Application of near infrared spectroscopy for nondestructive evaluation of protein content in ginseng

Guo-lin Lin, Mi-Ryeong Sohn, Eun-Ok Kim and Rae-Kwang Cho

Deptartment of Agricultural Chemistry, Kyungpook National University, Taegu, 702-701, Korea

Introduction

Ginseng has been regarded, for a very long time, as a secret and expensive medicine in the East Asian countries of Korea, China and Japan. Even two thousand years ago, the medical effects of ginseng were recorded in some ancient Chinese medicine books.

Recently, many ginseng producers and consumers in Korea have been damaged because the low-priced Chinese ginsengs have been disguised as the high-priced domestic ones in the market. There are some traditional factors, such as colour, shape and size, to determine the country of origin by the naked eye. However, there is always a difference between individuals. The shape of Chinese peeled ginseng is very similar to that of the Korean one. It is very difficult to distinguish with the naked eye and the result is uncertain. For this reason, it is necessary to distinguish the place of origin and age of ginseng, rapidly and non-destructively. In a previous study we have already reported on the discrimination of origin and age of ginseng by using near infrared (NIR) spectroscopy.

In this work, we attempted to quantify protein content in ginseng by using NIR spectroscopy.

Materials and methods

Sample collection and preparation

Ginseng radix, the root of *Panax ginseng C. A. Meyer*, was studied. A total of 120 samples were used in this study, which consisted of six sets, 4, 5 and 6-year-old samples of Korea ginseng and 6, 7 and 8-year-old samples of Chinese ginseng, respectively. Each sample set was composed of 20 samples. All samples were prepared as a powder using a cyclone mill (Laboratory mill 120, Perten co.) and filtering with a 0.35 mm sieve.

Chemical analysis

The elemental content was measured using an EA1106 (Carlo Erba, Co.) elemental analyser for oxygen and an EA1108 (Carlo Erba, co.) for other elements such as N, C and H, respectively. The protein content was calculated from the nitrogen content (N) using a factor of 6.25. Conditions for EA were as follows: TCD detector, working in 1000°C for EA 1108 and in 1070°C for EA 1106, 0.1 mg of sample weight.

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Table 1. Mean value of O, C, H and N content in Korean and Chinese ginseng using an elemental analyser.

Elements	China ginseng (%)	Korea ginseng (%)
O	44.0	45.0
C	39.6	39.7
H	6.2	6.0
N	2.1	1.9
Others	8.1	7.4
Total	100	100

NIR analysis

NIR reflectance spectra were collected over the 1100 to 2500 nm spectral region with an InfraAlyzer 500 (Bran+Luebbe, Germany) equipped with a halogen lamp and PbS detector and data were collected every 2 nm data point intervals. The calibration models were carried out by multiple linear regression (MLR), principal component regression (PCR) and partial least squares (PLS) analysis using IDAS and SESAME software.

Results and discussion

Table 1 shows the results of the elemental analysis of Korean and Chinese ginsengs. The elemental contents of O, C, H and N are similar between both sample sets, respectively. The N content of the Chinese set is 2.1%, which is higher than the value of 1.9% for the Korean samples. Table 2 shows the minimum, maximum and mean value of the protein content of Korean and Chinese sample sets. In the Korean sample sets, the nitrogen content tends to increase according to the year of cultivation. The mean values for protein content were 12.52% for 4-year and 12.56% for 6-year old, respectively. In contrast, Chinese sample sets show the opposite results. The value gradually decreased according to the year of cultivation; 13.56% for 6-year old and 9.98% for 8-year old, respectively. Table 3 shows the calibration and prediction results for determining nitrogen content in ginseng by using NIR. We can find different results according to regression methods used and various spectral pre-treatments. The

Table 2. Protein content of ginseng sample sets by elemental analysis.

Sample sets	Protein Content (%)			
Origin	Cultivation years	Minimum	Maximum	Mean
Korea	4	8.55	15.15	12.52
Korea	5	8.76	17.23	12.56
Korea	6	9.28	24.41	13.45
China	6	9.58	18.69	13.56
China	7	9.41	18.08	12.39
China	8	5.16	14.30	9.98

Table 3. Calibration and prediction results of models developed by various regression method and pre-treatment.

Software	Regression	Pre-treatment	*R*	*SEE* (%)	*RMSEP* (%)	Number of Wavelengths/ factors
IDAS	MLR	Absorbance	0.984	0.506	0.717	8
SESAME	MLR	2nd Deriv.	0.972	0.623	0.596	9
	PCR	2nd Deriv.	0.922	1.17	1.120	6
		Normalisation	0.928	0.974	0.944	6
	PLSR	Absorbance	0.956	0.768	0.741	7
		Normalisation	0.969	0.659	0.630	9
		Smoothing	0.956	0.767	0.741	7
		2nd Deriv.	0.965	0.691	0.664	8

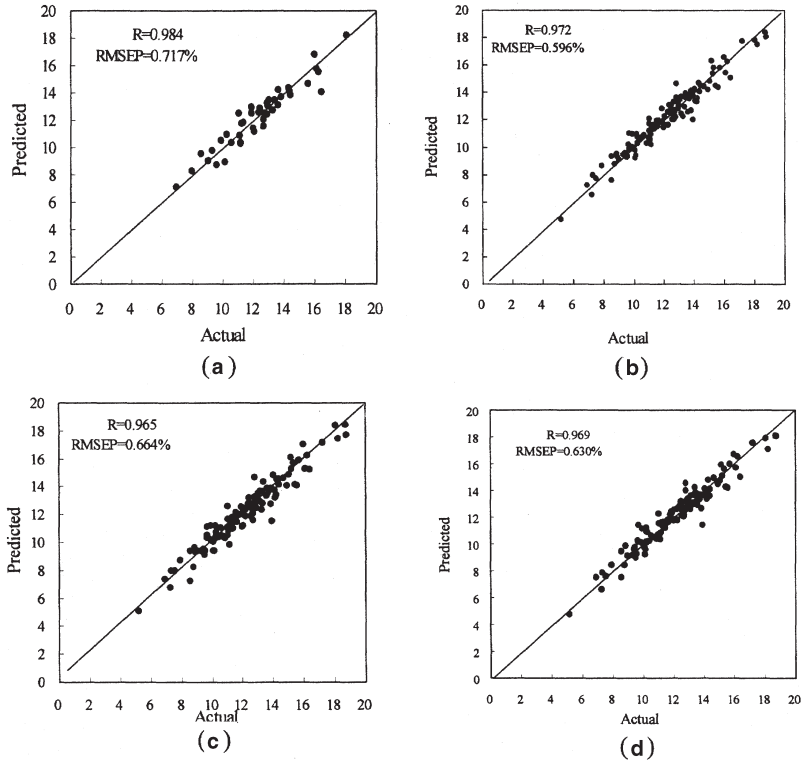

Figure 1. Scatter plots of NIR predicted versus measured protein content in ginseng. Calibration models were developed by different regression and pre-treatment, respectively: (a) MLR (IDAS) and absorbance treatment, (b) MLR (SESAME) and 2nd Derivative, (c) PLSR and 2nd Derivative and (d) PLSR and normalisation.

calibration model by IDAS is a little higher than the one by MLR. When the SESAME software was used, the calibration model was generally accurate in the order of MLR ($R = 0.972$), PLSR ($R = 0.956$–0.969) and PCR ($R = 0.922$–0.928). It was expected that improvement of the calibration model would be obtained by various pre-processing of the spectral data.

For example, *R* and *RMSEP* have the range of 0.9560 – 0.969 and 0.659%–0.767% in calibration models using raw absorbance, normalisation, smoothing and second derivative as the input variables. The best calibration model was obtained using second derivative processing and MLR regression, where *R* was 0.972 and *RMSEP* was 0.596%. The nine wavelengths, 1340, 1412, 1490, 1784, 1862, 1932, 2080, 2204 and 2290 nm were used for this calibration model.

This result indicates that NIR spectroscopy could be used for determine the protein content in ginseng radix with high accuracy. Figure 1 shows the relationship between NIR predicted value and the analysed protein content usind developed MLR calibration models.

Conclusion

The quantification of protein content in ginseng was studied using NIR reflectance spectroscopy and we investigated the effect of regression methods and various pre-processing of the spectral data. The protein content of Korean ginseng tended to increase according to the increase in cultivation years, 4 to 6 years old, but Chinese ginseng showed the opposite result. The accuracy of the calibration model decreased in the order of MLR, PLSR and PCR. The best calibration model was obtained by MLR and a second derivative pre-processing which resulted in 0.972 *R* and *RMSEP* of 0.596% of *RMSEP.*

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