Non-destructive estimation of soluble solids in intact melons by non-contact mode with a fibre optic probe

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Introduction

When soluble solids (°Brix) in intact fruits was measured non-destructively by near infrared (NIR) spectroscopy with a fibre optic probe, each fruit was placed on the end of the fibre optic probe (light receptor) so that the desired fruit location was centred on, and in direct contact with, the fibre optic probe ("contact mode").[1,2] The flesh in the blossom end of melon fruit is thinner than that in other parts. This suggests that °Brix of the flesh in the blossom end may be predicted by NIR with a fibre optic probe. But, in the case of measuring spectra of the blossom end, its surface and the end of the fibre optic probe can not be contacted all of fruits because of the hollow at the blossom end and the distance between the surface of the blossom end and the end of the fibre optic probe which influences the absorbance.

Even if the sensitive surface of the detector does not touch the surface of the melon, its spectrum can be measured ("non-contact mode") and the *SEC* was 0.82 %.[3] Therefore, the objective of this study was to determine if non-contact mode could improve the standard error (*SEC* and *SEP*) of the predicted °Brix of the flesh in the blossom end of melon fruit as well as with the contact mode.

Materials and methods

The netted melon cultivar,'Andes' (Sakata seed, Japan), which was used in this study was grown at NIVOT. The optical absorption spectrum was measured using a NIRSystems model 6500 spectrophotometer (Silver Spring, MA, USA) equipped with a fibre optic probe. The fibre optic probe had a concentric outer ring illuminator and an inner ring receptor. Light emitted by the outer ring enters the fruit and interacts with the tissue. Some of the non-absorbed light is internally reflected and exits the fruit to be collected by the inner ring receptor. To measure the optical absorption spectrum, each fruit was hand-placed on, or 2–4 mm apart from, the end of the fibre optic probe (the former is "contact mode", the latter is "non-contact mode") so that the blossom end was centred. A commercial spectral analysis program NSAS ver 3.27 (NIRSystems, Silver Spring, MA, USA) was used for multiple linear regression analysis. The wavelength region used for the analysis was 750 to 1100 nm, with 2 nm intervals. The original spectra were converted to the second derivative spectra with a segment size of 10 nm and gap size of 2 nm. Following optical measurement, a piece of tissue was cut out from the blossom end with a cork borer (diameter 18 mm). To obtain its juice, the tissue was comminuted with a grater and centrifuged. °Brix of the juice was determined using a temperature compensated refractometer. Moreover, the individual simple sugars (sucrose, glucose and fructose) were determined by HPLC.

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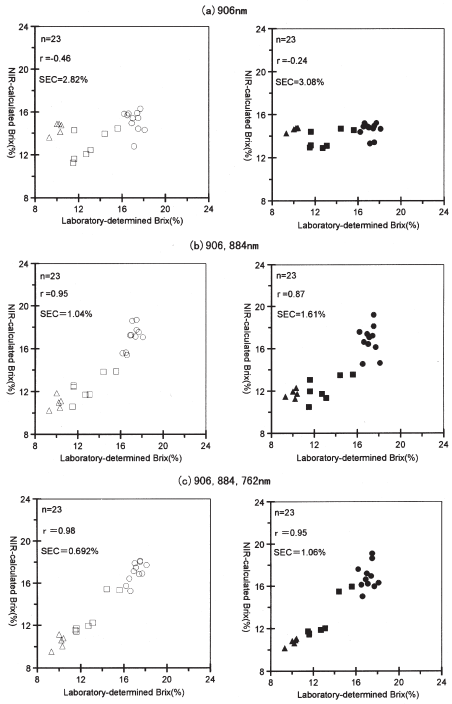

Figure 1. Plots of laboratory-determined Brix v. NIR-calculated Brix for melons in the calibration data set (*n* = 23). ❍□ : non-contact mode, ●■▲: contact mode (usual method). Seedling: ❍● 2/2/98, □■ 12/2, ▲ 24/2. Harvest 8/6/98.

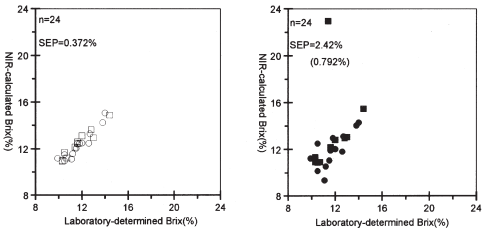

Figure 2. Plots of laboratory-determined Brix v. NIR-calculated Brix for melons in the validation data set (*n* = 24). ❍□: non-contact mode, ●■: contact mode (usual method). Seedling: ❍● 21/7/98, □■ 28/7, Harvest 4/10/98. Wavelengths: 906, 884 and 762 nm. Where ( ): *SEP* eliminated the one sample where the difference between laboratory-determined Brix and NIR-calculated Brix was biggest in the validation sample set.

Results

When the results for the contact mode and the non-contact mode are compared, the latter mode improved the former standard error. When spectra of melon were measured by contact mode, the standard error in the high °Brix area of the calibration sample set was larger than that in the low °Brix area. But the non-contact mode improved the standard error mainly in the high °Brix area (Figures 1 and 2). These regression equations for °Brix prediction can be written as follows:

Contact mode: NIR-calculated °Brix value (%) =
10.062–1820.161(906 nm) + 6063.542(884 nm) + 195.532(762 nm)
Non-Contact mode: NIR-calculated °Brix value (%) =
7.397–3008.493(906 nm) + 11950.570(884 nm) + 198.881(762 nm)

The combination of the wavelengths selected in these regression equations for °Brix could predict also sugar content (total quantity of sucrose, glucose and fructose) that accounted for 70 to 90% of the °Brix value (Table 1).

Discussion

The °Brix range of the calibration data set is much larger than would be found in normal eating quality, since we examined fruit with a wide range of maturity and ripeness. A high °Brix range for the validation data set could not be obtained because of the high temperature during cultivation.

Usually, individual cultivar calibrations are successful while predicting °Brix in the same cultivar's validation data set within the same season.[4] Therefore, we tried to validate other lots (fruits from different season) as a validation data set. Nevertheless, non-contact mode also improved the *SEP* of contact mode.

Table 1. Results of calibration and prediction for determining Brix and sugar[a] of the flesh in the blossom end of melon fruits.

Wavelength[b] (nm)	Non-contact mode						Contact mode (usual method)					
	R^b		SEC^c		SEP^e		R		SEC		SEP	
	Brix	Sugar	Brix	Sugar	Brix	Sugar	Brix	Sugar	Brix	Sugar	Brix	Sugar
906	–0.46	–0.45	2.82	2.46	1.15	1.20	–0.24	–0.26	3.08	2.66	1.19 (1.22)[f]	1.30 (1.33)[g]
906, 884	0.95	0.93	1.04	1.01	0.53	0.655	0.87	0.84	1.61	1.53	2.05 (0.953)	1.93 (1.11)
906, 884, 762	0.98	0.97	0.692	0.741	0.372	0.615	0.95	0.94	1.06	1.03	2.42 (0.792)	2.26 (0.982)

[a]Total quantity of sucrose, glucose and fructose
[b]Wavelength selected in each regression equation
[c]Multiple correlation coefficient of the calibration sample set
[d]Standard error of the calibration sample set
[e]Bias-corrected standard error of the validation sample set
[f,g]SEP eliminated the one sample that difference between laboratory-determined Brix and NIR-calculated Brix was biggest in the validation sample set

The individual simple sugars in the juice were determined by HPLC; the relationship between ethanol extraction (x) and squeezing method (y) on sugars (sucrose, glucose and fructose, respectively) determination was $r = 0.991$ with the regression equation $y = 1.06\,x + 0.08$.[5]

Interpretation of NIR models is difficult when dealing with models that involve many wavelengths. But 906 and 884 nm were selected as first and second wavelength, respectively, in each regression equation for °Brix and sugar. These selected wavelengths agreed with the result reported by Dull *et al*.[6] They had selected 913 nm as a numerator and 884 nm as a denominator for determining soluble solids in sliced cantaloup.[4] Other researchers had also selected these nearby wavelengths for °Brix prediction in onions,[7] peaches[1,2,4] and nectarins.[2] In addition, sugar content accounted for 70 to 90% for °Brix and R, SEC or SEP of °Brix and sugar were almost the same in contact mode and non-contact mode, respectively. It can thus be concluded that the combination of the wavelengths selected in each regression equation included mainly information of sugar content.

As the distance (0 to 6 mm) between the surface of the blossom end and the end of the fibre optic probe is bigger, those absorbances are nearer to its 0 value (Figure 3). Nevertheless

Figure 3. The 2nd derivative spectra of an intact melon (no hollow on the blossom end) set at five different distances (0, 1, 2, 4 and 6 mm) between the surface of the blossom end and the end of a fibre optic probe. As the above line is narrower, its distance is bigger.

compared with contact mode and non-contact mode, the latter mode improved the former standard error. When the distance between the surface of the blossom end and the end of the fibre optic probe was 2 and 4 mm, their NIR-calculated Brix values for non-contact mode were almost the same (15.514 and 15.301, respectively). On the other hand, when distance between the surface of the blossom end and the end of the fibre optic probe was 0, 1 and 2 mm (the depth of the hollow is usually 0 to 2 mm), their NIR-calculated °Brix values for contact mode were 14.338, 13.976 and 13.232, respectively. This may suggest that the standard error of contact mode is larger than that of non-contact mode because of the hollow on the blossom end. In the future, the behaviour of near infrared light to melons should be elucidated.

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