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Development of Real-Time Internal Quality Evaluation Technique for Korean Red Ginseng using NIR Spectroscopy

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Abstract: This study was conducted to develop a real-time internal quality evaluation technique for Korean red ginseng using NIR spectroscopy while they were moving to be graded. Internal qualities of Korean red ginseng were defined by color, amount of white core and cavity in the red ginseng. To evaluate the internal quality, PLS (Partial Least Square) model was developed. Spectrum saturation can be occurred when most red ginseng has a sound internal quality expressed by higher light transmittance ratio, but that could not found in the ginseng of internal white core under the same light situation. And, if spectrum saturation is obtained, it is hard to identify the exact information of internal quality.

In order to evaluate of the internal quality regardless of having internal normal core or white core, an integral time controlled method was used to obtain traditional spectrum. This procedure was applied in real-time process when red ginseng was moving to be graded in the line. Among the 450 samples including 223 internal normal ginsengs and 227 internal white core ginsengs, 315 ginsengs (70%) were used to develop a calibration model and 135 ginsengs were spent to validate the model. The result of quality evaluation by the model was very good showing SEP and bias were 0.3573 and 0.0310, respectively, and the accuracy was 95.6%.

Keywords: Red ginseng, Quality evaluation, Transmittance spectrum, PLS

Introduction

For the last 100 years, the Korean government had a monopoly of Ginseng industry for manufacture and sale. However, the monopoly system was discontinued on July 1997, and an individual and organization can manufacture and distribute the red ginseng. Thus, the high quality red ginseng produce is necessary for the value-added profit increase.

The consumers like fresh, white, and red ginseng. From the record of Ministry of Agriculture and Forestry, in Korea, the percentages of consumption of fresh ginseng, white ginseng, and red ginseng were 50%, 35%, and 15%, respectively, for the last 5 years. The whole fresh ginseng has been consumed in Korea, but the 80% of red ginseng has been exported as a good dollar source and hence becomes high-income product. Specially, the medical action and effect of Korean ginseng is the best quality among the ginseng products in the world.

The quality grades of red ginseng are classified into heaven, earth, and good grade. Heaven grade has delicate internal structure and its diameter of cavity is less than 0.5 mm and length is less than 10 mm. The price of heaven grade is three times more expensive than the good grade ginseng. The internal cavity and white core are detected by the naked human eyes under the backlight such as fluorescence or halogen lamp in a dark room. This detection method has a source of error due to the conditions of inspector such as subjectivity, fatigue and so on.

One of the representative automation of red ginseng's quality evaluation is an external quality evaluation. The grade evaluation process by using the image processing replaces the traditional process by manual labor. The grade is estimated by the shape, length of main root and rootlet, numbers of rootlet (Kim et al., 1997, Kim et al., 1998). Additionally, Chang et al. (2001) estimated the surface roughness quantitatively.

To evaluate the internal quality of red ginseng non-destructively, Lee et al. (2001) used NMR spectrometer to use the T1 and T2 values for the red ginseng grade evaluation possibility, and Lim et al. (2002) tried to evaluate the internal quality using the cross section image of red ginseng from Magnetic Resonance Imaging (MRI). Kim et al. (2001) obtain the internal image of internal cavity and normal fresh ginseng using the MRI, and measure the value of T1 and T2 to estimate the status of internal structure.

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Specially, the internal quality of fresh ginseng and softness were estimated using the MRI.

The internal quality is very important for grading evaluation of red ginseng but it is not easy to evaluate the red ginseng nondestructively. However, so far any automation system for evaluating the red ginseng has not been developed yet. The near infrared (NIR) spectroscopic method is very useful for nondestructive evaluation of agricultural products (Ren et al., 1997, Liu et. al., 2003, Fraser et. al., 2003) and many research results have been reported.

In this research, internal quality of Korean red ginseng was nondestructively evaluated by using NIR transmittance.

Materials and Methods

1. Samples

Samples are 450 red ginsengs which are including normal 223 and internal white core 227. Among the total samples, 315 ginsengs are used to develop calibration model and others are used to validate. The internal quality of red ginseng can be classified into normal (Fig. 1 (A), and (B)), internal half white core (Fig. 1 (C), (D)), internal white core (Fig. 1 (E)), and internal cavity with white core (Fig. 1 (F)). Samples for this research were normal, half white core and internal white core red ginsengs, which were sorted by the experts' from the Korea Ginseng Factory at Buyeo, Chungnam in Korea.

2. Consist of NIR system

A halogen lamp (Oslam Co., Germany) was used to transmit the visible and near infrared light through the red ginseng. A flexible fiber optic cable was used to collect the lamp light and to transfer the light to red ginseng. A spectrometer (USB 2000, Ocean Optics Inc., USA) was used to obtain the visible and near infrared transmittance spectrum of internal red ginseng. The system has another fiber optic cable to transfer the transmitted light to spectrometer, and a personal computer system (Pentium 4) to analyze the transmittance spectrum of internal quality and determine the grade.

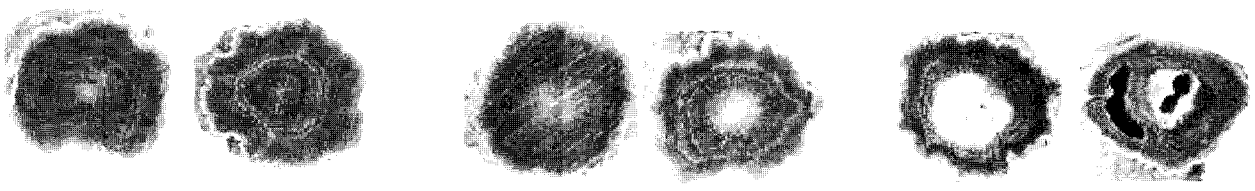
3. Analysis of transmittance spectrum of red ginseng

The tested red ginsengs were classified into normal and internal white core ginseng according to the internal quality. Their visible and near infrared spectrum were measured in the range of 400 and 1,100 nm. Cavity or internal white core was always found in right below region of a rhizome of red ginseng. Thus this region is excluded from the evaluation of internal quality, and 1.5 to 2 cm below from the rhizome was mainly to measure and analyze the transmittance spectrum of red ginseng. Various preprocessing methods such as MSC (Multiplicative Scattering Correction), range normalization, and smoothing were applied to all measured spectra to reduce light scattering, noise of instrument, and so on. Calibration were developed using the Unscrambler software (version 7.6) by Camo. The standard err on of calibration (SEC) and the coefficient of correlation (R) were used to assess the goodness of fit of the calibration. To validate the model, the cross validation method was used. The standard error of performance (SEP) and the coefficient of correlation (R) were used to assess the accuracy of calibration.

4. Performance test

To evaluate the internal quality of red ginseng, there used to be tested with two types of methods which are fixed light intensity and adjusted light intensity. It was investigated the result of internal quality evaluation according to the types of light intensity.

As shown in Fig. 2, large-diameter red ginsengs had a spectrum like (A) and small-diameter ones had a saturated spectrum like (B) at maximum light intensity. To solve the saturation problem in the spectrum of small-diameter red ginsengs, two different spectrum acquisition methods were



(A) (B) (C) (D) (E) (F)

Fig. 1 Samples of Korean red ginseng by internal quality. (A) and (B) : normal, (C), (D) : internal half white core and (E) : internal white core, and (F) : internal cavity with white core.

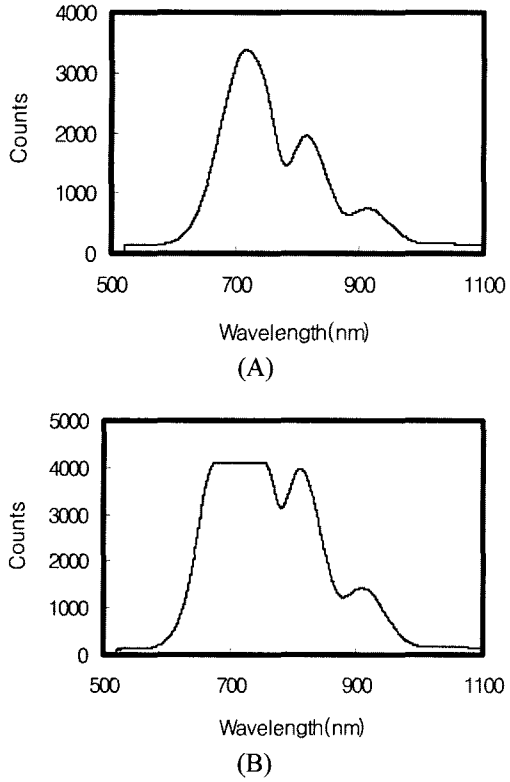


Fig. 2 Transmittance spectrum for internal normal red ginseng. (A) : traditional spectrum pattern and (B) : saturated spectrum.

used in this study. First method used maximum light intensity to acquire the spectrum, and second method used variable light intensity for acquisition of the spectrum of small-diameter red ginsengs. When saturation was occurred, the spectrum was manipulated to get rid of the saturation signal by adjusting integral time.

Results and Discussion

1. Internal quality evaluation of red ginseng by transmittance spectrum

Fig. 3 shows the traditional transmittance spectrum patterns of red ginseng according to internal qualities. The first and second peaks were 730 nm and 800 nm around, respectively. And third peak was 900 nm around. There is a difference between the first and the third peak at each internal quality. The intensity of first peak wavelength of normal ginseng was higher than internal half white core or internal white core ginseng. The internal white core ginseng has lower transmittance ratio than the normal one. As shown in Fig. 3, the quality of the red ginseng has strong relationship with the internal color. Specially, the yellowish brown color of normal ginseng distributed in the red color

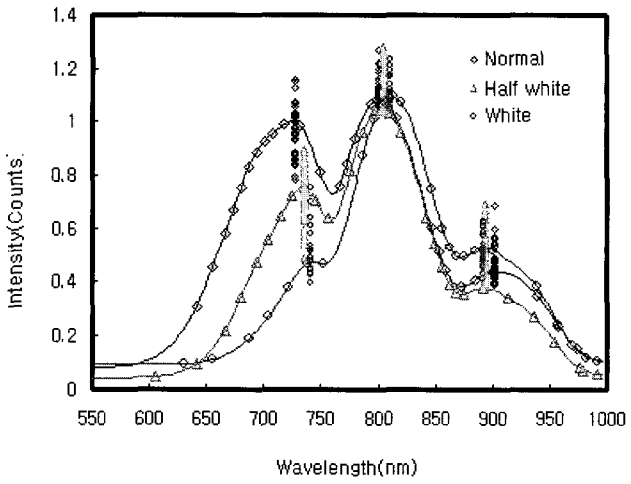


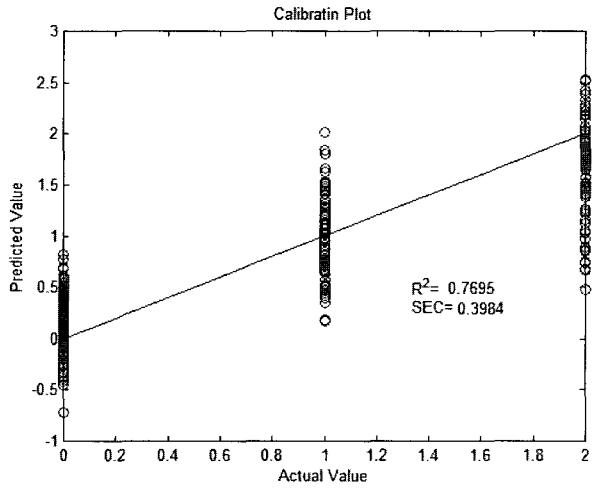
Fig. 3 Traditional transmittance spectrum patterns for Korean red ginseng according to the internal qualities.

region, and maximum peak value was obtained at 730 nm around. However, white core ginseng has weak yellowish brown color, and the peak value is lower than the normal ginseng case.

2. Results of internal quality evaluation of red ginseng by transmittance spectrum

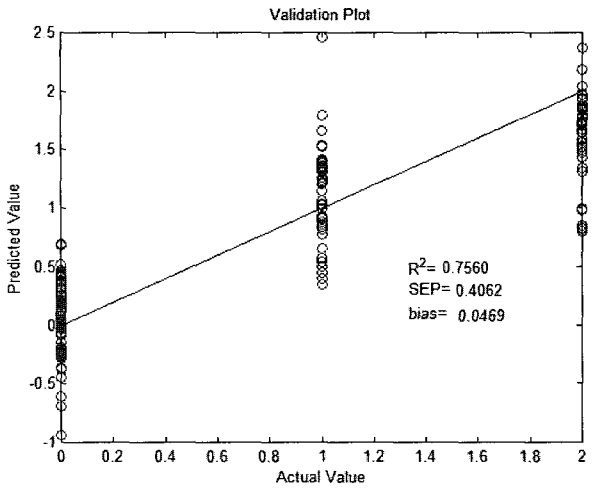
(1) Fixed light intensity

Fig. 4 shows the results of internal quality evaluation of

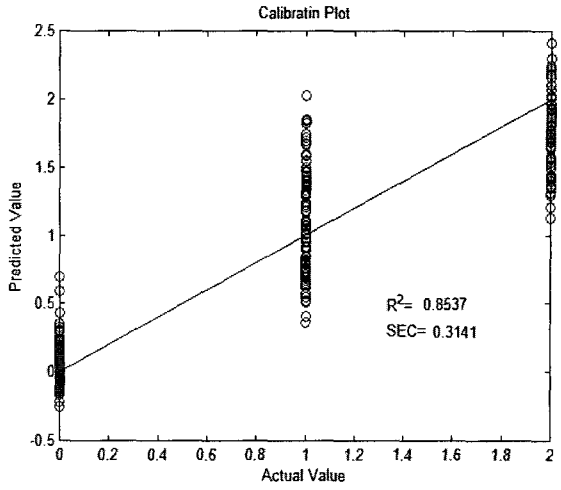


(A)

Fig. 4 Results of internal quality evaluation of red ginseng by fixed light intensity. (A) is a calibration results and (B) is a validation result of the developed prediction model. 0 is internal normal red ginseng, 1 is internal half white core red ginseng and 2 is internal white core red ginseng, respectively. (subsequence)



(B)



(A)

Fig. 4 Results of internal quality evaluation of red ginseng by fixed light intensity. (A) is a calibration results and (B) is a validation result of the developed prediction model. 0 is internal normal red ginseng, 1 is internal half white core red ginseng and 2 is internal white core red ginseng, respectively.

red ginseng by fixed light intensity. There are three grades, normal, half white and white core red ginseng. (A) is a calibration result and showed 0.3984of SEC value. (B) is a validation result of the developed prediction model and SEP and bias were 0.4062 and 0.0469, respectively.

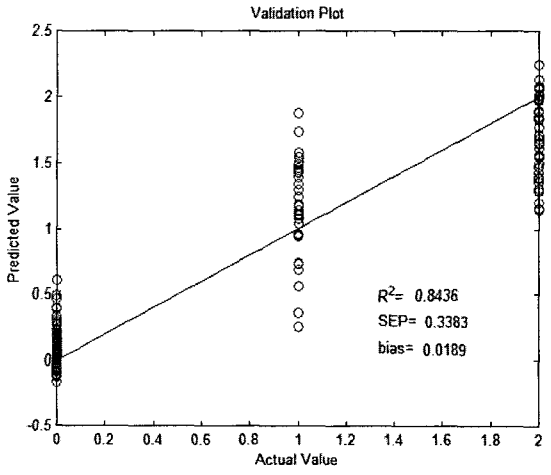
(2) Adjusted light intensity

Fig. 5 shows the results of internal quality evaluation of red ginseng by adjusted light intensity. There were more good result than using by fixed light intensity. SEP and bias were 0.3141 and 0.01899, respectively.

3. Accuracy of internal quality evaluation of red ginseng

Internal quality of red ginseng was graded into three classes : normal, half white, and white. For practical purpose, half white ginseng and white ones were treated as same quality, because they were considered as defect ones. For that reason, decision error was calculated from classification results of normal ginsengs from half white or white ginsengs.

Table 1 shows the result of internal quality evaluation of red ginseng by VIS/NIR spectroscopy. To validate the model, NIR transmittance spectra were acquired again from 135 red ginseng samples. Accuracy of internal quality evaluation was 95.6%.



(B)

Fig. 5 Results of internal quality evaluation of red ginseng by adjusted light intensity. (A) is a calibration results and (B) is a validation result of the developed prediction model. 0 is internal normal red ginseng, 1 is internal half white core red ginseng and 2 is internal white core red ginseng, respectively.

Table 1 Accuracy of internal quality evaluation by adjusted light intensity

Evaluation / Sampl	Normal	Half white core + White core
Normal	65	4
Half whitecore + White core	2	64
Total samples	67	68

Conclusions

A near infrared transmittance method was used to evaluate the internal cavity and white core in a red ginseng. To evaluate the internal quality of red ginseng, there used to be tested with two types of methods which are fixed light intensity and adjusted light intensity. It was investigated the result of internal quality evaluation according to the types of light intensity.

The results of internal quality evaluation of red ginseng by fixed light intensity, calibration showed 0.3984 of SEC value, and validation result of the developed prediction model showed 0.4062 of SEP and bias were 0.0469. Another results of internal quality evaluation of red ginseng by adjusted light intensity were more good result than using by fixed light intensity. SEP and bias were 0.3141 and 0.01899, respectively.

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