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NON-DESTRUCTIVE QUALITY ASSESSMENT OF FRUITS USING OPTICAL METHOD

Jozsef Felfoldi, Zoltan Gillay, Viktoria Muha
Corvinus University of Budapest, Faculty of Food Science, Department of Physics and Control, 14-16 Somloi str., Budapest, Hungary, jozsef.felfoldi@uni-corvinus.hu

Abstract: The importance of the non-destructive methods in the quality assessment of the horticultural produces is increasing continuously. Application of these methods is advantageous from the garden to the market, because they are suitable for quick investigation of the samples without any loss in market value. The contact spectroscopic methods of different wavelength ranges are able to provide with information about the internal properties of the samples, so they are important alternative methods besides the dynamic mechanical methods and noncontact machine vision applications. The measurement system, developed for the experiments, contains a PC-controlled hardware and a data analysis software, able for extraction of the desired features even in case of weak signal/noise conditions in industrial circumstances. The system was successfully applied for assessment of sugar content of several fruits.

Key words: fruit, quality, noncontact testing, spectrometer

INTRODUCTION

The penetration of the light into the tissue of different fruits and vegetables was investigated by many research groups. In case of several produces it was found, that the spectrum of the visible and near infrared light provides with information about internal properties of the sample. Our aim was to find correlation between the internal and spectral properties of the produce and to develop method and algorithms for objective characterisation of the quality for investigated species or cultivars.

METHODS AND MATERIALS

According to the publications dealing with hardware and software aspects of measurement and assessment of the spectral properties of the horticultural produces (e.g. Ventura et al., 1998, Schmilovitch et al. 2000) the visible to near infrared wavelength range covered by Si sensors (up to 1100 nm) can be informative in case of some quality-related chemical components - first of all, the sugar content. In this range the CCD sensor-array based spectrometers seem to be the most suitable instruments for the assessment of the internal properties of the different fruits and vegetables due to their optimum price and acceptable quality. The main disadvantage of these instruments comparing to the high quality laboratory NIR spectrometers is the relatively poor signal-to-noise ratio due to the Si based sensor elements. Furthermore, taking into account the high biological variability of the samples, the uncertainty caused by hardly determined contact parameters between the optical system and the intact sample surface, it's obvious that both the optical-mechanical setup and the mathematical methods applied for data evaluation have significant effect on the reliability of the measurement.

The Ocean Optics USB2000 PC-controlled spectrometer, selected for the tests, has high operation speed (it has no moving compartments so the full scan time is several milliseconds). The low (250:1) one-readout signal-to-noise ratio can be partly compensated by longer integration time. The spectrometer was configured to the 550-1100 nm wavelength range. The instrument is fitted with appropriate optical fibre cables to connections with the light source and/or the sample holder (Figure 1). Main technical parameters are shown on Fig. 2.

In order to ensure the robustness of the system, different transformations of the pure spectral signal - relative reflectance, log(1/R), first and second derivatives, etc. - known as effective tools for compression of the non-desired effects of the uncertain components, were evaluated with a wide range of the mathematical statistical methods (MLR, PLS, PCA, etc.).

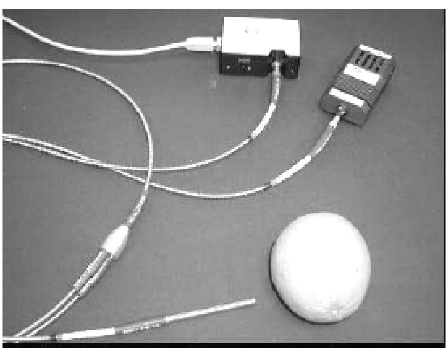

Figure 1: The spectrometer and the fitted optical components

Detector :	Sony ILX511 CCD
Spectroscpy characteristics: Integration time Dynamic range Signal/noise ratio (one reading)	3 - > 30,000 msec 2 x 108 250:1
Wavelength range: Resolution:	530-1100 nm 2048 step ~ 0,3 nm

Figure 2: Technical parameters of the Ocean Optics USB2000 spectrometer

Several fruits and vegetables were used during the tests in order to analyse the possible correlations between the spectral characteristics and internal properties (namely Brix and titratable acids, TA):

- apple (cv. Jonathan, Gala and Idared)
- mandarine (Clementine)
- orange (unknown cv.)
- vinegrape (unknown cv.)
- tomato (cv. Raissa and Credito)

Brix values were measured by an ATAGO PAL-1 digital pocket refractometer, TA concentrations (apple and tomato samples only) were determined with standard method.

RESULTS AND CONCLUSIONS

According to our experiences the spectral properties of the tested samples can be connected to their ripeness stage. Qualitative assessment of the surface characteristics of several produces (e.g. banana, mandarin) resulted in the conclusion, that change in ripeness stage caused significant change in surface spectral properties mainly in the visible range (red wavelength range around 670 nm, at the chlorophyll-peak) as it is demonstrated on Figure 3. in case of mandarin samples.

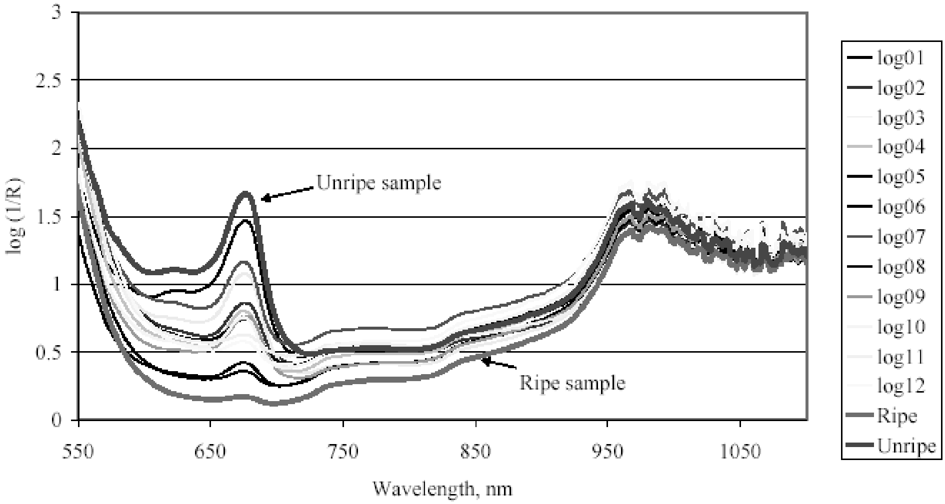

Figure 3: Spectral characteristics of mandarin samples of different ripeness stage

For the non-destructive investigation of the fruit flesh next to the peel a special interactance mode setup - similar to the one, shown e.g. by Renfu Lu et al, 2005 - was constructed (Figure 4.). In this arrange, flash layer of several mm width below the sample peel is illuminated from left and right side at 45o angle, and the diffuse light - going through some flesh part - is collected from bottom part of the sample by the input window of the optical cable (direct light from the source is excluded from the sensor).

The fruit and vegetable samples were tested using this setup. The correlation between the spectral characteristics and the Brix values determined by refractometer was analyzed using different multivariate mathematical-statistical methods.

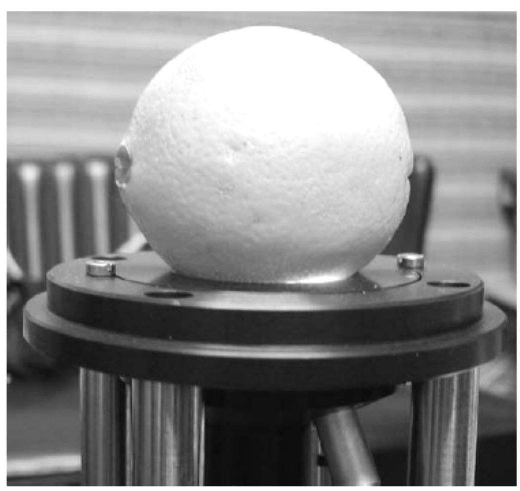

Figure 4: Orange sample on the special interactance sample-holder

The results of the PLS (Partial Least Squares Regression) analysis of first derivatives of the standardized spectra of the tomato samples (providing the best results for Brix assessment) are shown on Figure 5. The selected wavelength values, the linear model and the crossvalidation error are demonstrated on the Figure. The cross validation error in this case was less than 1 Brix%.

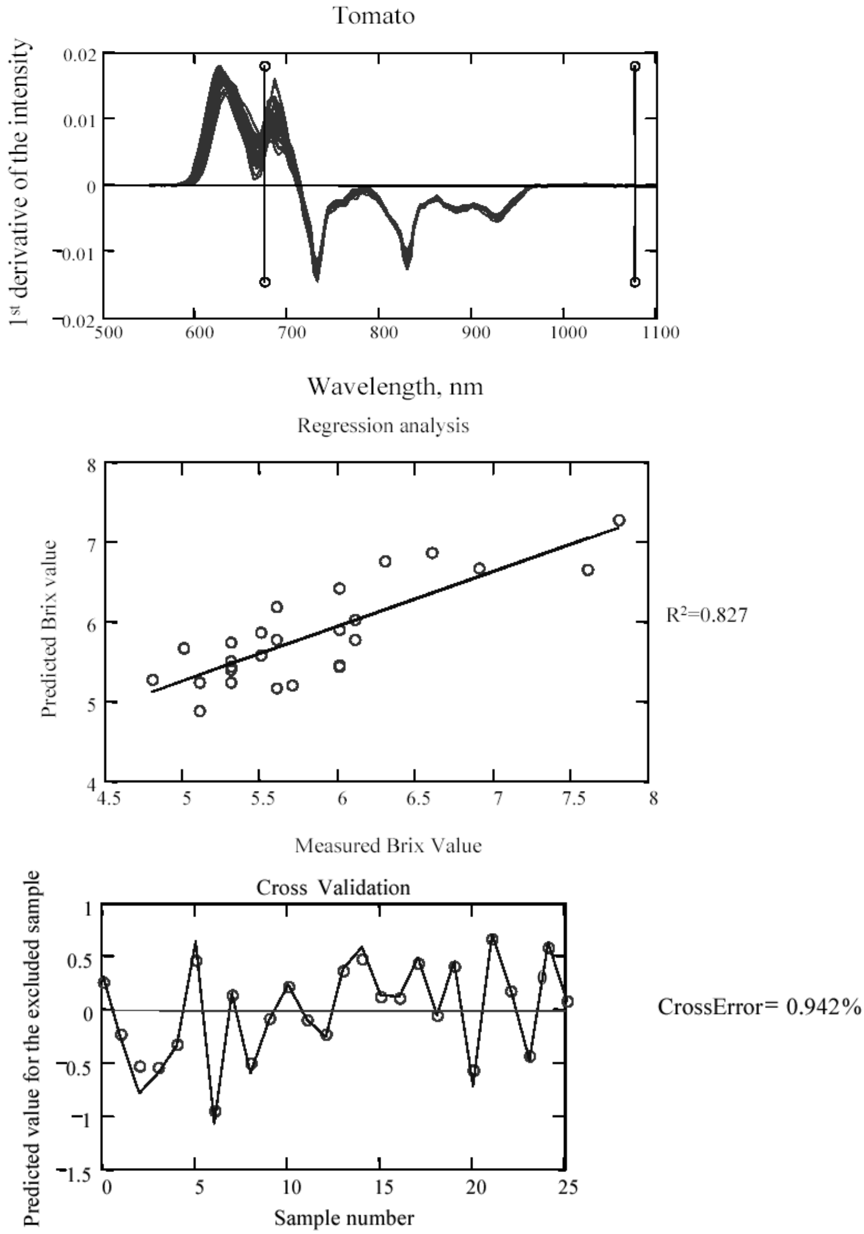

Figure 5: PLS-results of tomato spectral data for prediction of Brix value

Similar results were found for the other species as well. Generally, the cross validation error for Brix assessment of the tested produces was found to be less than 1-2 Brix%. It seems to be an encouraging result in the process of development the method and instrumentation for quick and non-destructive quality analysis.

Further data assessment methods are needed to increase the repeatability and robustness of the system. Data pre-processing, mathematical statistical methods, shape-recognition algorithms based on neural network, individual methods (e.g. “Red-edge” detection) will be tested during the further investigations in order to increase the efficiency of the system.

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NEDESTRUKTIVNO ODREĐIVANJE KVALITETA PLODOVA VOĆA PRIMENOM OPTIČKE METODE

Jozsef Felfoldi, Zoltan Gillay, Viktoria Muha

Corvinus University of Budapest, Faculty of Food Science, Department of Physics and Control, 14-16 Somloi str., Budapest, Hungary, jozsef.felfoldi@uni-corvinus.hu

Sadržaj: Značaj određivanja kvalitet voća i povrća nedestruktivnim metodama se konstantno povećava. Korišćenje ovih metoda ima više prednosti koje se najpre ogledaju u brzom istraživanju uzoraka bez ikakvih gubitaka u pogledu tržišne vrednosti. Kontaktne spektroskopske metode na različitim režimima talasnih dužina, u stanju su da obezbede informaciju o unutrašnjim svojstvima uzorka i zato su one važna alternativna metoda pored dinamičkih alternativnih metoda i bezkontaktnih vizuelnih aplikacija. Merni sistem, razvijen za izvođenje ovog eksperimenta, sadrži hardver PC kontrolera i softver za analizu podataka kojim se mogu izdvojiti potrebni podaci i u slučaju veoma slabih signala u bučnim industrijskim uslovima. Predloženi sistem je veoma uspešno iskorišćen pri analizi sadržaja šećera u plodovima pojedinih voćnih vrsta.

Ključne reči: *voće, kvalitet, bezkontaktno testiranje, spektrometar.*