

Title The effect of temperature and other factors on chlorophyll *a* fluorescence and the lower oxygen limit in apples (*Malus domestica*)

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Abstract

The effects of temperature, scan interval and rate of oxygen (O_2) decline on pulse frequency modulation (PFM)-based minimum fluorescence (F_{α}) and the F_{α} -based lower oxygen limit (LOL) were investigated using ‘Honeycrisp’ apples (*Malus × domestica* Borkh). The effects of temperature and hypoxic stress on pulse amplitude modulation (PAM) fluorescence parameters were also investigated. The PFM scan interval had no effect on the F_{α} baseline, but increases in the scan interval decreased the low- O_2 -induced fluorescence spike intensity (ΔF_{α}). Temperature negatively correlated with the F_{α} baseline while $\Delta F_{\alpha} \text{ } ^{\circ}\text{C}^{-1}$ was greater at lower than at higher temperatures. When using a PAM fluorometer, the minimum fluorescence (F_0), and to a lesser extent the maximum fluorescence (F_m), were similarly affected by temperature as was F_{α} . Temperature altered the LOL in fruit. Apples stored at 20, 10, 3.5 and 0 °C spiked at 0.72, 0.33, 0.22 and 0.08 kPa O_2 , respectively, under a rapid O_2 decline (i.e., 20.9 to <1 kPa O_2 in $\approx 5\text{--}6$ h). Although the low- O_2 F_{α} spike apex values did not change with temperature, the spike intensity increased with temperature due to a reduced fluorescence baseline. A slower O_2 decline rate produced slightly higher LOL and lower spike intensity values. In conclusion, temperature and rate of O_2 decline affected the low- O_2 -induced PFM fluorescence spike intensity as well as the LOL, while the PFM scan interval affected the spike intensity.