Use of NIRS to measure quality defects in intact macadamia kernels

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Introduction

A major defect of macadamia nuts is kernel immaturity, which can be quantified by measuring oil content. Other quality defects include insect damage, wrinkling, rancidity and discolouration. Discolouration may be due to mould growth, germination, decomposition or other causes[1] (Fig. 1). Moisture content is also an important parameter, having a major effect on product shelf life.

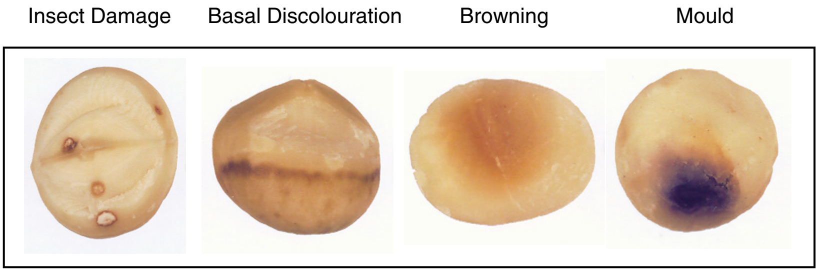

Figure 1. Kernel Defects

Near infra-red spectroscopy (NIRS) is widely employed for oil and moisture determination in the cereal and oilseed industries. For oil, strong absorption is reported around 2200 to 2400 nm (CH_2 stretch bend combinations), with weaker absorption around 1750, 1200 and 900 nm (CH_2 stretch first, second and third overtones)[2]. However, shorter wavelengths allow better penetration of biological samples, and this is useful in assessment of macadamia kernels.

Material and Methods

Samples of reject kernels for each of the defect categories being studied, were collected by a commercial processor and samples of sound kernel were also collected from the same kernel batches.

Sound kernels and kernels rejected on the basis of immaturity were utilised for oil content models. This approach enabled a wide range of oil contents to be studied.

For the moisture content study kernels with a range of moisture contents were obtained by taking nut samples before factory drying and at various stages of the drying cycle.

Three instruments, operating over different areas of the spectrum (400 – 2500, 300 – 1100, 800 – 1700 nm), using Si-PbS (NIRSystems 6500), Si (Zeiss MMS1) and InGaAs (Zeiss MMSNIR) detectors, respectively, and employing transmittance and reflectance sample presentation strategies, were used to collect spectra of intact and ground kernels (Table 1). The mean diameter of kernels used in this study was 12.7 mm.

Table 1. Population Statistics

Attribute	n	Range	Mean	Std. Dev.
Oil –intact (%)	200	18.9-81.0	60.7	16.84
Moisture – intact (%)	105	1.4-4.2	1.92	0.33
Moisture – ground (%)	35	1.5-2.9	1.98	0.34
Defects – 7 categories	140	n/a	n/a	n/a

Reference analysis was undertaken using a micro-soxhlet apparatus (standard error of +/- 3% from the mean) for oil content and a TGA-601 Thermogravimetric Analyzer (LECO Corporation) for moisture content (standard error of +/- 2% from the mean). WinISI and The Unscrambler software packages were used for chemometric analyses.

Results and Discussion

Oil MPLS

Calibration statistics for oil content models (intact kernels) were acceptable on all instruments (*RMSECV* similar to laboratory error), although the calibrations developed on the silicon photodiode instrument were slightly inferior to those developed on the InGaAs or Si-PbS based instruments.

For spectral data collected with the Si photodiode instrument (used in transmission mode), the best model performance was achieved using absorbance spectra, treated with SNV and detrend (data not shown). Typical statistics for calibration models on oil were: R^2 = 0.98; *RMSECV* = 2.7%; population mean = 62.3%; *sd* = 15.8% (Fig. 2). Calibration coefficients were consistent with absorbance due to the third overtones of CH_2 stretching (e.g. heavy weightings in the 70 –1000 nm region) (data not shown).

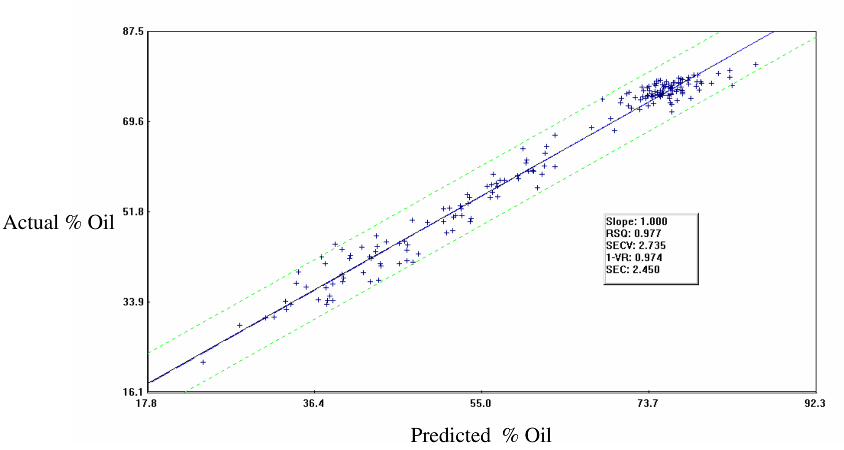

Figure 2. MPLS regression (calibration) for actual and predicted oil content in intact macadamia kernels, based on spectral data from the Zeiss MMS1 operated in transmission geometry and over the wavelength range 700 – 1100 nm. Regression performed on absorbance data, pre-treated with SNV and detrend.

Moisture MPLS

Calibration models for moisture content in ground samples were acceptable on all instruments, while calibration models for intact kernels were relatively poor ($R^2 = 0.51$, RMSECV > 0.19%). The performance of MPLS calibrations based on transmission spectral data was superior to that based on interactance or reflectance data (data not shown). Best model performance was achieved on first-derivatised absorbance spectra, treated with SNV (data not shown) (Fig. 3).

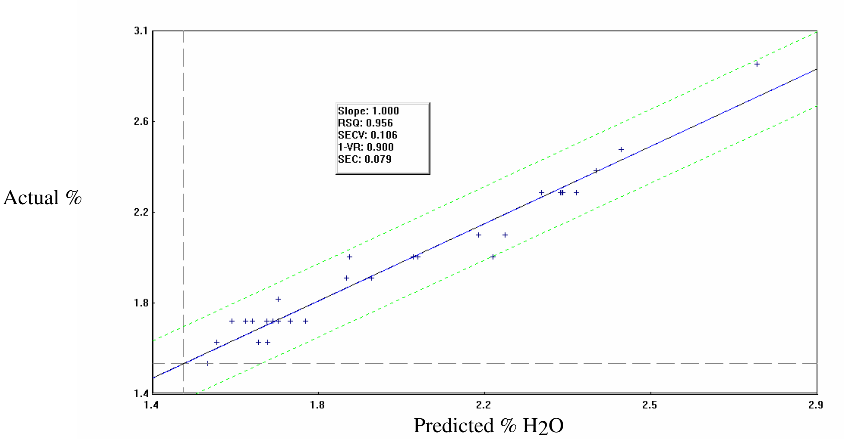

Figure 3. MPLS regression (calibration) for actual and predicted moisture content in ground macadamia kernels, based on spectral data from the Zeiss MMSNIR operated in transmission geometry and over the wavelength range 800 – 1700 nm. Regression performed on first derivative absorbance data, pre-treated with SNV.

Typical statistics for calibration models on moisture in ground samples (transmission mode) were: $R^2 = 0.93$; $RMSECV = 0.12\%$; population mean = 2.0%; $sd = 0.34\%$.

Calibration coefficients were weighted around 1360, 740 and 840 nm (data not shown), consistent with absorbance due to overtones of O-H stretching and combination.

Discriminant Analysis

Kernels with brown centres or rancidity could be discriminated from each other and from sound kernels using principal component analysis (PCA) (Fig. 4). Kernels affected by insect damage, discolouration, mould growth, germination and decomposition could be discriminated from sound kernels. However, discrimination among these defect categories was not distinct.

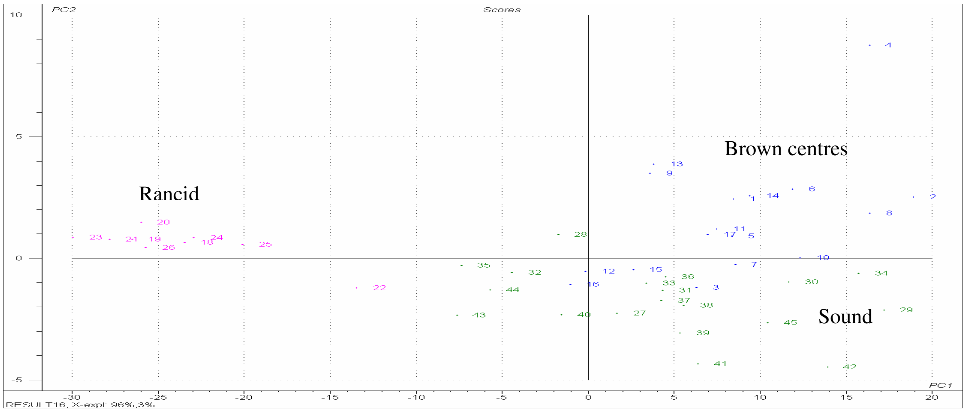

Figure 4 Discriminant analysis (PCA) of whole macadamia kernels using the Zeiss MMSNIR in transmission mode.

Conclusion

There is potential for a lower cost Si or InGaAs photodiode array instruments to be employed to measure some quality defects of intact kernels and moisture content of ground kernels in the process laboratory. However, the robustness of the calibration models will need to tested across different populations, including growing districts cultivars and times.

Acknowledgements

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References

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2. B.G. Osborne, T. Fearn and P.H. Hindle, Practical NIR Spectroscopy with applications in food and beverage analysis (2nd edition). Longman Scientific and Technical, Essex, UK (1993).