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Non-destructive Apple Ripeness Determination

Using Spectral Analysis in the Visible Band Range at Various Locations

Using spectral analysis in apple cultivation, the ripeness-dependent change in the basic green colour can be determined non-destructively. The fruit chlorophyll content is a sensitive ripening indicator, which is ascertained by measuring the characteristic light absorption in the visible wavelength range. In first comparative measurements in various cultivation regions, the development of fruit chlorophyll content in „Elstar" apples was measured spectrometrically, in order to assess the regional influence on fruit ripening development.

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Keywords

Fruit chlorophyll absorption, non-destructive detection, optimum harvest date, regional factors

Apples, reaching the market, have to comply with the market standards of the EU and the quality demands of the consumers. Therefore it is important to harvest fruits in a suitable ripeness stage. At this date the fruits should be ripe providing already good aroma quality, but on the other hand not over ripe for allowing long term storage [1]. The optimum harvest date (OHD) is affected by the cultivar, growing location, seasonal weather conditions [2], and targeted fruit processing (direct-marketing or storage).

Up to now determining the OHD is achieved by time consuming and destructive methods (starch-index, fruit firmness, and soluble solids content). The common use of colour cards is a non-destructive method but provides subjective results, which are often erratic.

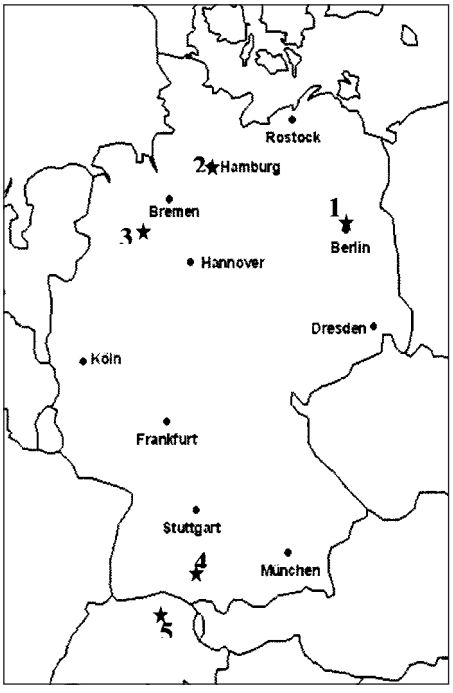

Fig. 1: Growing locations: 1) Werder, Fruit Grower Firm. Neumann; 2) Jork, Fruit Experimental Station of the Chamber of Farming Hannover; 3) Osnabrück, University of Applied Sciences: SF Fruit- and Horticulture; 4) Bavendorf, Experimental Plant of the University Hohenheim; 5) Wädenswil, Federal Institute for Scientific Research for Fruit-, Wine- and Horticulture

In the last years intensive investigations were carried out world wide to develop non-destructive methods for determining the stage of ripeness and the internal quality of fruit and vegetable. Spectral analysis exposed thereby as a promising technology. Measuring light absorption, provides a rapid, objective, and non destructive method. Fruit chlorophyll absorbance can be determined in the visible wavelength range (400 nm - 750 nm) [3]. Recent results show a strong correlation between the stage of fruit ripeness and changes in ground colour [4]. The time-course of such changes is strongly modified by the position of the orchard as well as climate and weather conditions as irradiation and temperature regime.

Methods for determining the stage of apple fruit maturity

In the season 2002 weekly measurements were carried out from the calendar week 35 to 37 at five different orchards in Germany and Switzerland (*Fig. 1*).

At each measuring place and date, partial transmittance spectra were recorded of 30 fresh harvested 'Elstar' apples. The ART-System (UP, Cottbus) was subsequently used to measure the destructive reference values of fruit firmness, soluble solids content (SSC), and starch index. Additional measurements were carried out two times per week at the Institute of Agricultural Engineering Bornim to measure the fruit respiration rate in climate chambers and the fruit chlorophyll content by wet-chemical analysis.

The modular, portable spectrometer system used was built up as follows: power supply unit, light-source with 20 W halogen lamp, electric control unit, monolithic spectrometer (MMS1 NIR enh., Zeiss, Jena) and a fruit probe with glass fibres and SMA-connectors (tec5, Oberursel) [3]. The spectrometer system was driven by a PC-notebook (Pentium 166 MHz, 16 MB RAM).

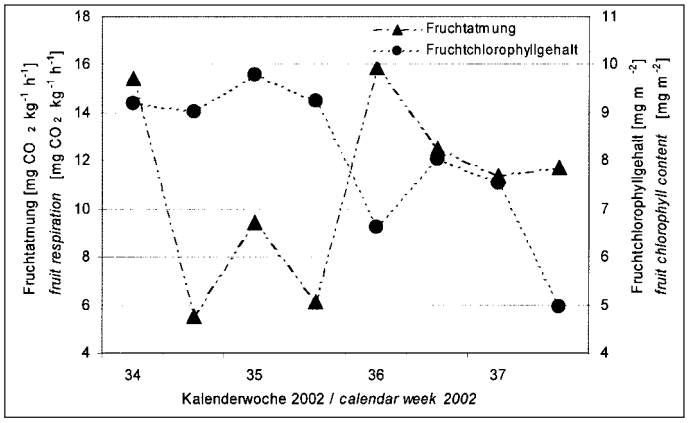

Fig. 2. Development of wet-chemically determined fruit chlorophyll content and of fruit „breathing" of Elstar-apples (n=30) from the area of Werder

In the partial transmittance mode white light conducted by 4 glass fibres penetrates the fruit. The entering light was scattered by the cellular elements or absorbed by the fruit compounds. The out-coming light was received and conducted by a glass fibre to the spectrometer. Measuring duration lasts between 3 and 4 seconds.

In the fruit spectra recorded in partial transmittance mode a typical minimum appeared between 660 nm and 680 nm due to light absorption of chlorophyll in this wavelength range. The inflection point of the long-wave flank of the chlorophyll absorption peak (red-edge) was used to achieve information on the fruit chlorophyll content according to Lambert Beers Law. The red-edge was calculated as $f''(\lambda) = 0$ using the second derivative spectra. The use of the inflection point allows calibration on the corresponding fruit chlorophyll content [3].

Results

In the Werder-orchard, apple fruit harvested in week 36 showed a strong increase of the respiration rate, indicating the OHD. The fruit chlorophyll content determined wet chemically decreased as well (*Fig. 2*). The spectrometric measurements showed a uniform development for each growing location during ripening of 'Elstar' apples. There was a red-edge shift to lower wavelength values during the fruit chlorophyll content decreased. A high correlation coefficient of determination (R^2=0.88) exists between the red-edge values and the fruit chlorophyll content analysed wet-chemically.

The SSC and starch index increased during fruit ripening as expected, while fruit firmness decreased.

However, regional differences where obvious in the present experiment. For all measuring dates apples of the orchards Bavendorf and Wädenswil showed a lower red-edge compared to the three northern orchards located in Osnabrück, Werder, and Jork (*Fig. 3*). The refractometer values in the South were on a higher level than the values in the North. The fruit SSC level indicated the same tendency with respect to the regional factor.

Decreased red-edge and enhanced SSC in Bavendorf and Wädenswil are indicators for an advanced fruit ripeness of 'Elstar' apples and an earlier OHD for these orchards compared to the northern ones.

The presented results show that spectral analysis in the visible wavelength range is a suitable method for non-destructively determining the OHD of 'Elstar' apple fruit at different growing locations.

Outlook

Further studies are planed for 2003 and 2004 at different orchards with expansion of cooperation to Skierniewize, Poland to confirm the results.

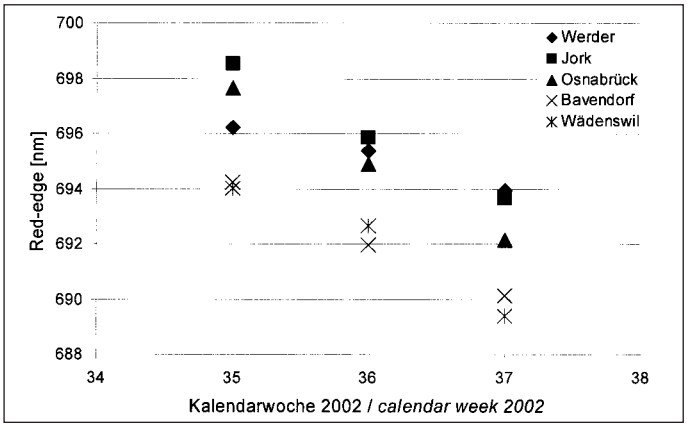

Fig. 3: Shifting of the turning point of the long wave edge of chlorophyll absorption bands (red-edge) in the course of fruit ripening, non-destructive spectrometic measuring of apples (n=30) of Elstar variety at five cultivation locations in Germany and Switzerland

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