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RANGAHAU AHUMĀRA KAI

Which optical geometry is best to detect vascular browning in apples?

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Introduction

Near infrared (NIR) spectroscopy is used for commercial grading of internal quality attributes of fruits such as taste and the presence of rots. However, detection of small and/or localised internal defects is often very difficult. Different NIR optical geometries are being investigated in our laboratory in an effort to improve success rates for small defect detection.

Vascular browning (VAB) in apples is challenging to detect, characterised by small open cavities near the core, which is itself an open cavity (Figure 1). VAB cavities discolour only mildly, going light brown with oxidation. The combination of small size, proximity to the core and the lack of strong absorbance changes makes detection challenging.

Methods

Approximately 700 'Braeburn' apples, with 5% VAB incidence, were harvested from orchards in Hawke's Bay (New Zealand). MRI scanning isolated 43 apples with clear VAB symptoms, 16 of which were severe (score>1); 64 symptom-free apples were added to create a dataset of 107 (Figure 2).

Two NIR methods of differing optical geometry, termed Systems 1 and 2, were used (Figure 3). System 1 is a popular geometry, first used commercially in Japan in the late 1990's. Our System 1 used a pair of Halogen lamps (50W) and a Zeiss MMS1 spectrometer. System 2 is far less common, probably due to lower transmitted light levels, but this may change with recently available sensors of higher sensitivity to low light. Our System 2 used a single Halogen lamp (150W), with a focusing lens, and a Control Developments CCD spectrometer (CD024321). Measurements were taken for two different apple orientations, 180° rotations around the central axis, doubling the spectral data set to 214 samples. For both orientations, the stem-calyx axis of the apple was horizontal, as shown in Figure 3.

After the NIR measurements, the apples were cut in half, and scored by severity of the defect (Figure 1). Partial Least Squares Discriminant Analysis (PLSDA) was used to build models using 10-way venetian blind cross-validation (PLS_Toolbox, Eigenvector Research, WA, USA).

Figure 1: Cut surface of three 'Braeburn' defective apples, which were scored 1, 2, and 3 for vascular browning

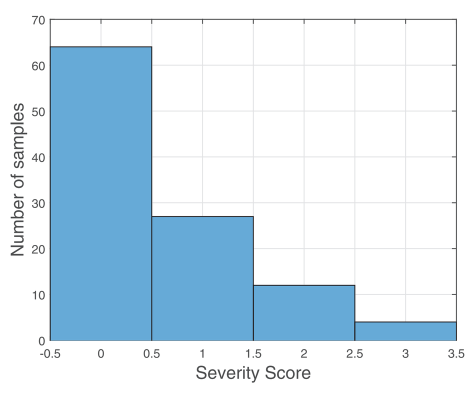

Figure 2: Severity score of the 'Braeburn' apples used in the experiment. Score 0 represents healthy apples with no vascular browning.

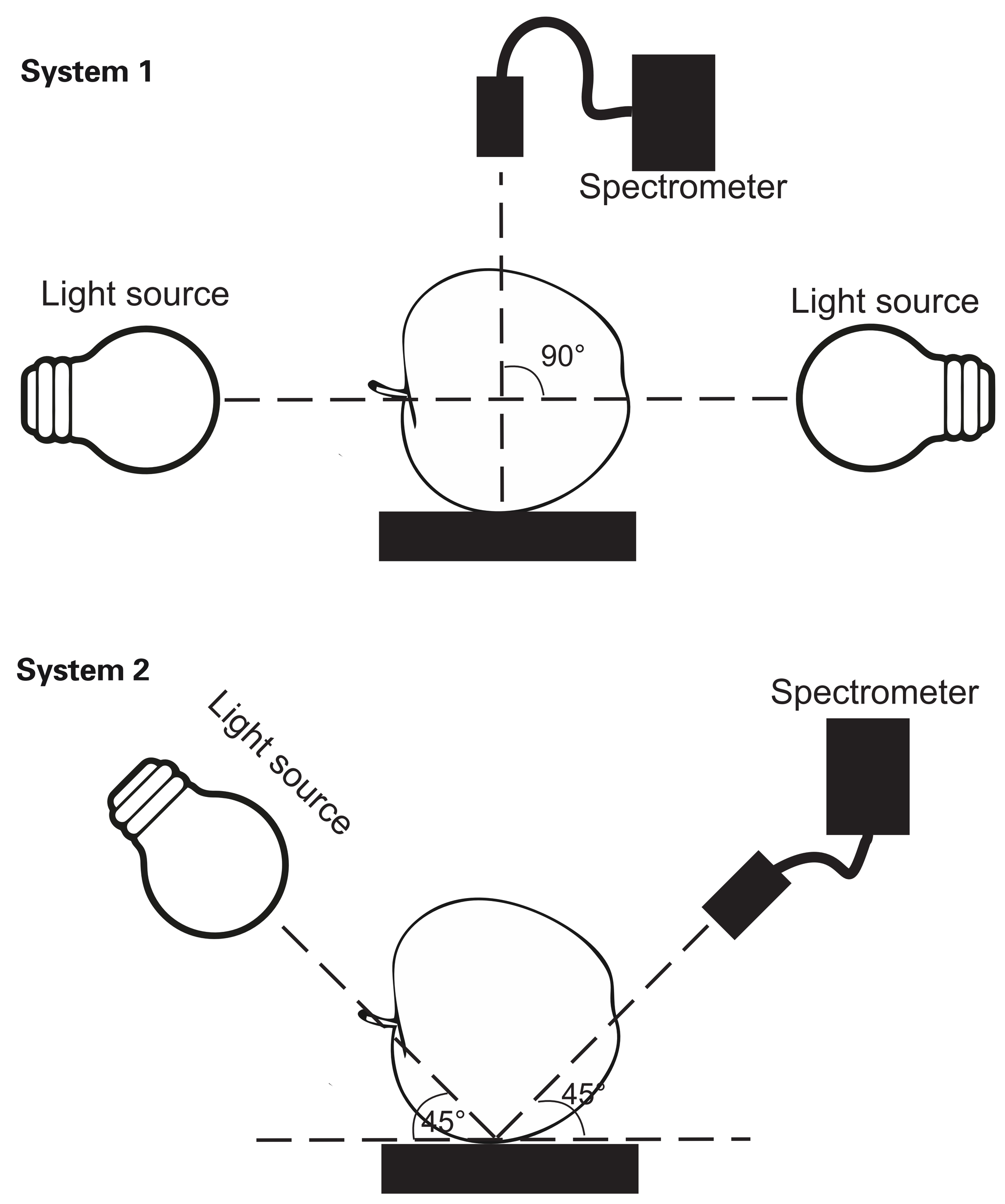

Figure 3: Hardware setup of the near infrared (NIR) sensors: System 1 (top) and System 2 (bottom).

Results

The average spectra from each system were quite different irrespective of severity score. Despite being noisier, System 2 spectra showed stronger absorbance features for chlorophyll at 670 nm and for water at 740, 840 and 970 nm (Figure 4). Monte Carlo (MC) simulations of the light transport in a model fruit, assuming average optical properties for the two systems, revealed quite different light path lengths (Figure 5). The System 1 path length distribution is peaked near 0 mm, whereas for System 2 the distribution peaked at 1000 mm. Longer path lengths mean stronger light absorbance, matching the observation of System 2. System 1 also had a much higher photon count density, which is consistent with the measured spectra being smoother in that case.

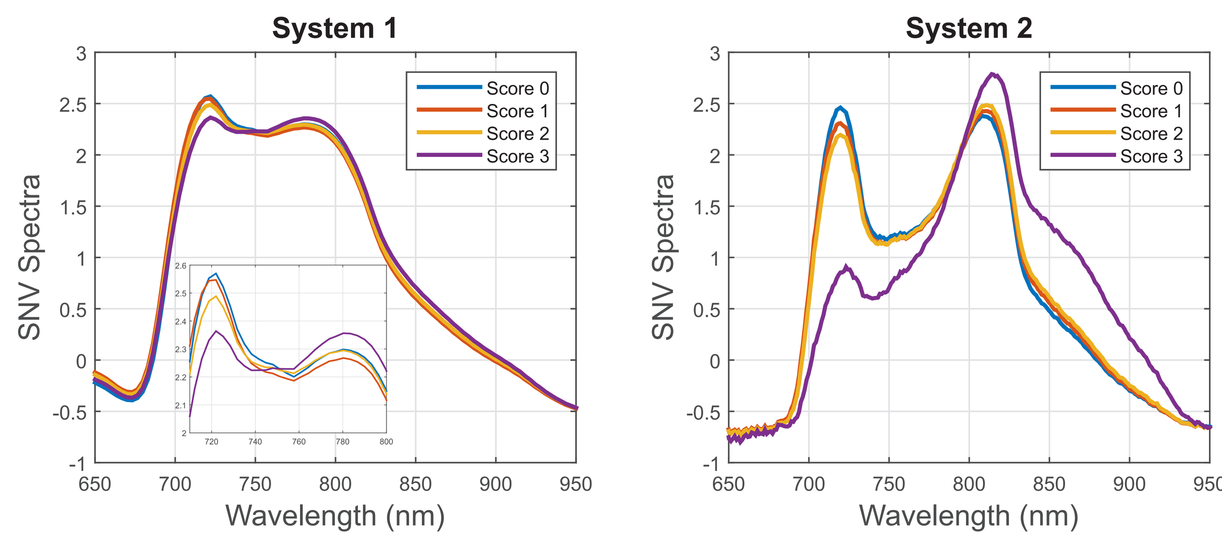

Figure 4: Average spectra of each 'Braeburn' apple severity score for vascular browning under the two systems.

For System 1 the optimal true positive rates (TPR) and false positive rates (FPR) were 63% and 23%, respectively (Figure 6). The rates for System 2 were significantly better, at 84% and 20% respectively (Figure 7). There were higher detection rates for the more severe samples (Table 1), although neither system detected all the severe cases (score 3).

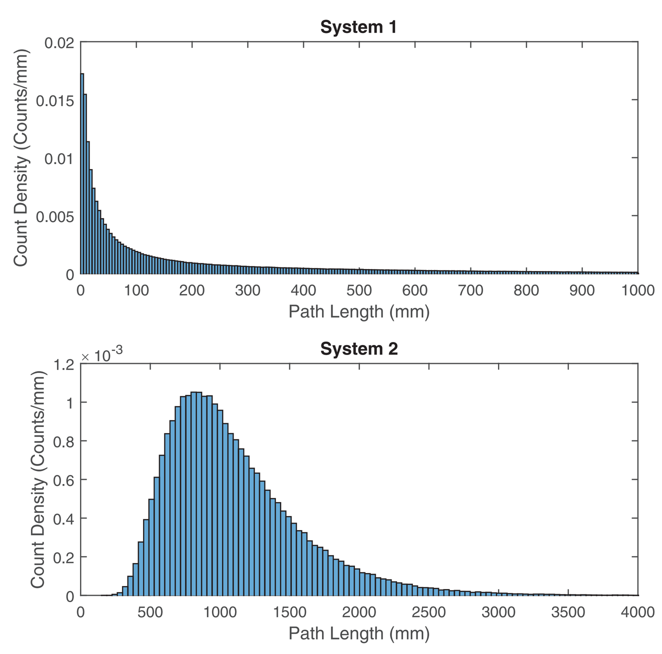

Figure 5: Monte Carlo (MC) simulations of the light path distributions in the two systems.

Table 1: Detection rate for each vascular browning severity score in 'Braeburn' apples.

Severity score	System 1	System 2
0	77%	80%
1	61%	83%
2	63%	88%
3	75%	88%

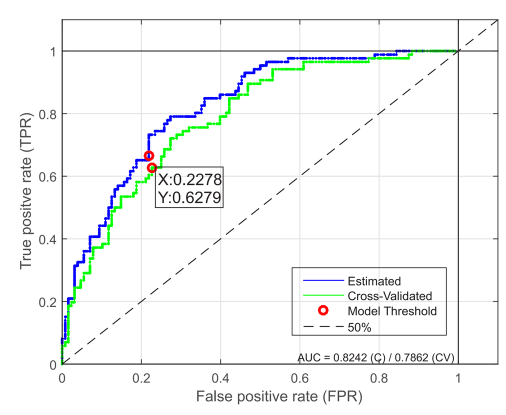

Figure 6: True and false positive rates of detecting 'Braeburn' apples with vascular browning with System 1.

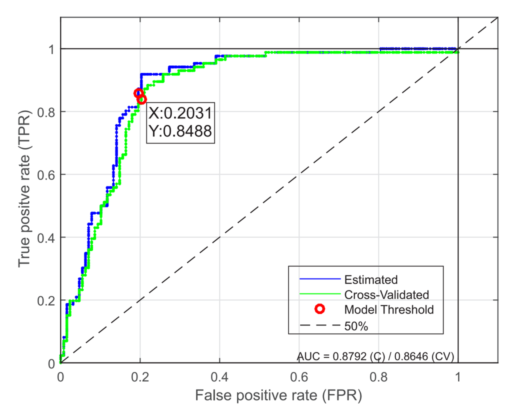

Figure 7: True and false positive rates of detecting 'Braeburn' apples with vascular browning with System 2.

Conclusion

- The optical geometry in System 2 was better than that in System 1 for VAB detection, with a TPR at 84% and FPR of 20%; the better System 2 result was supported by MC simulations revealing much greater light path lengths.
- VAB remains a difficult defect to detect by NIR methods; not every severely VAB-affected apple was detected.