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Assessment of peach internal flesh browning through colorimetric measures

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ABSTRACT

The purpose of this trial was to develop an objective internal flesh browning (IFB) assessment methodology for fresh peach. Six peach and three nectarine cultivars were used in this research. The fruit was maintained at 4 °C for 21 and 31 days. They were then evaluated after three additional days of maintenance at 20 °C. The differences in the CIELAB color parameters of the flesh ΔL^*, ΔE^*, $\Delta h°^*$, ΔC^*, Δa^*, and Δb^* were then assessed. ΔL^* were assessed with both fresh fruit and fruit after postharvest treatments; after regression analysis, this resulted in the best CIELAB parameter to describe IFB. A trained sensory panel was used to corroborate the results. Between ΔL^* and the panel assessment of IFB, was obtained the highest determination coefficient ($R^2 = 0.84$). Furthermore, through a triangular test, it was determined that $\Delta L^* = 4.7$ corresponds to the IFB peach flesh threshold, as perceived by the panel. Afterward, through a regression tree, four IFB categories were defined: (1) no IFB symptoms, when $\Delta L^* < 4.7$; (2) incipient IFB symptoms, when $4.7 \leq \Delta L^* < 8.0$; (3) severe IFB symptoms, when $8.0 \leq \Delta L^* < 21$; and (4) extreme IFB symptoms, when $\Delta L^* \geq 21$. We recommend the use of ΔL^* when objective phenotyping of IFB of peach flesh is required.

1. Introduction

Internal flesh browning (IFB) is a frequent postharvest disorder that can be observed when peach and nectarine are maintained in cold storage for long periods. It is genetically and environmentally determined (Lurie and Crisosto, 2005). The genetic origin of IFB is not completely known, but it has been documented that there is a solid genetic base, with broad heritability over 0.5 and tightly associated with the melting/freestone locus (Martínez et al., 2011). It is linked with enzymes such as polyphenol oxidase, which acts on the phenolic substrates with which they come into contact (Kader et al., 1984), but additionally, the leucoanthocyanidin dioxygenase gene is also responsible for the development of IFB on peach (Ogundiwin et al., 2008). Up to now, there have not been available, easy-to-use kits or markers to predict the incidence and/or the susceptibility of a peach to IFB in advance, so the evaluation of the symptom, which is a brown color on the flesh, has remained the only reliable tool to study IFB.

Together with flesh mealiness and bleeding, IFB is part of a complex syndrome called chilling injury, which is normally visible when fruit are withdrawn from cold storage (Lurie and Crisosto, 2005). The negative effect of the appearance is likely to influence consumers' potential purchase of the fruit. There are no standardized methods for IFB assessment, and often only arbitrary scales are used to measure it. These scales are normally based on the visual appreciation of the symptom (Brummell et al., 2004; Cantin et al., 2010; Cao et al., 2010), thus they lack standardization. As color perception depends on the observer, an objective assessment for contrasting one's subjective judgment is needed to standardize the procedure and generate comparable data (Van Oeckel et al., 1999).

Colorimeters are devices frequently used to assess fruit color objectively. These devices use the CIELAB color space, where the luminosity coefficient, L^*, ranges between 0 = black and 100 = white. In addition, the positive parameter a^* indicates a reddish-purple color, a negative a^* indicates a bluish-green color, a positive b^* indicates a yellow color, and a negative b^* indicates a blue color (McGuire, 1992). In other studies, CIELAB parameters have been used to assess the enzymatic browning of apple and potato incubated with polyphenol oxidase, where color differences were given in terms of the coordinates L^*, a^*, and b^*; these were then expressed as the total color difference (ΔE^*) (Girelli et al., 2004). Additionally, L^* has been used to measure the flesh browning of freshly cut apple and peach purees using a Hunter D-25 colorimeter (Lee et al., 1990). The CIELAB space provides parameters that are highly correlated with human perception of

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food color (Pedreschi et al., 2011; León et al., 2006). The CIELAB space has been used as an indicator of the enzymatic flesh browning of fresh peach subjected to minimal processing, which showed high correlations with sensory evaluations (Gonzalez-Buesa et al., 2011).

In different studies, the CIELAB space has been used to assess peach flesh browning, however this data has not been compared to human perception of the disorder (Martínez et al., 2011; León et al., 2006), thus the results have sometimes been difficult to interpret. For this reason, there is a need to associate the objective assessment of color with human perception, and particularly, with the threshold of human perception. When the color of a food is evaluated, it is particularly useful to have a skilled panel specifically trained on the range of colors of interest who are able to perform comparisons with instrumental assessment (O'Sullivan et al., 2003)

When peach flesh color is studied, one should consider that the samples are highly perishable. Preserving the sample is a challenge due to quick color changes when exposed to air. To overcome this problem, color photos are one simple, promising method, as they make it possible to "freeze" the fruit color exactly at the time of assessment. The photos can then be stored for a long period. In this way, it is possible to train judges and then to perform comparative or descriptive tests with consistent standards and samples (Brugiapaglia and Destefanis, 2009).

The aim of this research is to develop an objective method to evaluate peach IFB as a consequence of prolonged postharvest cold storage, associating the instrumental assessment of the color changes of the flesh with sensory evaluations of IFB assessed by a trained panel.

2. Material and methods

2.1. Fruit material

The peach cultivars chosen in this trial are representative of different types in terms of their harvest periods, flesh types, and color. We used the yellow cling peach cultivars 'Andross', 'Corona', and 'Dr. Davis'; the yellow melting fleshed peach cultivars 'Sweet September', 'September Sun', and 'Ryan Sun'; the yellow melting fleshed nectarine cultivars 'Andes Necl' and 'Summer Fire'; and the white melting fleshed nectarine cultivar 'Arctic Snow'. Seventy-two fruit of each cultivar were used, with the standardized ripeness determined nondestructively by the chlorophyll absorbance index (I_{AD}) of the skin. The I_{AD} of the skin was assessed with a portable DA-meter (Sinteleia, Bologna, Italy), and a range between 0.2 and 0.6 units was chosen, which corresponds to a "ready to eat" peach (Shinya et al., 2013).

Peach with similar I_{AD} have shown standardized ripeness in terms of flesh firmness (Ziosi et al., 2008; Shinya et al., 2013), so the close association between I_{AD} and flesh firmness allows one to reduce the number of samples and still obtain quite robust results (Shinya et al., 2013). Hence, for this investigation, 12 fruit were used in each evaluation. In the first term, 12 fruit were used to characterize the harvest ripeness. After this, another 12 fruit were transferred to trays covered with a nylon film and maintained for three days at 20 °C, at which point they were used to assess the CIELAB parameters of the flesh. This stage was considered the IFB-free flesh point for each cultivar. This data was then used to calculate the variation of the parameters CIELAB of fruit submitted to postharvest. The remainder of the fruit was maintained at 4 °C for either 21 or 31 days, to induce different degrees of IFB; they were then evaluated after 3 days at 20 °C.

2.2. Instrumental color evaluation

A portable CR-400 colorimeter (Minolta, Tokyo, Japan) with a D65 power illuminant and 0° observer angle was used to assess color. A 5 mm diameter piece of skin of each fruit cheek was removed, and the L^*, a^*, and b^* parameters were measured directly on the flesh of each cheek. Afterward, *hue* and *chroma* were scored by averaging the scores of both cheeks. The variations of L^*, a^*, b^*, *hue*, and *chroma* were measured on the flesh of the fresh fruit and after the postharvest storage. These variations were registered as ΔL^*, Δa^*, Δb^*, $\Delta h°^*$, and ΔC^*, respectively. Further, the ΔE^*, corresponding to the total color change, was also calculated.

2.3. Visual evaluation

A stable, trained sensory panel composed of 13 judges was used for assessing color. Each judge had performed fresh fruit analysis

Table 1
Determination coefficients for the sensory evaluation of the internal flesh browning (IFB) in function of the ΔL^* and ΔE^* parameters in different peach cultivars after the induction of browning symptoms on postharvest.

Cultivar	Determination coefficients	
	R^2 flesh ΔL^*	R^2 flesh ΔE^*
'Andross'	0.85	0.79
'Corona'	0.88	0.88
'Dr. Davis'	0.86	0.85
'Sweet September'	0.94	0.93
'Ryan Sun'	0.92	0.88
'September Sun'	0.62	0.65
'Andes Nec 1'	0.85	0.81
'Artic Snow'	0.72	0.47
'Summer Fire'	0.71	0.38

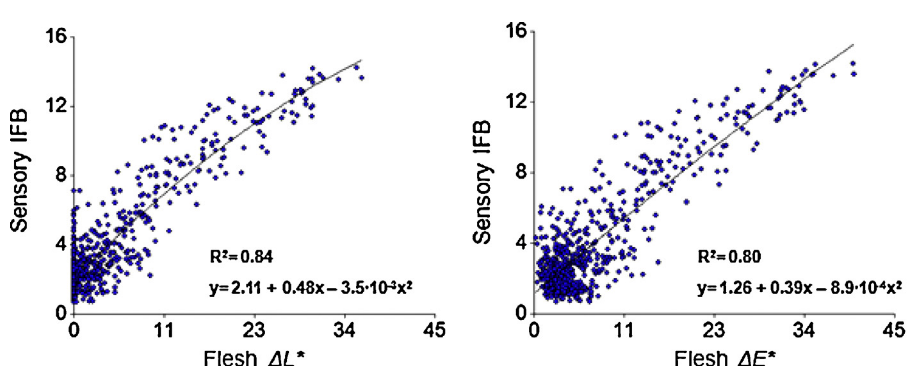

Fig. 1. Peach sensory evaluations of the internal flesh browning (IFB) in function to the ΔL^* *and* ΔE^* color parameters. ΔL^* and ΔE^* were assessed with a Minolta colorimeter, and the sensory IFBs were assessed by a trained panel, who used a 15-point unstructured scale: 0 = absence of browning, and 15 = highest degree of IFB.