Non-destructive determination of soluble solids and flesh firmness in nectarines by near infrared spectroscopy

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Introduction

Peach and nectarin fruits are traditionally graded on the basis of such external appearance factors as skin colour, fruit shape, absence of defects, commercial size and so forth, which are currently determined by machine on a given number of fruits. Other parameters, which may better fit consumers expectations, are represented by internal characteristics like sugar, acidity and starch content—traits traditionally determined in a destructive manner. However, non-destructive methods using near infrared (NIR) spectroscopy to evaluate parameters for estimating maturity have been used on several fruit species (orange, peach, apple, blueberry, papaya, kiwifruit, persimmon).[1–11]

NIR determination of soluble solids content (SSC or °Brix) and flesh firmness (FF), traditionally the most common parameters used to establish harvest date as well ripening changes in field and cold storage, has already been employed on a commercial grading machine in Japan.[12,13] The present study reports the initial results recorded with an NIR instrument used to estimate SSC and FF in nectarine fruits.

Materials and methods

Equipment

A commercial, single-beam spectrometer (Ocean Optics S-2000, Giotto High Technology, Italy) featuring a standard diffraction grating (650–1200 nm, near infrared) was employed. The light was generated by a tungsten halogen lamp (360 nm—2 microns, with a colour temperature of 2960°K), coupled to a bundle consisting of six 200 μm optical fibres and carried to the probe end: the sample selectively reflects light back into a seventh fibre that transfers the information to the spectrometer. The probe end is a stainless steel cylinder, 50 mm long × 6.35 mm in diameter: the reflection head is positioned on the fruit surface and a sponge ring surrounding the probe head touching the fruit ensures that only the light reaching the probe is reflected by the fruit; the probe head was also placed inside a black box to prevent external light interfering with the measurements.

For data acquisition the spectrometer interfaces to a PC via an analog-to-digital converter card (the ADC-500 is an ISA-bus compatible 12-bit A/D card for use with benchtop spectrometer with a 500 kHz A/D frequency). Card selection depends on the spectrometer platform and the operating software can modify the spectrometer setup and store the spectra. Each spectrum was recorded as log (1/*R*), where *R* is reflectance, by averaging 10 scans.

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Table 1. Calibration and prediction data sets of nectarine fruits used for the experiment.

Trait	Data set for	Mean	Min.	Range	SD
Brix	Calibration	10.5	8.3	4.6	1.22
	Prediction	10.6	8.6	4.0	1.01
Flesh Firmness	Calibration	6.2	3.0	9.4	1.75
	Prediction	6.2	3.0	6.5	1.54

Plant material

Fruits of the nectarine cvs. 'Weinberger' and 'Springred' were kept under cold storage and used for the NIR readings and destructive analysis at room temperature. After NIR readings, and on the same side of each fruit where FF was recorded, a cylindrical core of flesh was removed for juice and SSC determination by an Atago digital refractometer.

Regression analysis

The spectrum counted 1000 values in the range of 650–1200 nm, and the readings, taken at an interval of 0.3 nm, were used for both calibration and prediction. A segment of 4 nm, chosen to reduce the number of selected wavelengths, was tested to calculate the log (1/*R*) spectra: a segment represents the number of points that are averaging at a given wavelength.[2]

The first derivative was used as the independent variable in the regression, where SSC and FF values were dependent variables. On the calibration set, the standard NIR analysis procedures, multiple linear regression (MLR) and forward stepwise analysis, were performed using an SAS statistical package that allowed the software to select the best equation fit for the studied phenomena; the equation calculated on the calibration data set was applied to the prediction data. The standard errors for calibration (*SEC*) and prediction (*SEP*) were determined as reported in literature.[11,7,14]

Results

The calibration and prediction statistics for the SSC and FF data are reported in Table 1; the spectrum and the first derivative are reported in Figures 1 and 2. The analysis yielded a value of R^2 of 0.66

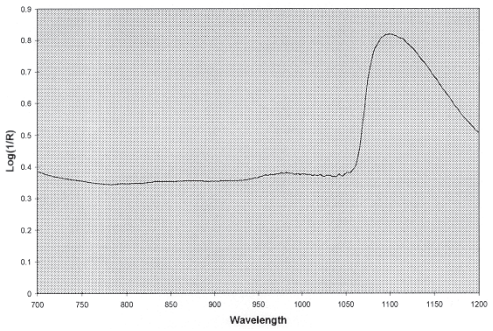

Figure 1. NIR spectra of intact nectarine fruit.

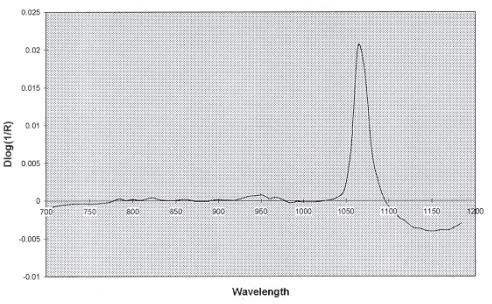

Figure 2. First derivative spectra of intact nectarine fruit.

Table 2. R^2, standard error of calibration and prediction and bias calculated for brix and flesh firmness.

Trait	R^2	*SEC*	*SEP*	BIAS
Brix	0.66	0.81	0.72	0.001
Flesh firmness	0.75	0.93	0.87	–0.0004

for the former and of 0.75 for the latter (Table 2). The scatter plots of the values measured for SSC vs the SSC values estimated by NIR and the scatter plots of the FF values are reported in Figures 3 and 4. Both the SSC and FF prediction data were similar to the data collected destructively, the latter being taken as the reference measurement. The *SEC* for °Brix determination was 0.81°Brix (R^2 = 0.66) and the *SEP* for the wavelength selection was 0.72°Brix (Figure 3); twenty near infrared wavelengths of the original 91 point spectra in the 850 to 1139 range were used. The *SEC* for FF was 0.93 kg cm^{-2} and the *SEP* for wavelength selection was 0.87 kg cm^{-2} (Figure 4); 12 near infrared wavelengths of the original 91 point spectra in the 858 to 1122 range were employed.

Discussion

The given range of nectarine fruit samples and the standard NIR data analysis procedures employed on the spectra made it possible to predict measured values of SSC and FF with a standard error of 0.72 and 0.87, respectively. While these preliminary results yield a sufficiently accurate estimation of both values, note that part of the reported variation is probably due to errors in the destructive measurements employed.

The number of selected wavelengths employed in the present study is higher than the number selected in similar studies,[11] especially for the SSC determination and the conversion of an NIR spectrum to a sugar concentration or flesh-firmness value does not involve so many mathematical steps as to make it unmanageable for current computer software packages in term of difficulty and time. It should also be noted that it is possible to predict the component concentration by a single NIR reading.[7]

The methodology employed in the present experiment involved stationnary fruits, although as *supra*[12,13] NIR systems can be mounted on standard commercial sorting machines for prediction in peach, apple and nashi—fruits whose thin peel make it possible to read several parameters, for exam-

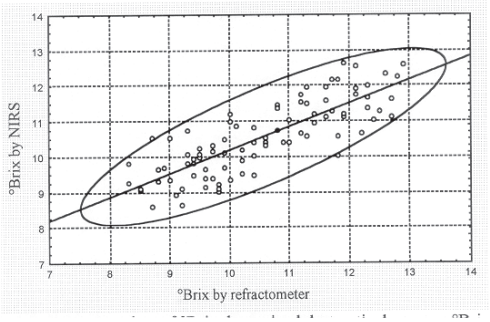

Figure 3. Scatter plots of °brix determined destructively v. °brix values estimates by NIR.

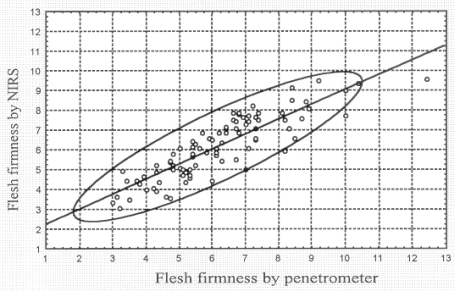

Figure 4. Scatter plots of flesh firmness determined destructively v. flesh firmness values estimated by NIR.

ple, sugar, FF and probably acidity, at the same speed as that used to size fruits. Given, too, that the device is portable, NIR may be employed even in the field to establish a more precise evolution of the changes in certain ripening parameters on the same fruit samples.

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