Prediction of hass avocado maturity via FT-NIRS

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Keywords: fruit, avocado, dry matter, maturity, near infrared spectroscopy, eating quality

Introduction

Most commercial quality classification systems for fruit and vegetables are based on external features of the product, for example: shape, colour, size, weight and blemishes. For avocado fruit, external colour is not a maturity characteristic. Also its smell is too weak, and appears later in its maturity stage.[1] Because maturity is a major component of avocado quality and palatability, it is important to harvest mature fruit, so as to ensure that fruit will ripen properly and have acceptable eating quality. Currently, commercial avocado maturity estimation is based on destructive assessment of the percentage of Dry Matter (%DM), and sometimes percent oil, both of which are highly correlated with maturity.[2,3] A rapid and non-destructive system that can accurately and rapidly monitor internal quality attributes would allow the avocado industry to provide better, more consistent eating quality fruit to the consumer, and thus improve industry competitiveness and profitability.

The aim of this study was to assess the potential of FT-NIR diffuse reflectance spectroscopy as an objective non-invasive method to determine Hass avocado maturity and thereby eating quality, based on %DM, and its ability to predict over several growing seasons.

Materials and Methods

Hass avocado fruit were obtained over the 2006, 2007 and 2008 growing seasons (harvest months: May to August) from a single farm in the major production district of Childers, Queensland (Latitude: 25º 14´ S, Longitude: 152 º 16´ E). Avocado fruit were harvested from the same trees in the orchard within an individual year at three maturity stages, corresponding to early, mid and late season harvests over the three growing seasons. Approximately 100 fruit were collected at each harvest giving a total of around 900 individual fruit.

The spectra of whole, intact Hass avocado fruit were collected using a commercially available Matrix-F, FT-NIR spectrophotometer (Bruker Optics, Ettlingen, Germany; operating software: OPUS™ version 5.1– 6.5) in the 780–2500 nm range. Spectra were obtained in diffuse reflectance mode, using a 4 × 20 watt tungsten light source fibre-coupled emission head, with a path-length of approximately 170 mm, to obtain a circular scan area on the avocado of approximately 50 mm in diameter. In obtaining each sample spectrum, 32 scans at a resolution of 8 cm^{-1} were collected and averaged. Fruit spectra were acquired after sample temperature equilibration in an air-conditioned laboratory at approximately 22–24°C, and within two days of harvest. The spectral characteristics of the fruit were measured midway between the peduncle and base for each opposing half (i.e., two spectra per fruit). A core perpendicular to the surface of the fruit with a radius equal to the NIRS sampling area was taken on opposing sides of the fruit using a 50 mm diameter steel corer, and excising both skin and underlying flesh to a depth of approximately 10 mm. The flesh core was cut into pieces to facilitate drying and dried in a fan-forced oven at 60–65°C to constant weight (approximately 72 hours) for determination of %DM by percentage weight difference.

Data analysis was carried out using "The Unscrambler" Version 9.8 (Camo, Oslo, Norway). The sample spectra for each data set were separated into a calibration set and prediction set to develop the calibration and prediction models respectively. Fruit were assigned to the calibration set from the principal component analysis (PCA) results to provide a global representation of the attributes of the entire fruit population while eliminating repetition. Partial least squares (PLS) regression was used to build the prediction models of the diffuse reflectance spectral data, using segmented cross validation. Before calibration model development, the variation of the spectral data was analysed by PCA, and obvious spurious spectra eliminated. All models presented in this study were based on a combination of a 25 point Savitzky-Golay (SG) spectral smoothing (2^{nd} order polynomial) and a first derivative transformation (25 point SG smoothing and 2^{nd} order polynomial).

Results and Discussion

The influence of seasonal variability was investigated over three years (Table 1).

The 2006 calibration model was used to predict on the 2007 season population. The selected calibration sets from 2006 and 2007 seasons were combined to develop a calibration model that

Table 1. Preliminary PLS calibration and prediction statistics for %DM for whole Hass avocado fruit for 2006, 2006-7 and 2006-08 (Combined) seasons.

Harvest		Spectra n (outliers removed)	SD	LV	R^2	RMSECV	RMSEP	SDR
Calibration	Prediction							
2006		207 (1)	3.7	10	0.83	1.56		2.4
	2007	609 (0)	3.1		0.20		2.73	1.1
2006 & 07		415 (0)	3.5	9	0.82	1.50		2.4
	2008	608 (0)	5.3		0.82		2.27	2.4
Combined		624 (1)	4.6	10	0.89	1.52		3.0
	Combined	1224 (0)	4.3		0.89		1.41	3.1

Note: LV = latent variables.

was then subsequently used to predict the 2008 season population. A combined calibration set of 2006, 2007 and 2008 seasons was used to predict over all 3 years.

As expected, the application of single seasonal calibrations to populations from other growing seasons was not very successful. The 2006 calibration model could not be used to predict the 2007 season population. Model predictive performance improved as more biological variability was included in the model, as seen when the combined 2006 and 2007 model was used to predict on the 2008 season. The combined 2006, 2007 and 2008 calibration model was sufficiently robust to predict %DM of whole Hass avocado to within 1.41% with a coefficient of determination of the validation set (R_v^2) = 0.89 and standard deviation ratio (SDR = standard deviation of the data set / root mean square error of cross-validation (RMSECV) or root mean square error of prediction (RMSEP)) of 3.1. This indicated an ability to sort the fruit into three categories with approximately 80 % accuracy.[4]

Conclusion

The potential of NIRS to assess internal quality attributes of intact horticultural produce is well established in literature. However, in the majority of publications, the robustness of calibration models with respect to biological variability from different seasons and years has been neglected and therefore these earlier calibration models may be ambitious, with respect to predicting on future samples in practical applications, such as grading lines.[5, 6]

The present study showed that the model's robustness increased across years, when more variability was included in the calibration set. The results indicate the potential of FT-NIRS in diffuse reflectance mode as a non-invasive method to predict the %DM of whole Hass avocado fruit, and the importance of calibration model development incorporating seasonal variation. Thus, FT-NIR reflectance spectroscopy provides an alternative to standard dispersive systems and PDA spectrometers for the commercial, in-line, non-destructive %DM evaluation of avocado fruit. Further work is required to optimize this technology, with calibration development and speed of throughput for an in-line setting being required for commercial adoption. As demonstrated, the calibration models need to be assessed over several years to increase their robustness and ensure their predictive performance.

Acknowledgements

We acknowledge the financial support of the Australian Research Council and Bret-Tech Pty Ltd for this project. The authors also wish to thank Lachlan Donovan for the supply of fruit; and Peter Hofman, John Cavallaro, Barbara Stubbings, Terry Campbell, Roberto Marques and Andreas Toldi for the organising and collecting of fruit.

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