Time- and spatially-resolved spectroscopy to determine the bulk optical properties of 'Braeburn' apples after ripening in shelf life

Maristella Vanoli, Robbe Van Beers, Nadja Sadar, Anna Rizzolo, Marina Buccheri, Maurizio Grassi, Fabio Lovati, Bart Nicolaï, Ben Aernouts, Rodrigo Watté, Alessandro Torricelli, Lorenzo Spinelli, Wouter Saeys and Angelo Zanella

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Abstract

Bulk optical properties, in terms of absorption (μ_a) and reduced scattering coefficients (μ'_s), can be used for the non-destructive monitoring of fruit quality during ripening. In this study, the performance of time-resolved (TRS) and spatially-resolved (SRS) spectroscopy were compared by analyzing 'Braeburn' apples over a 21 d period of ripening. Nine batches of 20 apples each were measured on the blush side by TRS (540–1064 nm) and SRS (550–1000 nm). Every fruit was analyzed for skin color, texture characteristics, relative internal space volume (RISV), total solid soluble and titratable acidity contents. TRS absorption spectra showed two maxima, the highest at 980 nm (water) and the second at 670 nm (chlorophyll), while in SRS spectra the main peak was measured at 550 nm (anthocyanins) followed by that at 670 nm. The values of μ_a580_{SRS} and of μ_a670_{SRS} were much higher than those measured at the same wavelengths by TRS suggesting that TRS and SRS actually explore the apple tissue (skin and/or flesh) in a different way. The values of μ_a980_{TRS} were higher than those of μ_a980_{SRS}, probably due to the fact that water content was lower in the skin (mostly probed by SRS) than in the flesh (mostly probed by TRS). No significant correlations were found between μ_a580_{SRS} and μ_a580_{TRS} and between μ_a980_{SRS} and μ_a980_{TRS} but a low positive relationship was observed between μ_a670_{TRS} and μ_a670_{SRS}. On the contrary, high correlations were found between μ_a670_{SRS} and the spectral index I_{AD} (index of absorbance difference) related to chlorophyll in the skin and between μ_a580_{SRS} and the spectral index ARI (anthocyanin reflectance index), related to anthocyanin content in the peel, suggesting that μ_a580_{SRS} is linked to the development of the red color in the peel. Both μ_a670_{TRS} and μ_a670_{SRS} decreased during fruit ripening, indicating a decline in chlorophyll in the flesh and skin, respectively. During the shelf life period, apples became soft and mealy, as mechanical and acoustic parameters decreased and RISV increased. Fruit softening was accompanied by increasing

values of both μ'_{sTRS} and μ'_{sSRS}. The μ'_{sTRS} and μ'_{sSRS} were positively related to each other, were positively correlated to RISV and negatively related to mechanical and acoustic parameters. Both the TRS and SRS technique were able to follow ripening processes in 'Braeburn' apples during the shelf life period, as absorption phenomena were related to changes in pigments present in the fruit flesh and skin, while scattering events mirrored changes in the flesh texture.