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Destruction-free determination of fruit development stages

The ripeness development of apples and other fruits is an important criterium for the harvesting decision – a decision which, up until now, is often subjective and depends on fruit appearance. For some varieties, colour charts are used for comparative evaluation of the ground colour.

The ground colour can also be determined with much more accuracy through spectronomic measurement. With the help of a miniature spectrometer with glass fibre sensor it is possible to identify the alterations in the ground colour very accurately during the harvesting period through the chlorophyll-specific light absorption in the wavelength sector from 600 to 750 nm.

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Keywords

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The market quality of fruit is to a great extent determined by degree of ripeness. An apple can only develop its variety-specific taste and through this achieve its highest quality when it is sufficiently developed before picking. During the harvest, therefore, the grower must keep himself continually informed over the development and maturity progressive of his fruit crop. Because, even within a single orchard, the fruit doesnít develop evenly, selective picking in successive harvesting operations has to be planned to achieve optimum quality. In order to be able to identify the fruit ready for picking, experienced harvesters are required. In this context, the objective determination of the ripeness stage of the fruit causes great difficulties.

Conventional ripeness determination

No quantitative information on the determination of ripeness degree is given in the EU quality standards [1]. Instead only qualitative characteristics for describing the ripeness progress (increase of breathing activity, production of ethylene). The fruit development is judged according to the following parameters: ground colour, fruit flesh colour, starch depletion, fruit flesh consistency, size, brix value, acid content and sugar-acid ratio. Apart from size and ground colour, the determination of these parameters is, however, not only too complicated for the grower, but also only possible through fruit-destruction.

A widely-used criterium for determination of harvesting time is the Streif index which takes account of the fruit flesh consistency, the starch depletion and the brix value. Less practical results are produced by a modified index by which the a*-value (L*a*b*-colour area) is a non-destruction measurement basis for the ground colour and takes the place of the destructive measurement for determining starch depletion [2]. Because the a*-value can be influenced through the red cover colour pigment, using this parameter causes problems. In practical farming, a cost-effective technical solution would be helpful with which the stage of fruit development and maturity can be speedily and sufficiently-accurately determined without destroying the fruit.

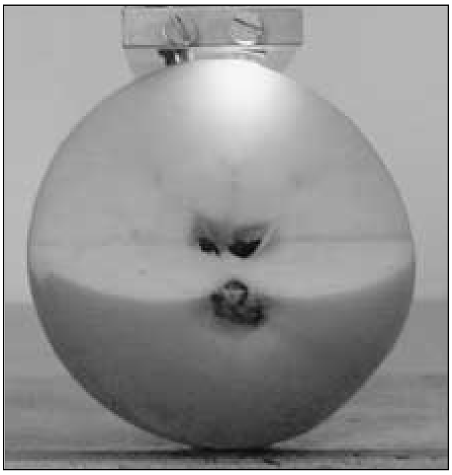

Fig. 1: Sensor probe for partial transmittance (light emission from emitting fibre in the fruit tissue of the apple)

With different measurement systems, the possibilities for the technical realisation of a suitable non-destructive system for the determination of fruit ripeness were investigated. According to all experience, however, it is still necessary when utilising the non-destructive methods to carry out a comparative calibration with the tried and tested destructive method.

Spectrometric determination of ground colour

At ATB investigations were carried-out in order to develop a sensor for the determination of the ground colour. Because of the already-known results [3] a spectrometric measurement system was chosen. Miniaturised spectrometer modules of small size and with specifications of just a few centimetres are available commercially. These basically fulfil the respective requirements in measuring sector, spectral dissolution, sensitivity and measuring speed. Through then use of glass fibre sensors it was investigated to what extent these sensors could be adjusted to sufficiently match practical operational conditions.

For laboratory investigations, a modular constructed mobile spectrometer for the wavelength sector of visible and near infra red light (400 to 1000 nm) was used. This consisted of an electricity supply (mains or battery), a control unit, an illumination module with 20 W halogen lamp and a spectrometer

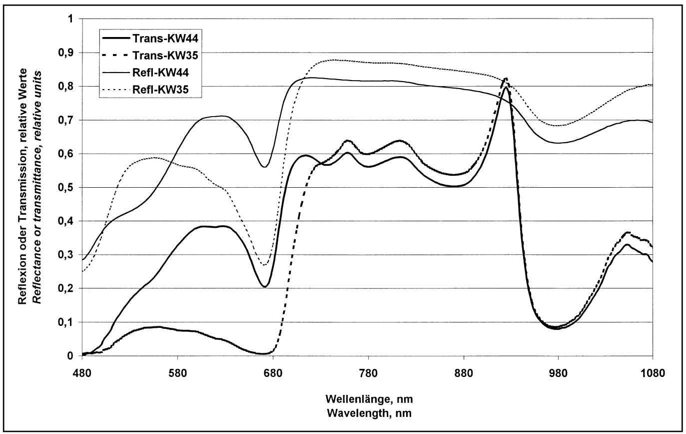

Fig. 2: Examples of reflectance and transmittance spectra of "Jonagold" at two harvesting dates (calendar week 35 and 44)

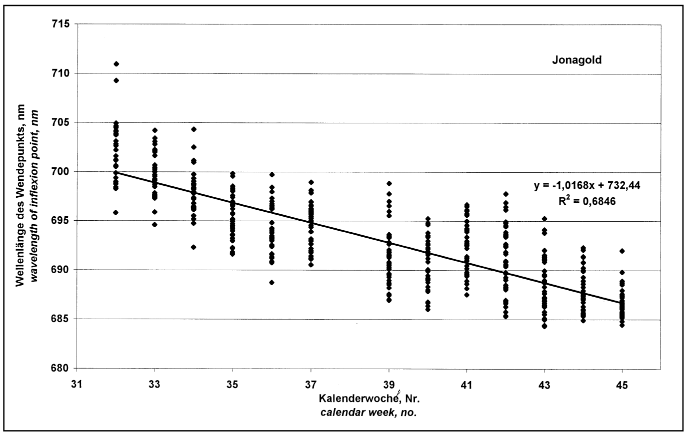

Fig. 3: Wavelength shift of inflexion point in transmittance spectrum of "Jonagold" during the period of September to November 1999

module (Zeiss MMS1). The spectral dissolution (Rayleigh-criterium) was 10 nm. With the help of a dioden array detector, the spectrum was broken-down with 256 pixels. The spectral pixel gap was 3.3 nm. The measuring head was linked over universally applicable quartz glass fibre bundles with SMA connections to the light source and spectral modules. This mini spectrometer was controlled with the help of a notebook PC (Pentium 166 Mhz, 16 MB RAM, WIN95) and could be equipped for different types of measurements. The user software was self-developed and contained modules for calibration, different measurement types, a direct view mode, an automatic sensitivity adjustment to various spectral sectors, a function for signalling malfunctions and also a function for data processing. For the results presented here, measurements were made with automatic sensitivity adjustment in order to secure a high signal-interference relationship.

Measuring the partial light transmission

Applied for measurement of fruit up until now was a sensor to measure diffuse reflection on the fruit surface (integrated sphere with measurement opening of 5 mm diameter) as well as a sensor for transmission through the skin and the adjacent fruit flesh ("partial transmission"). With apples, the ground colour depends on the peel of the fruit as well as on the flesh near the skin. In order to determine the influence in the measurement of both parameters, the sensor for partial transmission was used. This comprised a framework with two separately channelled light fibres for the transmitted and for the received light (*fig. 1*). The transmitting fibre concentrated the light from a halogen lamp onto one spot of the fruit surface. Through the cell structure in the fruit flesh tissue, the light rays are scattered as they enter the fruit and the light is absorbed at certain wave lengths, depending on the biochemical composition of the flesh. The receiving fibre gathers some of the scattered rays and channels them to the spectrometer. A single measurement lasts 3 to 4 seconds.

Investigations with both sensors on the same fruit showed that the spectrum of the partial transmission substantially differed from the spectrum of the diffuse reflection on the fruit surface. The specific absorption of chlorophyll at 680 nm, and from water at 980 nm, is much more strongly developed in the spectrum of the partial transmission through the skin and fruit flesh (*fig. 2*) Additionally, in the transmission spectrum between 480 and 650 nm there is also a higher absorption through cover colour pigments (anthocyanin) and carotine to be seen. The spectrum of the partial transmission also showed marked absorption bands in the near infra red area with 735, 780 and 870 nm which apparently had little or nothing to do with the chlorophyll absorption.

Evaluation of the reduction in chlorophyll content

The ground colour is determined through the chlorophyll-specific light absorption. A suitable parameter for the evaluation of the chlorophyll content in plant material is the situation of the turning point in the increase of the long wave flank of the chlorophyll absorption [4, 5]. For testing the system two varieties of apple were put through a comprehensive series of measurements. For every calendar week and variety of apple, 20 fruits were harvested and in each case two measurements made on opposite points of each fruit. In that the coupling of the spectrometer sensor on the fruit surface influenced a different presentation of the measurement values, the variability in the original spectrum is very high (as with the use of the difference value with the wave lengths 750 and 670 nm). Because of this, the direct spectrum which is influenced less from them, is preferred for evaluation (first and second diversion after the wave length). In the second diversion, the turning point on the flank of the chlorophyll absorption appears as intersection point with the wavelength axis (zero transit).The wavelength of this intersection can be numerically determined relatively easily. In-line with advancing fruit development in the autumn period, the turning point is shifted significantly in the direction of smaller wavelength values. This criterium is independent of the changes in other spectral areas such as, e.g., those caused by absorption through cover colour pigments. From this, the turning point appeared very suitable as a sensitive parameter for the evaluation of ground colour (*fig. 3*) The variability of the measurement values is considerable, however. To what extent they can be traced-back to the actual individual ripening development of the fruit in the apple store has still to be determined through reference analyses.

Outlook

The transmission spectrum in the wavelength area from 400 to 1000 nm contains more information than is required for the determination of the chlorophyll-specific light absorption. Alongside information on the colour pigments in the visible spectrum can, especially in the near infra red spectrum (wavelengths over 750 nm), information be won on water and carbohydrates contents. This spectral area can be used, e.g., for the determination of the brix value.

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Books are signified with •

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