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Peach ripening: Segregation at harvest and postharvest flesh softening

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ABSTRACT

The peach melting flesh cultivars 'Ryan Sun' and 'Sweet September' and the non-melting, 'Kakamas' were harvested according to their visually assessed ground color and divided into four, ripeness classes (M1, M2, M3, and M4). The following aspects were determined: fruit mass, soluble, solids content (SSC), ground skin hue angle ($h°$) and chroma (C^*), the absorbance difference at 670 nm and, 720 nm index (I_{AD}), and the texture (fruit firmness measured with a needle, flesh firmness measured, with a 7.9 mm plunger, and uniaxial compression strength). Considering that in peaches, the $h°$ of the, ground color and the I_{AD} are maturity indicators closely associated with ripeness and particularly with, flesh firmness, the texture parameters and their relationship to $h°$ and I_{AD} were examined. The visual, assessment of the ground color was validated as the criterion for sorting the ripeness levels in peaches, as confirmed by $h°$ and I_{AD}. Fruit firmness assessed with the needle and that with the 7.9 mm plunger, were highly correlated with each other and with the $h°$ and I_{AD}, whereas the compression strength, exhibited less correlation with the optical properties of the skin. The non-melting 'Kakamas' showed, the poorest correlation between texture and $h°$ and I_{AD}. Comparing both optical properties, the I_{AD}, showed a higher correlation with texture features than the $h°$. In a second experiment, fruit from the M3 ripeness class was maintained in a ripening chamber (20 °C, and 80% RH) until the flesh was softened for consumption. During postharvest, the first two principal, components of a principal component analysis explained 85% of the total variance of the texture, components and the optical properties of the skin. PC1 (67.2%) was defined positively by the texture, parameters and I_{AD}. The $h°$ of the ground color was negatively related to all texture parameters, and, I_{AD}. PC2 (17.8%) was associated positively with the juice content, and this parameter proved to be, independent of all others.

1. Introduction

Predicting the potential lifespan of a peach along the commercial chain is crucial to planning the storage, transport, and postharvest handling and selling to guarantee high fruit quality and consumer satisfaction. A first point to be considered is the fruit physiological state at harvest because peach shelf-life performance is heavily determined by its ripeness at this key stage (Ruiz-Altisent et al., 2006). One of the most important challenges for the peach industry is the segregation at harvest of fruit into homogeneous groups in terms of state of ripeness. Tijskens et al. (2007) highlighted the importance of grading individual fruit at harvest into classes of usability and of selecting fruit with different ripeness stages for different market segments on the basis of a reliable prediction of their softening rate. The goal is to guarantee a flesh firmness adequate to transport and sufficient ripening potential to reach good eating quality. Commercially, a common criterion for distinguishing immature from mature fruit is the visual evaluation of the ground skin color (Kader, 1999; Zerbini et al., 1994; Tijskens et al., 2007). Although separating peaches on the basis of comparable visual appearance is a common and inexpensive method, the segregation of batches with similar postharvest life potential is a major technical challenge. There are two main difficulties in using this simple approach: first, the ground color of the peach in the new cultivars is masked by the covering blush, and second, the flesh typologies of new peach cultivars do not demonstrate equal behavior, particularly the stony hard (Yoshida, 1970) and non-melting flesh cultivars. Unlike the melting flesh cultivars, these genotypes do not exhibit the melting period of softening, which is marked by a strong decline in firmness, increased solubility of both loosely bound pectins and matrix glycans, and decreases in the numbers of tightly bound molecules (Brummell et al., 2004).

Peach flesh firmness has been traditionally determined by the Magness–Taylor pressure test using a 7.9 mm plunger, and this is the most popular method in the peach industry as well as for postharvest studies. When harvest time is near, fruit are sampled at the orchard, and then an appropriate flesh firmness score is associated with a ground skin color. In this way, the skin ground

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color of the fruit becomes a reliable and non-destructive indicator of the flesh firmness and therefore of its potential market life. There are high correlations between surface ground color and physiological maturity in peach and nectarine (Kader, 1999), and the hue angle (h°) in particular has been shown to be highly informative and closely associated with ripeness (Ferrer et al., 2005). It has also been observed, however, that the same h° could be associated with different levels of firmness because the fruit is influenced by the light environment in which it develops (Lewallen and Marini, 2003). This maturity indicator should therefore be used with caution. Recently, the I_{AD} (difference of fruit absorbance spectra (A) at two wavelengths $I_{AD} = A_{670} - A_{720}$), determined non-destructively using a portable device called Delta-A instrument (Sinteleia, Bologna, Italy), has been shown to be a reliable method for assessing ripeness (Ziosi et al., 2008). High correlations between I_{AD} and ripeness level have been reported for peach (Ziosi et al., 2008), prune (Infante et al., 2011a), and Japanese plum (Infante et al., 2011b). The I_{AD} of the skin is especially informative in those cultivars where the covering color does not allow the ground color to be viewed. Herrero-Langreo et al. (2012) combined chlorophyll-related optical indexes and low mass impact (LMI) to successfully assess peach maturity using the mean values of sequential harvest dates.

In peach, ripeness is a complex process that cannot be fully characterized by a single determination; there are many parameters that change during ripening. In the fresh peach industry, the most limiting factors of fruit quality along the commercial chain are those dealing with the mechanical properties of the flesh and particularly with the softening speed. The evaluation of different methods to assess flesh firmness at harvest will improve the quality and homogeneity of fresh peaches in the marketplace. In addition, there is no knowledge of the mechanical properties of the newer typologies of flesh or of their evolution on-tree and at postharvest, both of which are cultivar-dependent traits; this lack of knowledge makes it essential to test alternative methods for determining firmness.

The optical properties of the skin, measured either as the h° of the ground color or as I_{AD}, are both non-destructive and reliable indicators of the physiological age of a fruit. The proposed hypothesis of this study is that flesh firmness determined by means of a puncture test with a 7.9 mm plunger is not correlated with these indicators in peaches of different flesh typology, thereby making it necessary to evaluate alternative methods of texture assessment.

2. Materials and methods

2.1. Fruit material

Three peach cultivars, all characterized by the visibility of their ground color, were evaluated: the melting flesh genotypes 'Ryan Sun' and 'Sweet September' and the non-melting 'Kakamas'. Fruit was harvested from a commercial orchard located in the Central Valley of Chile. Fifteen trees of each variety, uniform for production, were selected. The fruit was sequentially harvested every 2–3 days for a total of 240 samples. Fruit ripeness was established visually at the orchard, and fruit was harvested into separate batches, based on the ground color of the skin. Afterwards, the fruit was transported to the lab and was re-classified under white light conditions into four ground color levels that represent the ripeness classes used in this trial: M1 (green), M2 (green yellow), M3 (yellow) and M4 (yellow orange), containing 60 fruit each.

2.2. Segregation of ripeness classes

At harvest, for each cultivar and utilizing the ripeness levels previously sorted based on the visually assessed ground color (M1, M2, M3, and M4), the fruit mass, soluble solids content (SSC), ground skin color, I_{AD}, fruit/flesh firmness, and uniaxial compression strength were determined.

The SSC was measured with a thermo-balanced PAL-1 refractometer (Atago, Tokyo, Japan). The skin color was measured with a CR-400 colorimeter (Minolta, Tokyo, Japan). The chroma (C^*) and hue angle (h°) were used to characterize changes in skin color from green to yellow during ripening. The I_{AD} was measured on the skin of both cheeks of each fruit, and three measurements per cheek were performed. The mean of the six measurements per fruit were used for data analysis. The I_{AD} was measured with a portable Delta-A instrument (Sinteleia, Bologna, Italy).

Firmness was measured by two methods, based on puncture tests: (1) fruit firmness with a needle that penetrates 5 mm into an intact fruit and (2) flesh firmness with the plunger traditionally used on stone fruit (7.9 mm diameter), penetrating 10 mm into the flesh, with the skin having previously been removed with a scalpel. In both cases, a FTA GS-14 texture analyzer (Güss, Strand, South Africa) was used, whose probe ran at 5 mm s^{-1}. Firmness value was calculated as a mean of four measures performed on both cheeks and on both shoulders of each fruit.

The uniaxial compression strength was determined with a wide plunger (21 mm diameter) that deforms the intact fruit; the haul of the plunger runs 1 mm deep from the time the plunger contacts the skin. A FTA GS-14 texture analyzer (Güss, Strand, South Africa) was used, whose probe ran at 5 mm s^{-1}.

2.3. Monitoring flesh softening during postharvest

The M3 ripeness class was chosen for the postharvest monitoring of texture changes because this class represents the most frequent ripeness level employed by the industry that focuses on the fresh fruit market. Forty fruit per cultivar were harvested and transported to the laboratory. Fruit were placed in a ripening chamber, which was set at 20 °C and 80% relative humidity. Evaluations were performed until fruit dehydration reached 5% fresh weight loss, which was determined by monitoring a sample of 10 fruit maintained in the same conditions exclusively for this purpose. 'Ryan Sun' and 'Sweet September' fruit were maintained in this condition for five days, whereas 'Kakamas' was maintained for four days.

The fruit mass, SSC, h° and C^*, I_{AD}, fruit/flesh firmness, compression strength, and juice content were determined on the first, third and fifth days for a sample of 10 fruit each time for 'Ryan Sun' and 'Sweet September', and on the first, second and fourth days for 'Kakamas'.

The juice content was quantitatively determined by weighing the free juice absorbed by an ordinary absorbent paper from a flesh sample (2 mm wide and 15 mm long) squeezed by the action of two metallic rolling cylinders (Infante et al., 2009).

2.4. Data analysis

In the first experiment, data were submitted to analysis of variance (ANOVA) for each cultivar, and 60 fruit of each ripeness class (M1, M2, M3 and M4) were considered. The means were separated with Duncan's test (<0.05).

A linear regression between h° and I_{AD} was performed. The relation between optical and texture (measured with the 7.9 mm plunger, the needle, and by uniaxial compression) parameters was analyzed as a polynomial linear regression.

In the second experiment, focusing on the postharvest performance of the cultivars, the mechanical properties of the fruit/flesh and the optical properties of the skin throughout the postharvest period were submitted to a principal component analysis (PCA), followed by a multivariate analysis of variance (MANOVA) to