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Product Monitoring and Process Control in the Crop Supply Chain

The use of real time spectroscopy in the visible wavelength range to monitor produce quality along the supply chain is illustrated using fresh carrots as an example of the generic issues of produce quality management. The technique is well-suited to quality monitoring where the quality of produce is correlated with tissue pigment concentrations, or tissue components with characteristic absorption spectra.

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Keywords

Carrot, process management, product monitoring, shelf life, spectrometry, supply chain

Assuring healthy human nutrition and improving the economic success of farmers are priority targets in the context of current global changes. In the age of IT, process-oriented data analysis is predicted to form the basis for economic growth. The general consensus is that especially in agricultural economies new innovative technologies are needed for an appropriate process management. This should help to maintain the nutritional product quality and decrease losses due to produce decay along the supply chain of fresh, perishable agro-food and, therefore, make the processes more economical.

Product quality during production is determined by the plant genome, environmental conditions and micro climate as well as the production system. At the point of harvest fruit quality appears heterogeneous. In postharvest the quality level generally decreases as a function of time, dependent on conditions, for instance during product display, which affect the rate of quality decrease. Thus, initial quality level at harvest and subsequent conditions determine postharvest keeping quality by determining the length of time quality remains above the quality acceptance level. From an economical point of view the produce is finally lost when quality drops below this level. In principle, precise knowledge on the specific physiological, biochemical and physical properties of individual products and often complex interactions is essential for process management during harvesting, preparation, storage and marketing.

- For product monitoring the development of non-invasive analyses methods for physical and biochemical product properties is needed, targeting the online information gathering at determining the physiological stage of the living products.
- The process control will use the data obtained for the product along the supply chain, with the aim of adapting production and postharvest measures to the stage of

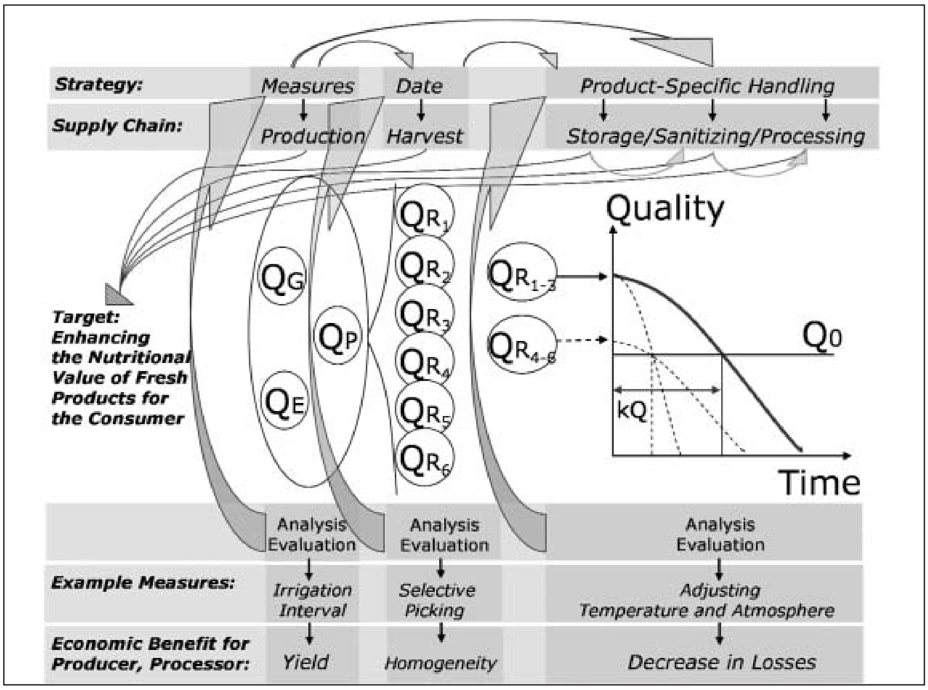

Fig. 1: Quality of perishable products along the supply chain with the major influencing factors in the production, and as a function of time in the postharvest sector. Q_E, Q_G, Q_P =quality-influencing factors (environment, genome, production system); Q_{Ri} = real product quality; Q_0 = acceptance limits; kQ = coefficient for shelf life [5].

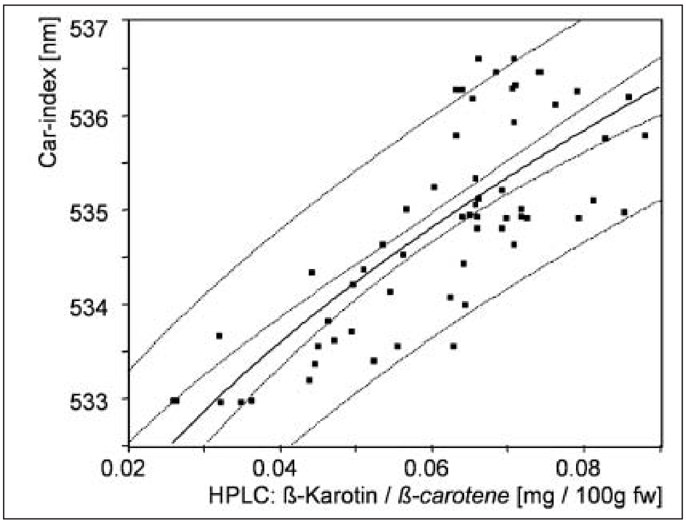

Fig. 2: Carotenoid content analyzed by means of HPLC and non-destructive remittance spectrometry using the car-index (y=a+bx0.5, with a=528.19 and b=26.96). Confidence intervals are given for 95 and 99%.

Literature

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the product in real-time (lower part of *Figure 1*) and developing product-based strategies for maintaining product quality (upper part of *Figure 1*).

Due to the rapid and precise recording of the product parameter in question, optical methods are well-suited for use along the entire supply chain. The industry [1] in cooperation with research [2, 3] has recently developed new sorting lines using spectrometry in the visible and near-infrared wavelength range, e.g., for peach, apple, and melon grading according to the fruit soluble solids and pigment contents. Also desktop modules and portable instruments for individual product testing were developed in the last four years based on the same technology [4]. For instance, product pigment contents can be assessed directly in the process and subsequently checked in the entire supply chain. It is precisely this repeated analysis along the supply chain that is essential for developing methods to assess the impact of processes in production and postharvest on the product quality.

As an example, in carrot the main pigments are the carotenoids, of which ß-carotene dominates, also providing the nutritional value of carrots as a source for provitamin A. Carotenoids degradation appears due to enzymatic and non-enzymatic oxidation and isomerisation. It is generally accepted that the initial stage of oxidation due to heat, light, and acids involves the formation of an epoxide. Subsequent fragmentation results in low molecular weight compounds that lose their absorbance characteristics. As a result absorbance spectrometry can provide valuable data on the impact of postharvest conditions on the provitamin A content of carrots.

In particular, the absorbance peak widths of carrot carotenoids undergo characteristic changes associated with pigment content. For determining carotenoids in carrots the

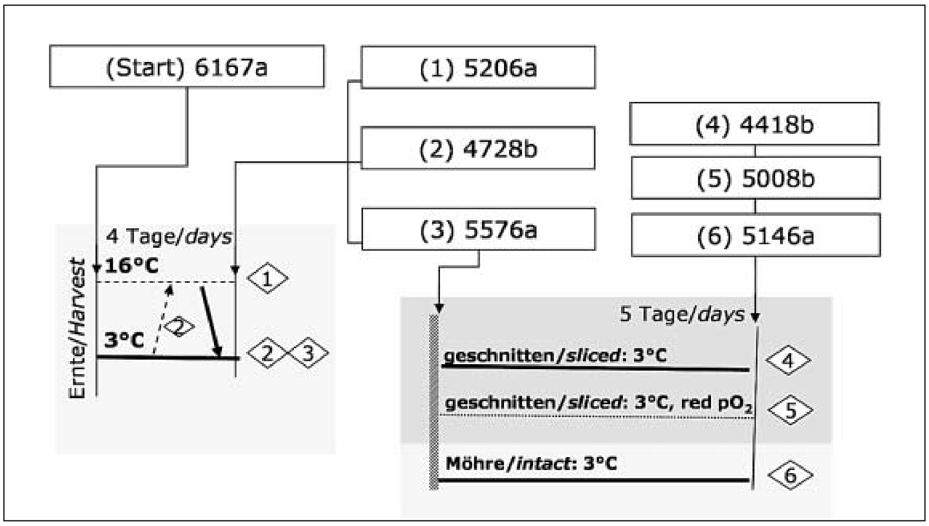

Fig. 3: Carrot ß-carotene content [µg / 100 g fw] analyzed after different postharvest conditions by means of non-destructive spectrometry. Different characters indicate significant variation at 5 % level.

inflection point of the longwave flank of carotenoid absorption was calculated on the fruit remittance spectra by $f''(\lambda_{450\text{-}650\ nm})$ [nm]=0 (car-index).

The car-index and the chromatographically (HPLC) analysed ß-carotene content were used for calibration, leading to a coefficient of determination of R^2=0.80 in the present study (*Fig. 2*). This method was used to monitor the nutritional value of carrots in terms of ß-carotene content during fresh keeping after harvest.

After four days keeping time at the recommended temperature of 3°C the ß-carotene content remained stable (*Fig. 3*). Carrots kept at 16 °C showed decreased ß-carotene contents. Also a large effect of a break in the cooling chain on the carotene content was observed. After slicing the carrots a similar trend was observed, when storing under different conditions.