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Influence of environmental and instrumental variables on the non-invasive prediction of Brix in pineapple using near infrared spectroscopy

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Summary. The Brix content of pineapple fruit can be non-invasively predicted from the second derivative of near infrared reflectance spectra. Correlations obtained using a NIRSystems 6500 spectrophotometer through multiple linear regression and modified partial least squares analyses using a post-dispersive configuration were comparable with that from a pre-dispersive configuration in terms of accuracy (e.g. coefficient of determination, R^2, 0.73; standard error of cross validation, SECV, 1.01°Brix). The effective depth of sample assessed was slightly greater using the post-dispersive technique (about 20 mm for pineapple fruit), as expected in relation to the higher incident light intensity, relative to the pre-dispersive configuration. The effect of such environmental variables as temperature, humidity and external light, and instrumental variables such as the number of scans averaged to form a spectrum, were considered with respect to the accuracy and precision of the measurement of absorbance at 876 nm, as a key term in the calibration for Brix, and predicted Brix.

The application of post-dispersive near infrared technology to in-line assessment of intact fruit in a packing shed environment is discussed.

Additional keywords: *Ananus comosus*, fruit quality, humidity, pre-dispersive, post-dispersive, scans, temperature.

Introduction

Near infrared spectroscopy (NIRS) is widely used for the identification of organic compounds, and has found increasing use for the non-invasive quantification of organic constituents within biological material. For example, the technique is widely used in the Australian grains, forage and oil seeds industry (e.g. assessment of protein and moisture contents). In Japan (Mitsui Mining and Smelting Corp., Omiya, and Maki Manufacturing Co., Hamamatsu), commercial in-line near infrared (NIR) sensors are being used in packing sheds to assess the sweetness, ripeness and acidity of relatively smooth and thin skinned temperate fruits (citrus, apples, pears and peaches), at 3 pieces per second per lane (Kawano 1994). These units are not commercially available in Australia.

The thick, rough skin of pineapple fruit is expected to compromise the application of the technique to the assessment of Brix in this fruit. Shiina *et al*. (1993), Guthrie and Walsh (1997) and Guthrie *et al*. (1998) have reported the development of calibrations for Brix in pineapple fruit, under laboratory conditions. The error of prediction (SEP), however, was higher in these studies than those reported for thin skinned fruit.

The application of the NIRS technique to the prediction of pineapple Brix in a packhouse setting, as opposed to a laboratory setting, will involve additional sources of error. For example, the ability of a NIR spectroscopic system to predict the Brix of fruit will be influenced by the effect of environmental parameters (e.g. light, temperature, humidity) of the sample on the NIR spectrum (a spectroscopic problem), by characteristics of the illumination system (e.g. effective depth of fruit from which information is acquired, use of ‘white’ or monochromatic incident light), by the effect of

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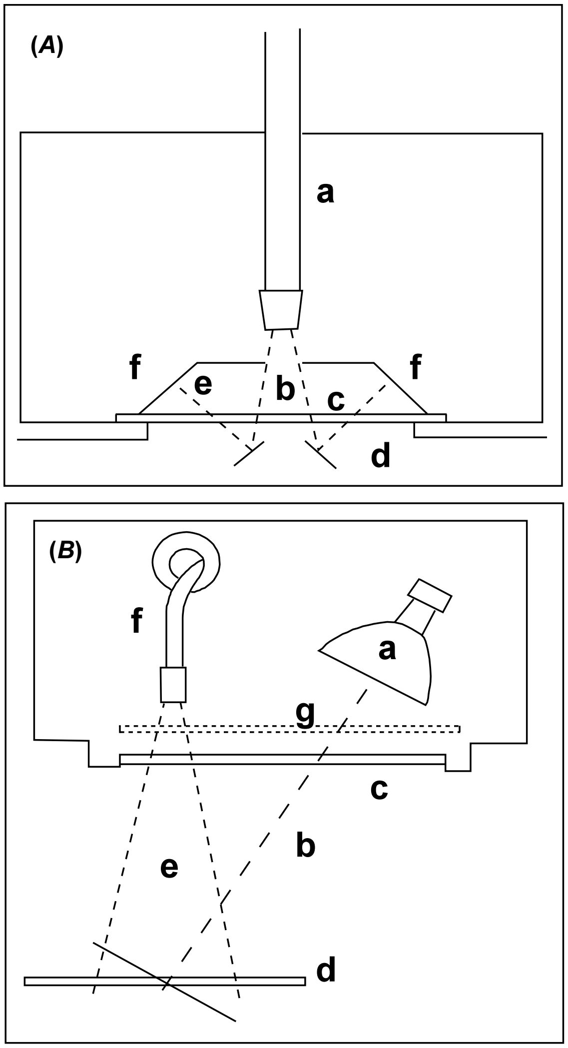

Figure 1. Schematic diagram of sample presentation to pre- and post-dispersive instrument configurations (NIRSystems 6500). (*A*) Remote reflectance fibre optic probe employs monochromatic light generated by a scanning monochromator conveyed via a fibre optic bundle (a). Light leaves the fibre optic, radiates at 22° (a function of the numerical aperture of the fibre), passes a slit (b) and a quartz glass window (c) before interacting with the sample (d). The direction of incident light is perpendicular to the sample surface. Diffusely reflected radiation (e) is measured by detectors (f) mounted at 45° to the sample surface. Two lead sulfide detectors and one silicon detector are mounted on each side of the incident light slit. The sample (d) was positioned adjacent to the quartz glass window (c). (*B*) Direct light sensing head employs white light generated by a 75 W tungsten halogen lamp (a). The incident white light (b) was directed at the sample surface (d) immediately under the fibre optic (f). The sample was positioned 7 cm from the quartz glass window (c). Diffusely reflected light (e) was conveyed via the fibre optic (f) to a scanning monochromator and detector system. A ceramic reference (g) is pneumatically positioned under the lamp and fibre optic between sample measurements.

environmental parameters such as temperature and humidity on the instrument, and by performance characteristics of the spectrometer (e.g. signal : noise ratio, reflecting mechanical considerations such as grating positioning, electronic considerations such as detector dark current and A/D conversion of data and optical considerations such as stray light within the spectrometer). The post-dispersive mode should offer advantages over the pre-dispersive mode with in-line applications because light intensity is lost in passage over the diffraction grating (for a concave holographic grating, as used in the NIRSystems 6500, maximum light transmission is typically 30% at the blaze wavelength). Thus the post-dispersive system has the advantage of delivering a higher intensity of all wavelengths onto the sample, improving the effective depth of penetration into the sample. Also, external light around the sample will have less effect on the detector response. While NIRS is in commercial use in Japan, there is little published consideration of the effect of such variables for the prediction of fruit quality attributes. In this study, we consider the influence of these parameters on the assessment of pineapple fruit Brix, with a view to the application of NIRS to the sorting of pineapples for Brix content in an in-line setting.

Materials and methods

Plant material and constituent analysis

The pineapples [*Ananas comosus* (L.) Merrill, var. Smooth Cayenne] used in the experiment were grown commercially on a Yeppoon, Central Queensland farm, and transported to the laboratory on the day of harvest. Spectra were acquired after sample temperature equilibration and within 3 days of harvest, in an air-conditioned laboratory at 22–24°C. After scanning, a 60 mm diameter stainless steel corer was used to excise both skin and underlying flesh to a depth of 20 mm. The skin was subsequently removed and the flesh squeezed manually through a nylon cloth to extract the juice. The extracted juice was measured for Brix content using an Erma digital refractometer (accuracy ± 0.2°Brix).

Near infrared spectrometry

A scanning monochromator (Model 6500, NIRSystems, Silver Springs, MD, USA) driven by NSAS software (Version 3.3, NIRSystems) was used in 2 configurations. In the 'pre-dispersive' configuration, light from a 75 W tungsten halogen lamp passes through a slit and is dispersed by a moving grating. The dispersed light passes through order sorting filters, with the primary spectrum delivered via a 1.6 m fibre optic cable to a remote reflectance probe (Fig. 1). Thus monochromatic light is incident on the sample, and detectors in the probe (mounted at 45º to the sample surface) monitor the intensity of reflected light. In the 'post-dispersive' configuration, light from a 75 W lamp directly illuminates the sample, and light returning from the sample is delivered via a 1.6 m fibre optic to a spectrometer (Fig. 1). Light passing a slit is dispersed by a moving grating, and is delivered through order sorting filters onto the detectors (positioned normal to the incident beam).

Table 1. MLR- and MPLS-based calibration of NIRS and pineapple Brix level (fruit harvested in 1995)

Results are summarised for two protocols for the partitioning of a population into prediction and calibration sets (boxcar and ranked sequential) for the MLR procedure

	Pre-dispersive	Post-dispersive
MLR—boxcar calibration (760–1300 nm)		
Calibration		
n	105	105
Wavelengths (nm)	740, 764, 788	1188, 708
R^2	0.740	0.705
SEC	1.155	1.219
Prediction		
n	103	103
R^2	0.28	0.38
SEP	1.49	1.29
MLR—ranked sequential (760–1300 nm)		
Calibration		
n	104	104
Wavelengths (nm)	876, 764	1188, 1244, 708
R^2	0.650	0.652
SEC	1.055	0.992
Prediction		
n	104	104
R^2	0.50	0.50
SEP	1.36	1.30
MPLS—6 cross validation groups (760–2300 nm)		
n	208	208
Number of terms	4	3
R^2	0.642	0.728
SEC	1.060	0.876
SECV	1.112	1.011

The protocols of Guthrie and Walsh (1997) for pre-dispersive work were adopted. Briefly, intact fruit were held in a light-proof polyvinyl chloride (PVC) box with a 60 mm diameter window. A laboratory jack held the fruit against the window so that the fruit skin was in direct contact with the quartz glass window of the NIRSystems remote reflectance probe. The same population of pineapple fruit was then scanned with the direct light NIRSystems 6500, with lamp and fibre optic positioned 7 cm above the intact fruit. In both configurations, spectra were obtained at the centre of the fruit's longest dimension, from each half of the fruit (i.e. 2 spectra per fruit), and reference scans were undertaken between each sample spectrum, using a white ceramic tile as the reference.

Calibration development

Calibration equations were developed on second derivative spectral data using multiple linear regression (MLR) and modified partial least squares (MPLS) analysis with ISI (Version 3.0) software. Spectral and Brix analyses were obtained for 208 samples (mean 15.44, range 11.9–20.4, s.d. 1.74°Brix). In the MPLS calibration procedure, the population was partitioned into 6 subgroups, with each group sequentially used as a predicted group and the remainder as a calibration group (such that every sample is predicted once). In contrast, in the MLR procedure, the population was divided into equal groups for use as calibration and prediction sets.

Two procedures were used in dividing the population for the MLR procedure. In the rectangular ('boxcar') distribution method for analyte concentration, the population was first ranked into groups varying by 1°Brix, and then 14 samples (if the division had less than 14, all were used) were taken from each group to make the calibration set. In this method the calibration set is equally weighted for samples across the full Brix range of the population, although the remaining prediction set is overweighted with samples about the mean. In the 'sequential' method, samples were ordered in ascending Brix values, then sequentially paired and a value from each pair randomly split into either calibration or prediction sets. In this procedure both sets are equally weighted for the range of Brix levels present in the population.

Instrumental and environmental variables

The noise within a spectroscopic condition was characterised with respect to absorption at 876 nm and the predicted Brix value of the assessed fruit. Absorbance at 876 nm was chosen, as the derivative of absorbance at this wavelength was important in the calibration (MLR, pre-dispersive) developed for pineapple Brix (Table 1). Absorbance values at 876 nm were averaged, and the average divided by the standard error as an estimate of the signal : noise ratio.

Number of scans. The 'default' option used on the NIRSystems 6500 was to average the spectra of 50 scans per spectrum acquired. With each scan taking about 1 s, spectrum acquisition therefore requires about 1 min. A fewer number of scans are expected to decrease the signal : noise ratio of the measurement. This effect was studied by collecting 5 spectra of a sample (intact pineapple) with paired reference spectra, using either 1, 2, 4, 8, 16, 32, or the maximum allowed, 50 scans per spectra.

External light. To consider the influence of light, spectra were acquired using the pre-dispersive system under the following 4 conditions: (i) 'standard' practice (e.g. as used by Guthrie and Walsh 1997), with the remote reflectance fibre optic probe sealed close to the object of interest (a pineapple fruit) in a light proof box; (ii) the lid of this box left open within a room with windows in which the fluorescent overhead lights were turned off; (iii) the lid of the box left open, with room fluorescent lights on; and (iv) a tungsten halogen floodlight directed at the open box. Similarly, spectra were acquired using the post-dispersive system under the following 4 conditions: (i) darkness; (ii) room with unshuttered windows; (iii) room with fluorescent lights on; and (iv) floodlight directed at the fruit. Spectra were acquired at 2 locations on 5 fruit (10 spectra) for each of these conditions, for both the pre- and post-dispersive systems.

Depth of sample assessed. The effective depth of the sample from which diffusely reflected light was acquired was estimated using the pre- and post-dispersive configurations. Spectra were acquired of filter paper (Whatman No. 42, 18.5 cm diameter) soaked in 10% (w/v) sucrose, within a petri plate on a teflon background. The number of filter papers was varied between 1 and 20. In an alternative consideration, spectra were collected from 10 pineapple fruit in which flesh was sequentially trimmed from the side away from the skin surface facing the NIRS probe.

Temperature and humidity. To consider the effect of temperature, 5 fruit were varied in temperature between 2 and 60°C, and spectra acquired using both systems (instruments held at 22–24ºC). Fruit temperature was measured using a thermocouple

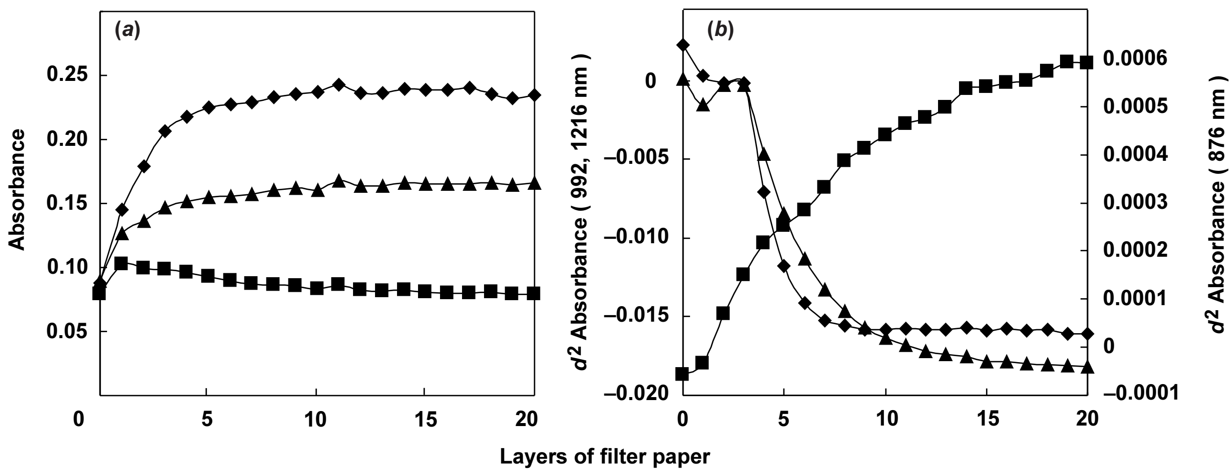

Figure 2. (*a*) Absorbance and (*b*) second derivative of absorbance at 3 wavelengths (■ 876 nm, ▲ 992 nm, ◆ 1216 nm) plotted against the number of layers of filter paper soaked in 10% (w/v) sucrose solution. Measurements were made using a pre-dispersive system.

placed under the skin of the fruit. Reference spectra (ceramic) were taken at laboratory temperature. In a parallel experiment, relative humidity of the environment of the remote reflectance probe and sample was varied, and spectra acquired. Reflectance probe and sample or spectrometer were enclosed within a cabinet and the humidity decreased by recirculating air through a cold trap, and increased by introducing steam into the recirculating air supply, and monitored using a Tinytag datalogger.

The effect of humidity was also considered with respect to the instrument. In this experiment, the instrument was housed in the chamber in which humidity was altered, and the probe and sample were maintained under ambient laboratory conditions (i.e. constant humidity and temperature).

Results and discussion

Calibration for pineapple Brix

MLR calibrations developed using post-dispersive analysis were equivalent to those using pre-dispersive analysis in terms of calibration and prediction regressions (Table 1). For the MPLS-based calibrations, post-dispersive analysis yielded a superior result to the pre-dispersive analysis, in terms of coefficient of determination (R^2), standard error of calibration (SEC) and standard error of cross-validation (SECV) (Table 1). Coefficients of determination of 0.73 and 0.64, achieved using post- and pre-dispersive analyses, respectively, will allow grading of articles into 3 grades at a success rate of 70 and 65% respectively (Shenk and Westerhaus 1993). High and low samples will be correctly identified with a success rate of 99 and 100% respectively.

Two procedures were used for the selection of calibration samples from the overall population for the MLR (Table 1). The 'boxcar' selection procedure gave a more uniform weighting across the range of Brix levels than the sequential selection procedure. This resulted in a superior R^2 for calibration, in comparison with the 'sequential' method. However, this protocol depleted the number of samples in the prediction set at the extreme ends of the range. In consequence, the R^2 and SEP of the prediction set were inferior in the 'boxcar', relative to the 'sequential', procedure.

Brix content was predicted for a population of fruit harvested in 1996 (Tables 2 and 3; Figs 3–5) using calibration equations developed from a previous growing season (1995, Table 1) for both pre- and post-dispersive systems. The predictions were reasonably precise but inaccurate, with an offset of 1 and 6°Brix for the pre- and post-dispersive systems respectively. This result confirms the need to develop robust calibrations across growing seasons (Guthrie *et al*. 1998).

The signal : noise ratio for A_{876} (as indexed by the ratio of mean to standard error for 5 measurements, Tables 2 and 3) was lower in the pre-dispersive, relative to the post-dispersive, system. We consider that this result is largely due to differences in the position of the ceramic reference, which was scanned between each sample. In the pre-dispersive system the reference was placed in the same position as the sample, whereas in the post-dispersive system the reference was built into the direct light head, which was held 7 cm above the sample. In consequence, the absorbance measured in the post-dispersive system was much higher than that measured

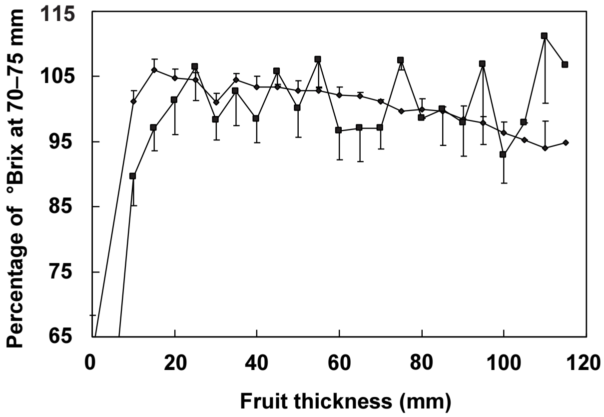

Figure 3. Predicted Brix of pineapple fruit, as a percentage of that predicted at 70–75 mm. Slices were cut from each fruit (on the side away from the light source and detector) between each measurement. Predictions were made using a pre- (◆) and post- (■) dispersive system, with calibrations reported in Table 1. Each data point represents the mean of 10 separate fruit with an associated s.e.m.

Table 2. Effect of varying external light conditions on absorbance (876 nm) and predicted Brix of pineapple fruit assessed using a pre- or post-dispersive system

Data presented as mean (n = 10) and mean/s.e. as an estimate of the signal : noise ratio
Values in parentheses are expressed as a percentage of the dark value

Light conditions	Pre-dispersive		Post-dispersive	
	Mean	Mean/s.e.	Mean	Mean/s.e.
		Absorbance (876 nm)		
Dark	0.1394	648	0.8832	2331
Ambient	0.1381	631	0.8820	2333
+ Fluorescent	0.1366	353	0.8791	2819
+ Floodlight	0.0413	4	0.8486	2392
		Predicted Brix (°Brix)		
Dark	19.7 (100)	263	14.8 (100)	18.7
Ambient	19.7 (99.8)	272	13.2 (89.1)	13.2
+ Fluorescent	20.9 (101.2)	314	13.9 (94.7)	19.1
+ Floodlight	17.7 (89.6)	37	14.7 (98.9)	14.0

in the pre-dispersive system. Given absorbance is a logarithmic scale, the post-dispersive system is expected to give a higher signal : standard error ratio (but at the expense of signal resolution).

Penetration

Spectra were acquired of filter paper soaked in 10% (w/v) sucrose using the pre-dispersive configuration (Fig. 2). Maximum separation of absorbance (actually reflectance) spectra occurred at 992 and 1216 nm, while absorbance at 876 nm was considered as a wavelength of significance in the pineapple Brix calibration (MLR pre-dispersive, Table 1). Absorbance at 992 and 1216 nm increased with number of layers, reaching a plateau at about 6 layers (6 mm thickness of paper layers). Absorbance at 876 nm demonstrated little relationship to number of layers, suggesting a greater penetration of the sample by the wavelengths 992 and 1216 nm. The initial slope of the relationship between absorbance and number of layers is related to the extinction coefficient of the sample.

As absorbance data is prone to spectral baseline shifts due to changes in sample surface reflectance, first or second derivative data are generally used in calibration exercises. The second derivative term is negatively correlated with the concentration of the analyte absorbing at that wavelength, to the extinction coefficient of the analyte, and to the pathlength (from Beers' Law). As expected, the second derivative of spectra provided more information about the sample. Depending on wavelength, spectral information was obtained from a depth of 10–20 mm of filter paper. The decrease in the second derivative of absorbance at 992 and 1216 nm, stabilising at about 10 layers (10 mm) can be explained by the absorbance of sucrose, water or cellulose at these wavelengths (i.e. to increasing number of paper layers). The increase in the second derivative of A_{876} stabilising at about 20 layers (20 mm) indicates that this term is negatively correlated with the analyte (in this case, number of paper layers). Similar data were obtained using the post-dispersive system (data not shown).

In an alternative approach to the question of the effective depth of the sample from which diffusely reflected light was acquired, Brix was predicted for fruit of varying slice thickness. Using the pre-dispersive configuration, the predicted Brix on a slice of pineapple fruit only 10 mm thick was not different to that of thicker slices of fruit (Fig. 3). Using the post-dispersive configuration, the predicted Brix of pineapple increased with fruit thickness up to about 20 mm. There was more noise on post-dispersive estimation of Brix. The temperature of the fruit will have increased during the prolonged exposure to high light intensity in this experiment. Temperature will affect the wavelength at which maximum absorption occurs for a given chemical bond, and thus the accuracy of a Brix prediction. However, the standard error of the prediction did not consistently increase with the time of exposure (i.e. as fruit was sliced and thickness decreased, Fig. 3) and thus change in temperature does not explain this effect. The consistent decrease of the pre-dispersive estimate with

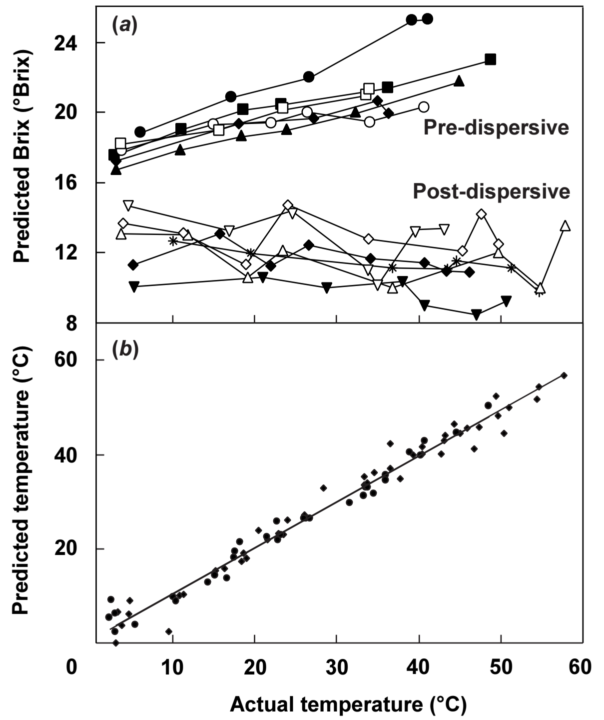

Figure 4. (*a*) Predicted Brix of 5 separate fruit over a range of temperatures using a pre- and a post-dispersive system. (*b*) Fruit temperature was predicted from spectra. For the pre-dispersive system (◆) a calibration R^2 = 0.97, SEC = 2.3 and SECV = 3.0°C was achieved. For the post-dispersive system (●) a calibration R^2 = 0.97, SEC = 2.7 and SECV = 3.4°C was achieved.

increasing thickness of fruit could be explained by reflection from the teflon background back into the fruit, although this trend was not apparent in the post-dispersive data.

The post-dispersive mode offers the advantage of a higher incident light intensity relative to the pre-dispersive mode, because of the loss of intensity with passage of light through a slit and over a diffraction grating in the pre-dispersive mode. If incident light intensity was doubled, the number of photons at all levels within the fruit will be doubled, improving the signal to noise of the diffusely radiated light and increasing the effective depth of sample for which useful spectral information is acquired. Therefore the diffusely reflected light should contain more relevant information about the internal composition of the fruit (i.e. flesh Brix).

External light effects

The pre-dispersive system is expected to be more sensitive to stray light entering the detector than the post-dispersive system. When using the post-dispersive system, A_{876} was not affected by background light levels (even a floodlight, Table 2). In contrast, the signal : noise ratio of measurements made using the pre-dispersive system was significantly decreased by increasing external light levels.

The use of second derivatives should remove the effect of (constant) external light on the absorbance spectra with respect to the calibration for fruit Brix, although only if this external light is spectrally ‘neutral’ (i.e. its influence is constant over that part of the spectrum of importance to the calibration). The mean and standard error of the predicted Brix of fruit assessed with the post-dispersive technique was not significantly altered by external light levels. The mean and standard error of predicted Brix of fruit assessed with the pre-dispersive technique was affected by the tungsten halogen floodlight, but not by fluorescent lighting. These results were expected as fluorescent light sources do not produce light of wavelengths relative to the Brix calibration, and the presence of additional white light from a tungsten halogen source should affect the pre-dispersive technique adversely.

Temperature

Kawano *et al*. (1995) has emphasised the need to incorporate samples over the range of temperatures expected in an operational setting within a calibration exercise. The calibrations reported in Table 1 were developed over a narrow temperature range (22–24°C). As the temperature of the fruit increased so did the predicted Brix values for the pre-dispersive configuration (Fig. 4). However, predictions for the post-dispersive configuration showed no consistent trend (Fig. 4). The increased light intensity on the sample inherent with the post-dispersive system adds a heat load to the sample. Fruit temperature (as monitored by a thermistor placed 10 mm under the skin surface) increased by about 2°C over the scanning period. However, this effect will be similar in both calibration and prediction samples and therefore does not explain the result.

Incorporation of a range of sample temperatures into a calibration equation, as suggested by Kawano *et al*. (1995), will reduce the accuracy and precision of the prediction. Alternatively, calibrations could be developed for a series of temperature ranges, to cover the expected sample temperatures. Temperature of the fruit sample was predicted reasonably accurately using either pre- or post-dispersive configurations (Fig. 4, R^2 = 0.97 and SEC = 2.3°C; R^2 = 0.97 and SEC = 2.7°C respectively). Such a temperature prediction could be used to select a relevant calibration equation.

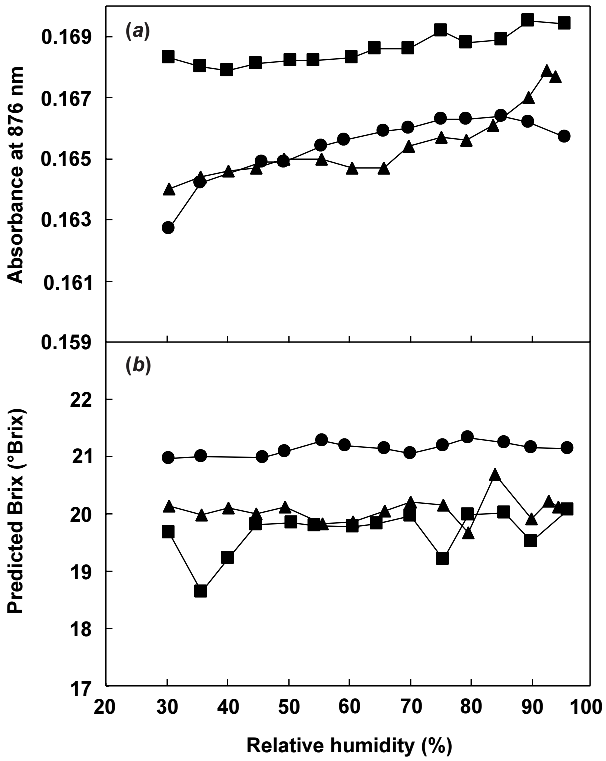

Figure 5. (*a*) A_{876} and (*b*) predicted Brix of pineapple fruit over a range of humidities. Humidity was varied in the vicinity of the sample and remote reflectance probe, with a reference value taken at 57% relative humidity only (●). The sample and remote reflectance probe were maintained under constant conditions while the spectrometer was subjected to varying humidities and either reference taken at one humidity level only (■) or taken paired with each sample (▲).

Table 3. Effect of varying number of scans averaged for each spectrum on absorbance and predicted Brix using a pre-and post-dispersive system

Data presented as mean and mean/s.e. for the absorbance data and as mean and s.e. for predicted Brix data (n = 5)
Values in parentheses are expressed as a percentage of 50 scans

No. of scans	Pre-dispersive Mean	Pre-dispersive Mean/s.e. or s.e.	Post-dispersive Mean	Post-dispersive Mean/s.e. or s.e.
		Absorbance (876 nm)		
1	0.0928 (92.7)	41	0.825 (100)	1761
2	0.0974 (97.2)	209	0.826 (100.0)	2611
4	0.0971 (97.0)	348	0.826 (100.1)	5449
8	0.097 (96.9)	321	0.826 (100.1)	5782
16	0.085 (98.3)	315	0.826 (100.1)	10 323
32	0.0997 (99.6)	448	0.826 (100.1)	5065
50	0.1002 (100)	537	0.826 (100.0)	5024
		Predicted Brix (°Brix)		
1	20.6 (97.8)	0.38	9.3 (72.2)	3.9
2	21.2 (100.4)	0.22	8.0 (64.9)	2.2
4	21.0 (99.7)	0.20	15.7 (124.1)	2.9
8	21.1 (99.8)	0.19	14.3 (113.3)	1.6
16	21.2 (100.4)	0.15	13.5 (105.7)	1.6
32	21.0 (99.6)	0.05	14.1 (119.4)	0.8
50	21.1 (100.0)	0.06	12.7 (100.0)	0.7

Relative humidity

Increasing the humidity of the sample environment, while temperature was held constant, had minimal effect on the predicted fruit sample Brix value using the pre-dispersive system (Fig. 5). However, when the instrument (i.e. monochromator) was subjected to a range of humidity values, the predicted Brix values were more erratic than in the former situation. This result could be caused by the light scattering effect of water droplets on the incident radiation. Re-referencing between samples, at the prevailing humidity, served to improve the precision of the Brix prediction.

Number of scans per spectrum

As noted with external light effects, predicted Brix was inaccurate, and the difference in the A_{876} mean/s.e. estimate between pre- and post-dispersive systems is interpreted as largely due to the position of the reference (Table 3). The mean/s.e. ratio of both A_{876} and predicted Brix improved with the number of scans averaged for each spectrum in both systems. A standard error of less than 1° predicted Brix was achieved with only 1 scan in the pre-dispersive system, while 32 or more scans were required with the post-dispersive system to achieve the same result. The time required to acquire each spectrum is a limitation to the adoption of NIRS technology into pack house settings. Fruit packing lines currently sort fruit at rates in excess of 1 item per second (typical belt speed 1 m/s).

Conclusion

The use of a NIR-based technology for the sorting of fruit in a packing shed requires a robust and rapid technology, 'tolerant' of changes in temperature and humidity, and capable of assessment of at least 2 pineapple fruit per second. A post-dispersive optical configuration is recommended over a pre-dispersive system to increase the incident light intensity on the sample (i.e. to assess a greater depth of fruit) and to decrease sensitivity to stray white light. A detector array (CCD or photodiode) rather than a scanning grating and a single detector is required to decrease analysis time. These 2 features are seen in prototype 'bench top' NIRS units for Brix assessment of kiwifruit (Osborne *et al*. 1998), peach (Jaenisch *et al*. 1990), melon (Matumoto *et al*. 1996) and apple (Bellon *et al*. 1993).

The influence of relative humidity on prediction can be addressed by re-referencing as humidity changes, or by enclosing the spectrometer. The influence of sample temperature on prediction accuracy is suggested to be best addressed by predicting temperature using NIRS, and applying a calibration developed for this temperature. Consideration should also be given to the effect of temperature changes on the spectrometer. We are currently undertaking further work to integrate a post-dispersive array system into a commercial fruit packing shed.

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