperspectral imaging (NIR-HSI) can be used to obtain both spatial and spectral information that are important for evaluating composition of materials [9]. NIR-HSI has been used successfully as a non-destructive method of evaluating foods and agricultural products including hens' eggs [10], limes [11], cakes [12], tapioca starch [13], fresh meat [14], beef jerky [15], cocoa [16] and apple fruit slices [17]. These studies show the potential of NIR-HIS has a possible application for predicting the juice recovery yield of fresh pineapple fruit non-destructive and was therefore the objective of this study.

2. Materials and Mathod

A. Sample preparation

Pineapple fruits (Ananas comosus L.) were purchased from a wholesale market in Bangkok, Thailand, selecting fruit of various maturities (by observation of green skin to yellow skin) all within 14-21 cm in diameter. Fruit were maintained at 25°C for 24 hours before measurement.

B. Spectral Data Acquisition

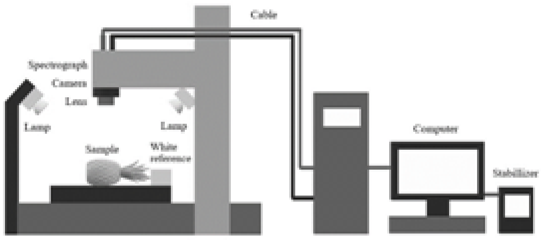

FIGURE 1. Schematic representation of the NIR-HSI system.

The NIR-HSI system used was Fx17, Spectral Imaging Ltd, Oulu, Finland, in reflective mode with a wavelength range of 935–1720 nm. The system was set at the light sources at a 45 degree angle to the sample. Each sample was placed on a moving tray with scanning speed at 15.00 mm/s as shown in (Fig. 1). A dark reference image obtained when the light sources was turned off and the lens covered. The white reference image was obtained using a white reference made from spectralon. Each sample was scanned individually to acquire the spectral image. The background image was removed and only the sample image was used.

C. juice recovery yield

After each sample was scanned the juice was extracted, by first carefully peeling using a sharp knife and cutting the flesh into small pieces and extracting the juice using the hydraulic press juicer (Sakaya Automate Co. Ltd.). In order ensure consistency, each sample was pressed 10 times, each time for 30 seconds in the same conditions. Juice recovery yield [18]. was calculated using the Equation (1)

D. Data analysis

Averaged spectra of each samples were used for analysis. Juice recovery yield was used as a dependent variable while the spectra in the wavelength of 935–1720 nm were independent variables. The calibration model was established using partial least squares regression (PLSR). Samples were divided into two groups as a calibration set (81 samples) and a prediction set (41 samples). The spectral pretreatments were carried out in order to obtain the highest correlation coefficient of the calibration model, including smoothing (Savitzky-Golay), first derivative differentiation, second derivative differentiation, multiplicative scatter correction (MSC) and standard normal variate transformation (SNV). The best model was determined using the highest correlation coefficient of cross validation (RCV) and the lowest root mean square error of cross validation (RMSECV). The accuracy of the model for prediction was determined by the correlation coefficient of prediction (Rp) and the root mean square error of prediction (RMSEP). Microsoft Office Excel (Microsoft, USA), the UmBrio Evince hyperspectral image analysis software (Prediktera Evince, version 2.7.5, Sweden) and the Unscrambler (CAMO, Oslo, Norway) were used for analysis.

3. Results And Discussions

A. Juice recovery yield of various sizes analysis

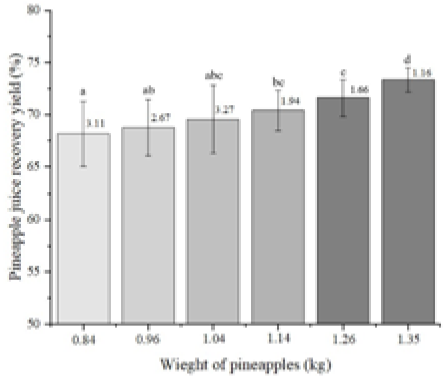

FIGURE 2. Juice recovery yield of various sizes of pineapples: a, b, c and d indicates significant differences ($p<0.05$) using the Duncan's Multiple Range test.

The pineapples were divided into various sizes based on each averaged weight group and different standard deviation. The relation between juice recovery yield and the size of pineapple shows that the larger fruit had significantly higher ($p<0.05$) amounts of juice (Fig. 2).

B. Spectral feature of pineapple

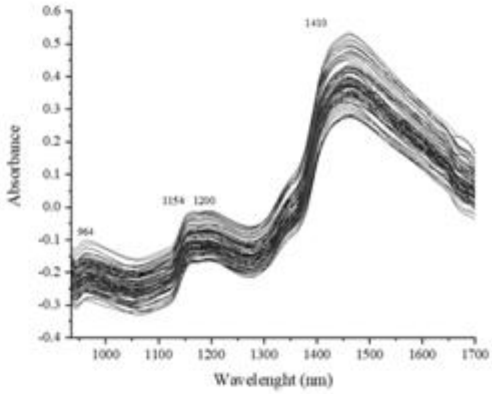

FIGURE 3. The average original absorbance spectra of pineapples in the range of 935–1720 nm.

The spectra of individual fruit were similarly characterized with the same peaks at the specific wavelengths (Fig. 3). This could be explained by all the fruit had similar components, within the range of 80 to 90%. The peaks of spectra were influenced by the absorption peaks of water at 964, 1154, 1200 nm and 1410 nm [19-21] which were clearly much higher than other components.

C. Performance of the PLS regression models for Prediction Juice recovery yield

The range of the data in the prediction set was totally covered by the range of data in the calibration set (Table 1). The distribution of the data in the calibration set and in the prediction set were close, which means that samples were suitable for use to test the effectiveness of the model.

TABLE 1. Juice recovery yield of pineapples in the calibration set and the prediction set.

Characteristic	Items	Calibration set	Prediction set
Juice recovery yield	Number of samples	81	41
	Range (%)	62.37-74.83	62.57-74.01
	Average (%)	69.76	69.99
	Standard deviation (%)	2.46	2.24

The results show that the best model for juice recovery yield with the highest Rcv and lowest RMSECV was acquired using Savitzky-Golay smoothing spectral pretreatment (Table 2). Therefore the Savitzky-Golay smoothing spectral pretreatment was used to establish the calibration model in this study.

TABLE 2. Results of cross validation of the PLSR model for juice recovery yield of pineapple in the calibration set using various spectral pretreatments.

Pre-processing techniques	Juice recovery yield		
	Factor	R_{cv}	RMSECV (%)
Original	10	0.64	1.92
Smoothing	**9**	**0.66**	**1.85**
1st Derivative	7	0.63	1.96
2nd Derivative	4	0.47	2.21
MSC	7	0.59	2.01
SNV	7	0.60	1.98

Savitzky-Golay (Smoothing), first derivative differentiation (1st Derivative), second derivative differentiation (2nd Derivative), multiplicative scatter correction (MSC) and standard normal variate transformation (SNV), root mean square error of cross validation (RMSECV), the coefficient of determination of cross-validation (Rcv)

The results for the accuracy of the model for predicting juice recovery yield of pineapples showed the model obtained Rc = 0.77 and RMSEC = 1.55% (SEC = 1.56, bias = 0.0000025), and Rp = 0.73 and RMSEP = 1.54% (SEP = 1.56, bias = -0.88325) (Table 3). This means that the model had the possibility for use in predicting juice recovery yield in pineapple.

Parameter	Pretreatment	F	Calibration			Prediction		
			N	R_c	RMSEC (%)	N	R_p	RMSEP (%)
Juice recovery yield	Smoothing	9	81	0.77	1.55	41	0.73	1.54

TABLE 3. Summary of PLSR model for predicting juice recovery yield of pineapple.

Number of samples (N), correlation coefficient for calibration and prediction (Rc and Rp), root mean square error of calibration (RMSEC), root mean square error of prediction (RMSEP), standard eror of calibration (SEC), standard eror of prediction (SEP).

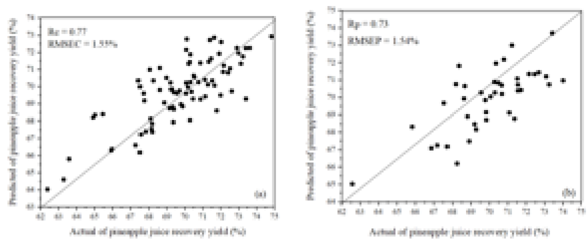

FIGURE 4. Scatter plot of actual and predicted juice recovery yield by the PLSR model (a) in the calibration set and (b) in the prediction set.

The scatter plot between the actual value and predicted value of pineapple juice recovery yield by the PLSR model (Fig. 4). showed that the data was distributed closely to the 45o (target line) in the same direction as previously reported the PLSR model showed that it was in preliminary prediction [22].

4. Conclusions

Results show a clear correlation between juice recovery yield and the size of pineapple. NIR-HIS system in the wavelength range of 935–1720 nm could be used to develop the PLSR model for prediction of juice recovery yield. The Savitzky-Golay smoothing spectral pretreatment was shown to give the best accuracy of the calibration model. Therefore, it was concluded that this model could be used as a non-destructive method for predicting juice recovery yield of pineapples that could have application in a commercial on-line grading system for use in pineapple processing factories.

Acknowledgments

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