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PII: S0308-8146(96)00363-9

Food Chemistry, Vol. 60, No. 3, pp. 433–436, 1997

0308-8146/97 $17.00+0.00
Analytical, Nutritional and Clinical Methods Section

Determination of moisture content of ginseng by near infra-red reflectance spectroscopy

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(Received 16 August 1996; revised version received 16 November 1996; accepted 16 November 1996)

Near infra-red reflectance (NIR) spectroscopy was used to measure the moisture content in the hot-air dried Asian ginseng (*Panax ginseng*) roots, freeze-dried Asian ginseng roots, red Asian ginseng roots and hot-air dried American ginseng (*Panax quinquefolium*) roots. The convection drying method was used as the reference method. The calibration equation was obtained using the wavelength segment 1100-2500 nm with first derivative and scatter correction. A high correlation was obtained between the two analytical methods ($R^2 = 0.998$), with a standard error of prediction (SEP) of 0.14% for the NIR method. The bias between the two methods was insignificant, being only 0.12%. © 1997 Elsevier Science Ltd

INTRODUCTION

Asian ginseng (*Panax ginseng*) and American ginseng (*Panax quinquefolium*) are the two important herbs in the global medicinal and health food industries. Asian ginseng roots have been used as medicinal material for over 2000 years in China, while American ginseng roots were first added to Chinese medicine in the early 18th century. Recently, ginseng was used for making health foods, such as ginseng candy and ginseng beverage (Ren *et al.*, 1995). Ginseng is now also widely used in Korea, Japan, Hong Kong, Canada, America and many European countries (But *et al.*, 1995). The worldwide annual production of fresh ginseng roots is about 20 000 tons, three quarters of which is Asian ginseng, whereas the rest is American ginseng. Usually, fresh Asian ginseng roots are processed into white Asian ginseng by hot-air drying or freeze-drying, or into red ginseng by steaming and subsequent hot-air drying, while most of the fresh American ginseng roots are processed into white American ginseng by hot-air drying. All these processed ginseng roots are estimated to be worth about 443 million US dollars in 1992 (Ference & Associates, 1991).

Moisture content is one of the most important quality indexes of the processed ginseng roots which should be monitored during the processing and storage. This is because moisture is much related to preserving characteristics. For example, high moisture content may enhance activities of micro-organisms and enzymes in the processed ginseng roots, and consequently reduce both the medicinal and commercial values of the products. At present, moisture content of the processed ginseng roots is measured by the oven-drying method. However, this method is time-consuming, and requires accurate weighing of samples and careful control of heating temperatures and time.

Near infra-red reflectance (NIR) spectroscopy has been used for the determination of moisture content of some agricultural products, such as fruits and vegetables (Gold, 1964) and mushrooms (Roy *et al.*, 1993). This technique is very efficient, one measurement can be completed in several seconds, and it requires only simple preparation of samples. The objective of this study was to assess the potential of the NIR spectroscopy to measure the moisture content of the four differently processed ginseng roots.

MATERIALS AND METHODS

Fresh ginseng roots

The fresh Asian ginseng (*Panax ginseng*) roots and fresh American ginseng (*Panax quinquefolium*) roots were obtained from the Institute of Special Plants and Wild Animals, Chinese Academy of Agricultural Sciences, Zoujia, Jilin City, People's Republic of China.

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Preparation of processed ginseng roots

Hot-air dried Asian ginseng roots: fresh Asian ginseng roots were dried with a hot-air oven at 38°C for 7-8 days.

Freeze-dried Asian ginseng roots: fresh Asian ginseng roots were dried with a freeze-dryer at −53°C and 0.08 Pa for 1–2 days.

Red Asian ginseng roots: fresh Asian ginseng roots were steamed for 2 h, and subsequently dried with a hot-air oven at 60–65°C for 2–3 days.

Hot-air dried American ginseng roots: fresh American ginseng roots were dried with a hot-air oven at 38°C for 7–8 days.

Preparation of ginseng powder

Processed ginseng roots (i.e. hot-air dried Asian ginseng roots, freeze-dried Asian ginseng roots, red-Asian ginseng roots and hot-air dried American ginseng roots) were cut into small pieces, then ground with a blender, and screened using a 200 mesh sieve. The powder samples were prepared at various moisture contents by varying the drying time.

Spectral analysis

Near infra-red reflectance spectra of the ginseng powder were measured using an NIR system (model 6500, Perstorp Analytical Inc, Silver Spring, MD, USA) over a wavelength range of 400-2500 nm, and recorded as the logarithm of the reciprocal reflectance, log(1/R) at 8 nm intervals.

Moisture analysis

After the spectral analysis, the ginseng powder in the sample holder was transferred to an aluminium container, and weighed. The sample was then dried with an oven at 105°C for 4 h, cooled to room temperature, and weighed again. The procedure was repeated until constant weight was achieved.

Data analysis

The Infrasoft international software, NIRS 2, version 3.0 (Infrasoft International, Port Matilda, PA, USA) was used to collect and analyze the data, perform the calibration and validation, and predict the moisture content of the ginseng powder. Modified partial least square regression (factors: 9) (Shenk & Westerhaus, 1991) was used to develop the equations. Scatter correction (SNV) and detrend (particle size correction) were used. The calibration programme was set up with derivative math treatment of 1, 4, 4, 1 (where the first number is the order of the derivative function, the second number is the segment length in data points over which the derivative was taken, the third number is the segment length over which the function was smoothed and the fourth number, 1, means no second smooth).

Table 1. Number of ginseng samples used for calibration and validation

	Calibration	Validation
Hot-air dried Asian ginseng	20	6
Red Asian ginseng	22	7
Freeze-dried Asian ginseng	9	3
Hot-air dried American ginseng	19	6
Total	70	22

RESULTS AND DISCUSSION

As shown in Table 1, all four types of processed ginseng powder were used for calibration and validation. The instrument scanned all wavelengths between 400-2500 nm, which were divided into two segments. Segment 1 was from 400 to 1100 nm and segment 2 was from 1100 nm to 2500 nm. Spectral data of the four types of processed ginseng powder were compared in Figs 1 and 2. As can be seen from the figures, the spectra of all the Asian ginseng powder were similar to those of the hot-air dried American ginseng powder. This may be because the two species belong to the same genus (*Panax* genus) of the Araceace family. It was found that their roots had similar chemical composition (Hou, 1977; Tanaka & Kasai, 1984) and physical properties (Ren *et al.*, 1996), so these two ginseng species might be used together to develop a prediction equation.

As shown in Figs 1 and 2, the moisture of all the ginseng samples had a maximum absorption near 1940 nm which was similar to those found in many other food products (Wehling *et al.*, 1988).

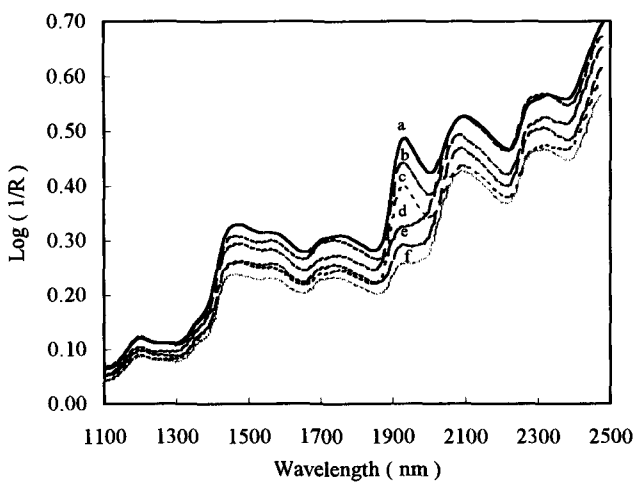

Fig. 1. NIR spectra of the red Asian ginseng powder (a, d), the hot-air dried Asian ginseng powder (b, e) and the freeze-dried Asian ginseng powder (c, f), before (a, b, c, moisture = 9.0%) and after (d, e, f, moisture = 0%) drying.

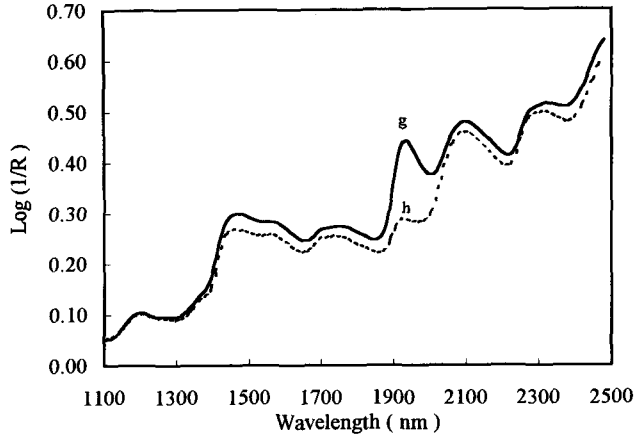

Fig. 2. NIR spectra of the hot-air dried American ginseng root powder, before (g, moisture = 9.0%) and after (h, moisture = 0%) drying.

The average of the NIR spectral data of the 70 processed ginseng samples for calibration is plotted against the wavelength (Fig. 3). The absorption band of the moisture was between 1858 nm and 2004 nm, and the peak of absorption band was at approximately 1938 nm.

Calibration

To determine the wavelength region in which the spectral data were best correlated to the moisture content of the processed ginseng powder, several wavelength regions were chosen to develop the calibration equations (Table 2). The most suitable wavelength was determined according to the performance of the corresponding prediction equations. The smaller standard errors of calibration (SEC), the more suitable wavelengths. The most suitable wavelength region was found to be 1100–2500 nm as within this range, the SEC was only 0.083% which was the minimun compared to that of the other ranges (Table 2).

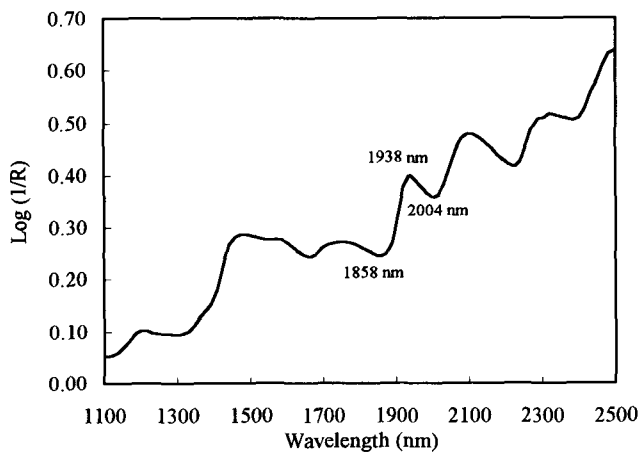

Fig. 3. Average NIR spectra of the 70 processed ginseng samples.

Table 2. Performance of calibration equation from different spectral regions

Wavelength (nm)	SEC (%)	R^2	Factors
1100–2500	0.083	0.998	9
1858–2004	0.087	0.998	9
400–2500	0.115	0.997	9
400–1100	0.332	0.976	9

Table 3. Performance of validation of the best equation

	Bias (%)	SEP (%)
Hot-air dried Asian ginseng	−0.02	0.10
Red Asian ginseng	−0.02	0.14
Freeze-dried Asian ginseng	0.10	0.12
Hot-air dried American ginseng	0.11	0.13
Total	0.12	0.12

Validation

Validation of the 'best' calibration equation was performed with the four types of the processed ginseng samples randomly selected from the total. The prediction errors which were small which are shown in Table 3 and Fig. 4. The standard errors of prediction (SEP) were 0.10–0.14%, and the biases of prediction were in the range of −0.02–0.12%. Compared with the equation ($R^2 = 0.899$, SEP = 0.671%) for the determination of moisture content of the hot-air dried Asian ginseng reported (Cho & Lee, 1995), the equation obtained in this study ($R^2 = 0.998$, SEP = 0.12%) was more accurate and reliable. This is probably because, in this research,

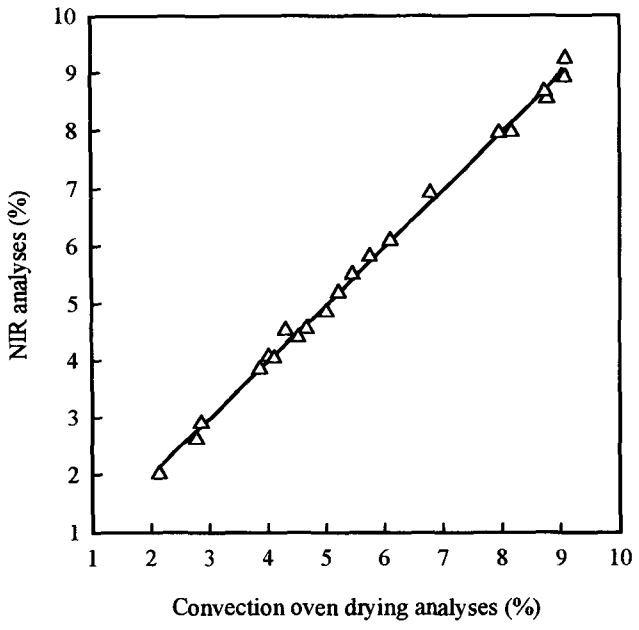

Fig. 4. Validation of moisture content of the ginseng powder (22 samples from the four different types of the processed ginseng were used for the validation).

more ginseng samples were used, and more suitable wavelengths were chosen for the calibration.

CONCLUSIONS

The present study demonstrates the potential of NIR spectroscopy to provide a fast and accurate analysis of moisture content of the four types of processed ginseng roots, including hot-air dried Asian ginseng, freeze-dried Asian ginseng, red Asian ginseng and hot-air dried American ginseng. With this method, sample preparation is simple; the measurement can be finished in several seconds, and the SEP is not more than 0.14%. The equation obtained from this study would be used for the quality monitoring and control of the processed ginseng roots.

ACKNOWLEDGEMENTS

The authors wish to thank Dr R. J. Xu for allowing them to use his equipment for this research. The financial supports of CRCG (the University of Hong Kong Committee on Research and Conference Grants) and RGC (the Hong Kong Research Grants Council) are gratefully acknowledged.

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