Non-destructive analysis of β–carotene and vitamin E in pumpkin

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Introduction

Pumpkin, also known as cushaw or summer squash, has been a favourite vegetable as well as a medicinal plant for many kinds of diseases since olden times.[1] The high content of various nutrients, especially β-carotene and vitamin E, has made this vegetable more and more attractive in terms of health protection.[2] A series of food products for health care as well as for babies and infants have already been developed.[3]

Nevertheless, the quantity of β-carotene and vitamin E varies considerablywith different cultivars of pumpkin. As indicated by our results, the value for β-carotene ranged from 0.1 to 8.91 mg g^{-1} fresh weight (f w), while that for vitamin E may be as high as 1.4 mg g^{-1} fw or as low as undetectable. It follows that each line of plant material must be evaluated for these two kinds of nutrients before they are used further in breeding or food processing. However, due to the inefficiency and high expense of conventional analytical methods, a simple and fast method is desired for the large amount of samples needed in research. In this regard, near infrared (NIR) spectroscopy complies fully with these requirements.[4–6] Our results of the analysis of β-carotene, as well as vitamin E, in pumpkin using non-destructive NIR methods are presented here.

Materials and methods

Samples

A total of 60 samples of pumpkin were collected, including 13 from Japan, Korea, Burma, Spain, Mexico, India, Yugoslavia, Zambia and 47 cultivars around China and Beijing, respectively.

Chemical analysis

β-carotene content of the pumpkin was determined by HPLC method (Waters. Co. Maximax 820); the detector used was the UV/vis 490E. Vitamin E content was determined by the fluorescence method, EX = 296 nm, EM = 325 nm.

NIR spectra acquisition

The NIR spectrometer used in this experiment was a commercially available Pacific Scientific model 6250 (NIR Systems Inc., Silver Spring, MD, USA). The spectral data of β-carotene and vitamin E were generated in the wavelength range from 1100 nm to 2500 nm.

Table 1. The range of β-carotene and vitamin E values in pumpkin

	Calibration		Prediction	
	β-carotene	Vitamin E	β-carotene	Vitamin E
Samples	40	40	20	20
Range	6.7–140.5	0.107–1.398	13.0–129.7	0.10–1.255
Average	77.83	0.483	68.84	0.474
CV	42.67	0.251	36.31	0.279
Unit	μg g.d.w.$^{-1}$	mg 100 g.f.w.$^{-1}$	μg g.d.w.$^{-1}$	mg 100 g.f w.$^{-1}$

g.d.w = gram dry weight; g.f.w. = gram fresh weight.

Data analysis

Multiple linear analysis were conducted using the NSAS data analysis software (NIR Systems Inc.).

Results and discussion

Because of the poor relativity between these two components in the 60 samples, the combinations of sample for calibration and prediction were based on their different gradients of content. The sample distribution and range of β-carotene and vitamin E content in the pumpkins are concerned with the quality evaluation and presented in Table 1.

Based on the chemical values (HPLC method and fluorescence method), a mathematical pattern of quantitative analysis in NIR was established, by using two equations of regression to evaluate the feasibility of the NIR method.

$$\mathbf{Y} = \mathbf{K}_0 + \mathbf{k}_l l(\lambda_1) + \mathbf{k}_2 1(\lambda_2) + \mathbf{k}_3 1\ (\lambda_3) + \mathbf{k}_4 1(\lambda 4) \quad (1)$$

$$\mathbf{Y} = \mathbf{k}_0 + \mathbf{k}_1 1(\lambda_1)/1(\lambda_{2)} + \mathbf{k}_2 1(\lambda_3)/1(\lambda_4) \quad (2)$$

$\mathbf{K}_0$: regression constant; $\mathbf{K}_{1\text{–}4}$: regression coefficients.
$\mathbf{L}(\lambda)$: log $1/R_{(\lambda)}$, d log $l/R_{(\lambda)}$, d^2 1og $l/R_{(\lambda)}$, λ: wavelengths

The results of the first derivative and second derivatives of two equations of regression are compared as shown in Table 2.

The best results were observed using the first derivative and four wavelengths for β-carotene and vitamin E which not only had good multi-correlation but also a low standard error of prediction.

The main parameters of β-carotene and vitamin E in pumpkin using NIR are presented in Table 3 and Figures 1–4.

According to the equation:

$$\mathbf{Y} = \mathbf{K}_0 + \mathbf{K}_1 \mathrm{d}\ (\log 1/R_{,\lambda 1}) + \mathbf{K}\mathrm{d}\ (\log 1/R_{\lambda 2}) + \ldots + \mathbf{k}_n\ \mathrm{d}\ (\log\ l/R_{\lambda n}). \quad (3)$$

A pumpkin sample can finish determining the two components in a minute.

Figures 1–4 show the relationship between NIR and chemical methods for β-carotene and vitamin E for calibration and prediction in pumpkins. They have a good linear relationship.

Table 2. Regression data of the two components.

	Math	Wavelengths	MR	*SEC*	*R*	*SEP*	Bias
Vitamin E	1D	1788	–.7278	0.174	0.798	0.768	0.03
	(1)	1788, 2246 1788, 2246, 1450 1788, 2246, 1450, 1798	0.9000 0.9820 0.9956	0.112 0.049 0.025	0.945 0.979 0.998	0.090 0.060 0.020	0.02 0.02 –0.01
	(2)	2094/1770 2094/1770 1930/1766	0.9608 0.9733	0.073 0.061	—	—	—
	2D	1586	–0.6244	0.199	—	—	—
	(1)	1586, 2066 1586, 2066, 2428 1586, 2066, 2428, 2152	0.8380 0.9320 0.9524	0.141 0.095 0.081	—	—	—
	(2)	1586/2434, 2038/2152 1896/1970, 2034/2312	0.9264 0.9621	0.097 0.072	—	—	
β-carotene	1D	1990	0.7233	29.80	0.610	28.0	11.3
	(1)	1990 1874 1990, 1874, 1530 1990, 1874, 1530, 2358	0.8895 0.9635 0.9980	20.00 11.90 2.870	0.881 0.969 0.996	17.2 9.00 3.08	6.29 2.94 0.20
	(2)	1990/1698, 1672/2368 1574/1762, 1972/1524	0.9054 0.9660	18.60 11.60	—	—	—
	2D	2116	0.4120	39.50	—	—	—
	(1)	2116, 2154 2116, 2154, 2086 2116, 2154, 2086 2012	0.7636 0.8926 0.9615	28.40 20.00 12.40	—	—	—
	(2)	2006/2152, 2146/1542 2186/2344, 2318/1372	0.9172 0.9511	17.50 14.00	—	—	—

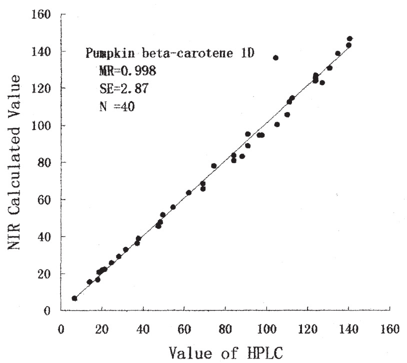

Figure 1. Relationship between NIR and HPLC methods for beta-carotene content in pumpkin.

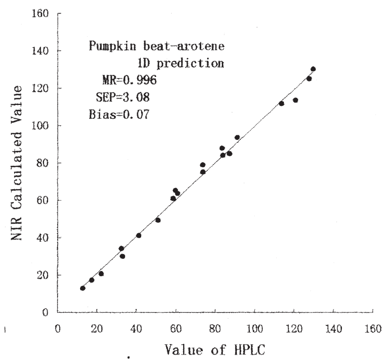

Figure 2. Prediction of beta-carotene content in pumpkin.

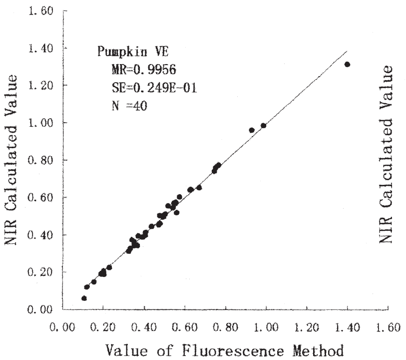

Figure 3. Relationship between NIR and fluorescence methods for beta-carotene content in pumpkin.

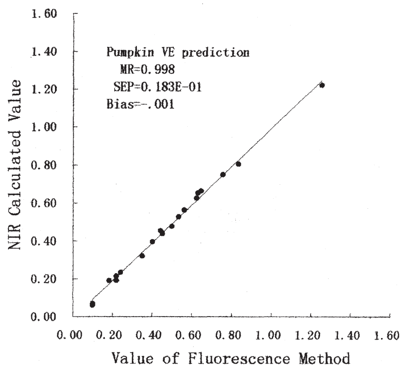

Figure 4. Prediction of vitamin E content in pumpkin.

Table 3. The principal data of the mathematical pattern using NIRS.

	β-carotene	Vitamin E
Math treatment	1D	1D
Wavelength selected ($\lambda_{1\text{–}4}$)	1990,1874,1530,2358	1788,2246,1450,1798
$\mathbf{K}_0$	20.022	–0.20
$\mathbf{K}_1$	49345.4	–1482.04
$\mathbf{K}_2$	42964.2	–172.25
$\mathbf{K}_3$	54337.2	205.005
$\mathbf{K}_4$	–33105,4	662.08
MR	0.9980	0. 9956
SEC	2.8 µg g.d.w.$^{-1}$	0. 025 mg 100 g.f.w.$^{-1}$
R	0.996	0.998
SEP	3.08 11 g/g. d. w	0.02mg/100g.f w.
Bias	0.203	–0.01

$\lambda_{1\text{–}4}$. Wavelengths
$\mathbf{K}_0$: regression constant
$\mathbf{K}_{1\text{–}4}$: regression coefficients
MR: multiple correlation coefficient of calibration
SEC: standard error of calibration
R: correlation coefficient of prediction
SEP: Bias-corrected standard error of prediction.

Conclusion

This study shows that NIR is a feasible method for the non-destructive analysis of β-carotene and vitamin E in pumpkin. Compared with chemical analysis, NIR not only has similar accuracy and precision, but also other advantages. With these merits, the results we have obtained can be applied to the nutritional quality evaluation, quality breeding, species resources identification and health food processing of pumpkin.

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