Abstract

The changes in total chlorophyll and carotenoid contents characteristic for on- and off-tree ripening of apple (*Malus* × *domestica* Borkh. cv. Antonovka) fruit taken from the inner part of the canopy were studied non-destructively over several seasons. During on-tree ripening, a synchronous decrease in the content of both pigments was found with stoichoimetry of 0.32 mol carotenoids per mole of chlorophylls. Fruit detachment triggered, after a lag phase of a few days, a sharp increase in carotenoid content with a stoichiometry of 0.66 mol of accumulated carotenoids per mole of chlorophylls degraded. The increase in carotenoid content as a result of 3–4 weeks of off-tree ripening comprised 40% of their on-tree level. Multi-season observations showed that off-tree patterns of both pigments as well as the rate of their ratio changes are closely related with on-tree chlorophyll content at harvest. In spite of the complex kinetics of chlorophylls and carotenoids during ripening, their stoichiometry revealed a tight interrelation of the pigments, and the relationship 'carotenoid-to-chlorophyll ratio versus chlorophyll content' displayed a strong correlation. The findings allowed us to devise a simple model taking on-tree chlorophyll levels as the only input which was successfully applied for reconstruction and prediction of ripening-associated changes in carotenoid content ($r^2 \approx 0.81$; RMSE ≤ 0.1 nmol cm^{-2}) and carotenoid-to-chlorophyll molar ratio ($r^2 \approx 0.96$; RMSE ≤ 0.1). The results suggest that pigment changes associated with apple fruit ripening proceed, to a large extent, via a common mechanism and obey a general law determined by a fruit physiological state attained by the date of harvest but not the harvest date per se. Chlorophyll content appeared to be a suitable internal marker of fruit ripeness, but the changes in the content of both chlorophylls and carotenoids should be used to follow the ripening process in apple fruit on and off the tree rather than the changes of each of the pigments alone.