Environmentally Friendly and Safe Technologies for Quality of Fruits and Vegetables

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The papers contained in this book report some of the peer reviewed Proceedings of the International Conference "Environmentally friendly and safe technologies for quality of fruit and vegetables", but also other papers related with the subject were included. The manuscripts were reviewed by the Editor and Editorial Board, and only those papers judged suitable for publication were accepted. The Editor wish to thank to all the reviewers and authors for their contribution.

Authors are responsible for content and accuracy of their papers.

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05. NIRS DETECTION OF MOLDY CORE IN APPLES

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Abstract
Moldy core of apples is undetectable until the fruit is cut or bitten into, it can therefore pose serious problems to both producer and consumer. Removal of diseased fruits prior to storage would be most desirable. The objective of this study was to evaluate the ability of VIS-NIR mini-spectrometers to detect moldy core in apples, on line. An apparatus which is qualified for online NIRS (near infrared spectrometry) measurements was developed based on off-the-shelf mini-spectrometers. 'Top Red' apples, were collected from several orchards before and during the commercial harvest, and were stored at 0°C pending the tests. The data were analyzed by chemometric procedures, specifically, by partial least squares regression (PLSR), and were classified by means of canonical discriminant analysis. The canonical variables were represented by the latent variables of the PLS models, which were based on the spectra. The accuracy of the classification results was high when the moldy fraction threshold was set at 5%; in such a case the mold covers only the seed carpals of the fruit, where it might remain without really damaging the fruit. Improvements should aim to reduce errors in classifying low-level damage, and also in misclassifying some healthy fruits. The rate of testing (1 s per fruit) is acceptable for quality control purposes, but should be accelerated for future packing-line implementation.
Keywords: *Alternaria alternata,* Fruit Quality, Near Infrared Spectroscopy

Introduction
Generally, mechanical and manual sorting are based on external indices and lack the ability to determine essential internal quality attributes. Non-destructive, rapid evaluation methods are in growing demand by growers, packinghouse operators and consumers. Moldy core of apples is undetectable until the fruit is cut or bitten into and can pose as such a serious economic problem to producer and consumer alike. The disease can be caused by a number of saprophytic fungi, of which the most prevalent are *Alternaria alternata* and *Cladosporium herbarum*. Infection occurs through the style of the flower and the disease develops in the orchard within fruit of open calyx cultivars, such as 'Red Delicious'. The infection, which spreads out from the seed cavity during fruit development, can be either dry (*A. alternata*) or wet (*C. herbarum*). At harvest, the former is the predominant cause, but during storage the latter develops more rapidly (Reuveni *et al.* 2002). Removal of diseased fruit prior to storage would be most desirable. Consequently, a reliable, non-destructive method for detecting and grading such fruit would be useful for the industry. The objective of this study was to evaluate the ability of CCD based hyper-spectral spectrometers to detect on-line moldy core in apples. Several types of spectrometers were tested in stationary and conveying conditions.

Near infrared spectroscopy (NIRS) is a non-destructive technology, which could supply rapid, quantitative evaluation of quality indices. Using statistical regression analysis, it can be used to determine ingredients such as water, sugars, dry matter, starch etc. The ability to detect internal disorders by NIR has been demonstrated in several studies (Upchurch *et al.* 1997; Clark *et al.* 2003). The commercial NIR instrument such as the F5 (Sacmi, Italy) is quite expensive. The objective of the present study was to evaluate the ability of a high speed, low cost CCD based spectrometer to detect moldy core in apples.

Materials & Methods

A preliminary study was conducted to test the ability of two spectrometers to detect internal decay caused by *A. alternata* in a stationary condition. The first was Liga (MicroParts, Germany) based on 64 diode array *InGaAs* in the range 1100-1750 nm, and the second S2000 (Ocean Optics, USA), operating in the range of 530 -1100 nm. The spectral analysis of these measurements showed promising results for the S2000. Based on these results, a new instrument was developed, consisting of a rotating table, the S2000 spectrometer, special cells to support the fruit and an illumination unit (Fig 1). The device is controlled by a PC. Specially designated software was developed for data acquisition and online analysis. A cylinder of white Teflon installed into the rotating plate is used as a reference background for transmittance spectra.

'Top Red' apples were picked from several orchards before and during commercial harvest. Some samples were stored at 0°C until used for testing. Twenty-one batches varying in sample size from 40 to 200 apples and totalling 955 fruit were examined with the NIR equipment. The fruit were scanned in transmittance mode with an integration time of 80 ms. The complete scan time was 1 s per fruit. Each intact apple was scanned three times in three placement positions, differing by 120° round the equator, relative to the stem axis. After scanning, apples were halved through their equator and the cut surface was photographed with a digital camera (Fig 2). The photograph was analyzed using an image analysis program, which evaluated the decay level as the ratio between the decayed area and the total area of the cut surface of the fruit.

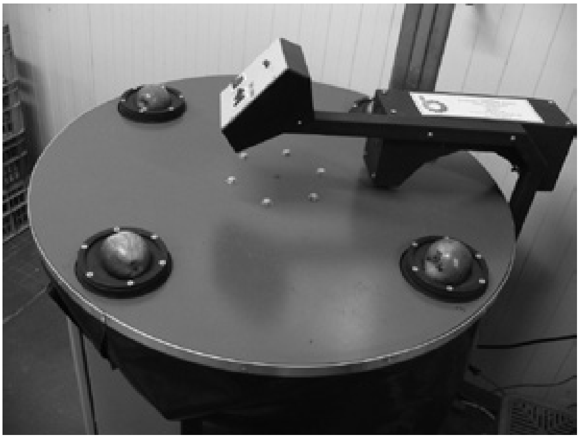

Fig 1. Overview of rotating table with special cells and illumination device for NIR transmittance measurements in motion.

Fig 2. Cut apple with view of advanced moldy core.

The spectral data were analyzed by chemometric procedures and Partial Least Squares (PLS) regression procedure was used for model development. PLS ensures that the loadings and scores reflect variance related to the varying constituent concentrations, by incorporating concentration information into the data reduction step (Martens and Naes, 1989). The raw transmittance spectra and manipulated spectra were analyzed with MATLAB © software. Comparisons were drawn between PLS performance related to treatment of the raw spectra T (transmittance), the first derivative of T (D1T), Log (1/T) and its second derivative (D2(Log(1/T)).

The optimal value for k, the number of factors to be used in the analysis, was obtained by predicting independent sets of samples for different values of k and determining the value of k, for which the root-mean-square prediction error was at a minimum or not significantly different from the minimum. This error is called the Standard Error of Prediction (SEP), also known as root-mean-square prediction error, and has been described and used as a measure of standard deviation for total bias (Biddy & Toutenburg 1977). The

SEP was estimated by cross-validation: one sample was removed from the calibration set, a model was developed by applying PLS to the remaining samples, and the decay level of the initially removed sample was predicted. This process was repeated for every individual sample in the calibration set.

Outliers were rejected according to statistical criteria (Rousseeuw & van Zomeren 1990). In these procedures, the leverage and the residuals of the multilinear regression defined the relevant zone for outlier data points. The spectra were also used to classify the samples into groups of fruit with different decay levels. Classification was performed by means of Canonical Discriminate Analysis. First, the canonical variables were represented by the latent variables of the PLS models that had been built from the spectra. The first N canonical variable calculated for each sample, was then used in discriminate analysis to assign samples to their respective groups. The canonical variables were used as independent variables and the decay level ranges were used as the class labels. Classification was done with the Maximum Likelihood method. One-third of the data were used for training the classifier, with the remainder used for validation (Duda *et al.* 2001).

Results & Discussion

Transmittance spectra for 'Red Top' apples are presented in Fig 3 showing the differences between rotten and healthy apples. For each spectrum, the level of decay is marked as the ratio of diseased to total area of the cut surface, indicating that 0.0 is a healthy fruit. However, as expected, results of whole batch spectra revealed a lot of overlapping, necessitating the application of chemometric methods for analysis.

The results of the SEP and number of factors obtained from the PLS regressions are presented Table 1.

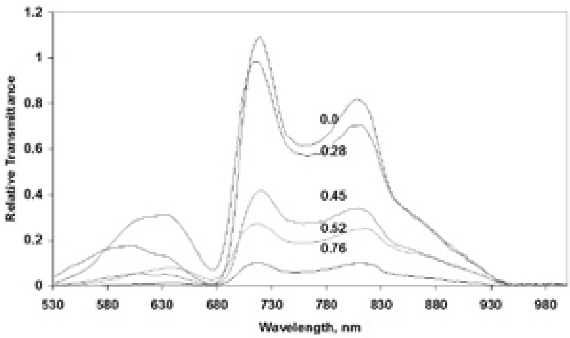

Fig 3. Example of transmittance spectra for 'Red Top' apples with different levels of moldy core. Numbers indicate area of fruit flesh affected by moldy core.

Table 1. PLS analysis of different models for spectral treatment.

	SEP	SEC	Latent factor	r
T	0.053	0.048	10	0.77
T (D1T)	0.052	0.049	4	0.77
Log (1/T)	0.052	0.046	10	0.79
D_2Log(1/T)	0.056	0.052	2	0.72

The table includes results calculated for the raw spectra (T), their first derivatives (D_1T), absorbance (Log (1/T)) and second derivatives (D_2Log(1/T)). It shows that from the point of view of SEP the Log (1/T) model has an advantage. However, the low number of latent factors for D_1T implies the robustness of this model. Example of PLS prediction results is shown in Fig 4.

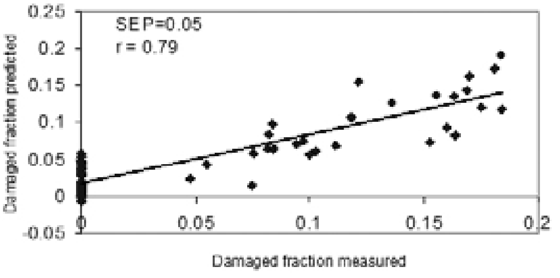

Fig 4. Typical prediction results for detection of moldy core in Top Red apples for Log (1/T) using replicate averages of 3 positions for each fruit.

The results of discriminate analysis are presented in a confusion table (Table 2), with groups of 0, 0-0.1, 0.2-0.3 and 0.3-1.0 levels of moldy core. The diagonal elements, from upper-left to lower-right, describe the accuracy of the classification results and should ideally reach the total number of samples. The off-diagonal elements, ideally, should be zero, and the higher the value of the off-diagonal elements, the greater will be the detection error. The results show a high classifying efficiency for all groups (86-100%).

Table 2. A confusion table depicting results of cluster analysis for one of the batches.

NIR results	Laboratory results				
	0	0-0.1	0.1-0.2	0.2-0.3	0.3-1
0	132	5	0	0	0
0-0.1	12	36	7	0	0
0.1-0.2	0	1	55	2	0
0.2-0.3	0	0	1	13	0
0.3-1	0	0	0	0	18
sum	144	42	63	15	18
error	12	6	8	2	0
Efficiency (%)	92	86	87	87	100

Conclusion

A newly developed NIR system showed promising results for detecting moldy core in ‹Red Top› apples. Improvements need to be made for decreasing errors with regard to low levels of decay as well of misclassifying healthy fruit. The testing rate (1 fruit per s) is acceptable for quality control purposes but will have to be increased for future online implementation.

References

Biddy J, Toutenburg H. 1977. *Prediction and Improved Estimation in Linear Models.* Chapter 2, pp:16-9. John Wiley and Sons, NY

Clark CJ, McGlone VA, Jordan RB. 2003. Detection of Brownheart in ‘Braeburn’ apple by transmission NIR spectroscopy. *Postharvest Biol Technol* 28:87-96

Duda OP, Hart E, Stork DG. 2001. *Pattern Classification.* 2nd ed. John Wiley and Sons, NY

Martens H, Naes T. 1989. Assesment, validation and choice of calibration method, pp:97-165. In: *Multivariate Calibration,* John Wiley. NY

Reuveni M, Sheglov D, Sheglov N, Eshel D, Ben-Arie R, Prusky D. 2002. Sensitivity of Red Delicious apple fruit at various phenologic stages to infection by *Alternaria alternata* moldy core control. *Eur J Plant Pathol* 108:421-7

Rousseeuw PJ, van Zomeren BC. 1990. Unmasking multivariate outliers and leverage points. *J Amer Statistics Assoc* 85411:633-51

Upchurch BL, Throop JA, Aneshansley DJ. 1997. Detecting internal breakdown in apples using interactance measurements. *Postharvest Biol Technol* 10:15–9