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Non destructive detection of brown heart in 'Braeburn' apples by time-resolved reflectance spectroscopy

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Abstract

Brown Heart (BH) is an internal disorder which is visible only when fruit are cut open. The aim of this work was to test whether time-resolved reflectance spectroscopy (TRS) can be used to detect BH in intact 'Braeburn' apples stored for 3 and 6 months in BH inducing (1% O_2 + 5% CO_2) and not-inducing (2.5% O_2 + 0.7% CO_2) conditions. At each storage time, at d0 and d14 of shelf life at 18°C, thirty apples were measured by TRS at 670 nm and in the spectral range 740-1100 nm on four points (A-D) around the equator. Afterwards, each fruit was cut open and evaluated for BH (position and severity), firmness, intercellular space volume (RISV), and pulp colour (in correspondence of TRS points). Fruit affected by BH showed significantly higher μ_a in the 740-900 nm spectral range than healthy ones, with the highest difference recorded at 740 nm. The μ_a740 and a^* increased and L^* and $H°$ decreased in fruit with moderate and severe BH and when BH was localized in the pulp. In parallel, RISV showed the lowest percentage in healthy apples and the highest when cavities were associated to browning. High correlations were found between μ_a740 and pulp L^*, a^* and $H°$; considering the correlation with L^*, at μ_a740<0.038 cm^{-1} only healthy pulp can be detected, while at μ_a740>0.08 cm^{-1} only severely browned pulp can be found.

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Keywords: internal browning, TRS, absorption coefficient, pulp colour

1. Introduction

The storage quality of 'Braeburn' apples is limited by the development of brown heart (BH) within the fruit flesh. The symptoms of BH include browning of the flesh and formation of cavities. Initially

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browning areas tend to be concentrated in the calyx end of the fruit and in the midcortex, and in severely affected fruit they are visible throughout the cortical tissues. Cavities may be present within the brown tissue regions of either the core or cortical areas of the fruit, being generally dry when cut, and presumably forming when the brown tissues become dehydrated [1].

BH is a CO_2-related injury: its incidence is associated with high CO_2 and can be aggravated by depressed O_2 partial pressure in the storage room [1,2]. However, the development of this disorder also depends on a range of pre-harvest factors; the incidence of BH was higher in late-harvested than in early-fruit and in fruit on light than on heavily cropping trees [2,3]. Delayed controlled atmosphere (CA) storage (21 days at 1°C in air before CA storage) resulted in a very low incidence of BH compared to fruit subjected to rapid CA [4].

The susceptibility of 'Braeburn' apples to BH is related to their structural characteristics, as they have a relative dense and firm tissue, poor flesh gas diffusivity and low skin gas permeance [5- 7].

The unpleasant nature of BH is not acceptable to consumers and causes economic losses. Unfortunately, external symptoms are not evident. Consequently, a reliable non-destructive method for on-line detecting and segregating damaged from healthy fruit would be readily accepted by large co-operatives and commercial packing-houses.

Time-resolved reflectance spectroscopy (TRS) provides a complete optical characterization of diffusive media with the simultaneous non-invasive measurement of the optical properties of absorption and scattering. TRS is based on the measurement of the temporal delay and the broadening experienced by a short laser pulse (pulse duration in the order of 100 ps) while travelling through a turbid medium [8]. By using an appropriate theoretical model of light penetration for the analysis of photon time distribution, it is possible to simultaneously estimate the absorption coefficient (μ_a) and the reduced scattering coefficient (μ'_s). Light penetration achieved by TRS in most fruit and vegetables can be as great as 1-2 cm, depending on the optical properties [9]. Hence, TRS provides information on the internal properties of the medium and is not significantly affected by surface features [10].

Previous studies have shown that TRS is able to detect BH in pears, as well as internal browning, watercore and mealiness in apples and chilling injury in nectarines. The presence of BH in 'Conference' pears caused an increase in μ_a from 710 to 850 nm, with sound tissue having $\mu_a720 \leqslant 0.04$ cm^{-1} [11]. Similarly, in 'Granny Smith' apples, μ_a750 made it possible to distinguish healthy from browned fruit, as the former showed values $\leqslant$ 0.030 cm^{-1} and the latter $\mu_a750 \geqslant 0.033$ cm^{-1} [12]. In agreement with what was found in apples, Lurie et al. [13] observed an increase in μ_a780 with the development of bleeding and browning in the pulp of cold stored nectarines. Other internal disorders, such as watercore and mealiness, were related to both μ_a and μ'_s. In 'Fuji' apples affected by watercore, healthy pulp was characterized by lower μa790 and higher μ'_s790 than zones affected by watercore [12]. In mealy apples, mealiness increased with increasing μ'_s750 and μ'_s780 in Jonagold apples [14] and increasing μ'_s790 and μ'_s912 and decreasing μ_a912 in 'Braeburn' apples [12].

In the present work, the optical properties measured by TRS were evaluated in order to test whether TRS can be used to detect BH in intact 'Braeburn' apples.

2. Materials and Methods

'Braeburn' apples, picked at commercial harvest in Belgium, were stored at 1°C in two controlled atmospheres: 1% O_2 + 5% CO_2 (BH inducing condition, BH storage) and 2.5% O_2 + 0.7% CO_2 with a 3 week delay of CA to prevent browning (low risk for BH, OPT storage).

After 3 and 6 months of storage, at arrival in the laboratories of Politecnico and of CRA-IAA in Milan, sixty apples/storage were measured by TRS at 670 nm and in the spectral range 740-1100 nm on four equidistant points (A-D) around the equator (the largest transverse circumference); after ranking on the basis of decreasing μ_a670 (increasing maturity), fruit were divided into two samples, correspondent to day