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Relationships between the instrumental and sensory characteristics of four peach and nectarine cultivars stored under air and CA atmospheres

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ABSTRACT

'Big Top' and 'Venus' nectarines and 'Early Rich' and 'Sweet Dream' peaches were picked at commercial maturity and stored for 20 and 40 d at −0.5 °C and 92% RH under either air or one of the three different controlled atmosphere regimes (2 kPa O_2/5 kPa CO_2, 3 kPa O_2/10 kPa CO_2 and 6 kPa O_2/17 kPa CO_2). Physicochemical parameters and volatile compounds emission were instrumentally measured after cold storage plus 0 or 3 d at 20 °C. Eight sensory attributes were assessed after cold storage plus 3 d at 20 °C by a panel of 9 trained judges, in order to determine the relationship between sensory and instrumental parameters and the influence of storage period and cold storage atmosphere composition on this relationship.

A principal component analysis (PCA) was undertaken to characterize the samples according to their sensory attributes. PCA results reflected the main characteristics of the cultivars: 'Big Top' was the nectarine cultivar with the highest values for sweetness, juiciness and flavor; 'Sweet Dream' was the sweetest peach and was characterized by high values for crispness and firmness, while 'Venus' and 'Early Rich' were characterized by their sourness. To assess the influence of storage period and CA composition on sensory properties, a PLS model of the flavor of the different samples was constructed using standard quality attributes and volatile concentrations as the *X*-variables. The model with 2 factors accounted for more than 80% of flavor variance. PLS results indicated that the main influence on flavor perception was storage period. Atmosphere composition also had an influence on flavor perception: flavor perception decreased from samples stored in a 2/5 O_2/CO_2 atmosphere composition to those of 3/10 and 6/17. These results can be qualitatively extended to juiciness and sweetness since all these sensory properties were strongly correlated.

1. Introduction

Peach and nectarine cultivars have a short shelf-life potential due to fast softening and overall ripening; this results in a limited period for commercialization before the product reaches the consumer. Refrigeration is a key tool for extending the commercial life of peach and nectarine fruit (Hardenburg et al., 1986), but low temperatures, particularly within the range of 2.2–5 °C, are associated with a physiological disorder known as internal breakdown (Lurie and Crisosto, 2005). This disorder is a syndrome associated with chilling injury (Lill et al., 1989; Crisosto et al., 1996; Lurie and Crisosto, 2005). Different practices have been studied to reduce the incidence of this postharvest disorder in peach cultivars (Lill et al., 1989; Lurie and Crisosto, 2005), including cold storage under controlled atmosphere (CA). CA storage has been shown to delay or reduce mealiness in peach and nectarine cultivars, particularly with high CO_2 and reduced O_2 levels (Streif et al., 1994; Budde et al., 1999; Roig et al., 2003; Girardi et al., 2005). Although this storage technology is known to have undesirable effects on the aroma profiles of several apple (*Malus* × *domestica* Borkh.) and pear (*Pyrus communis* L.) varieties (Fellman et al., 1993; Chervin et al., 2000; Lara et al., 2003), it has been reported that 'Fantasia' nectarines stored in 10–20% CO_2 for 4 weeks were juicier and had better flavor after storage than those kept in cold air (Burmeister and Harman, 1998). A study of the effect of CA storage on peach and nectarine flavor is of huge importance since this is one of the most important characteristics that consumers use to judge the quality of peaches and nectarines (Bruhn, 1995), together with appearance and texture. Accordingly, consumers often complain about the low quality of these species and this is an obstacle to repeat purchases.

Volatile compound profile and its contribution to the eating quality of fruit is very complex and is influenced by many pre- and post-harvest factors, including cold storage technology (storage time, storage temperature and storage atmospheres) and ripening

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time at 20 °C after cold storage (Zhang et al., 2011). The volatile compounds emitted by peach fruit have been investigated and more than 100 compounds have been identified (Aubert and Milhet, 2007). Abundant information is available on the variability of the volatile profiles of peaches and nectarines as determined by cultivar or maturity stage (Horvat et al., 1990; Chapman et al., 1991; Visai and Vanoli, 1997; Lavilla et al., 2002; Wang et al., 2009). The effects of storage temperature have also been the subject of a number of reports (Robertson et al., 1990; Infante et al., 2008a; Raffo et al., 2008; Cano-Salazar et al., 2012; Zhang et al., 2011) and it has been shown that the production of volatiles generally decreases during cold storage. However, a small number of research papers have reported CA storage having an effect on the volatile profile of peaches and nectarines (Ortiz et al., 2009, 2010).

The effects of CA depend on the fruit variety, physiology state, atmosphere composition, storage temperature and storage time (Kader, 2002). The objective of this work was therefore to assess the influence of different atmospheres, cold storage period and ripening time at 20 °C on the emission of volatile compounds, physicochemical parameters and sensory attributes of the ‘Big Top’, ‘Venus’, ‘Sweet Dream’ and ‘Early Rich’ cultivars.

2. Materials and methods

2.1. Plant material and storage conditions

Peach and nectarine fruit (*Prunus persica* L. Batsch) of ‘Early Rich’ (ER) and ‘Big Top’ (BT) (early-season cultivars) were harvested on June 30th, 2010 (115 and 125 d, respectively, after full bloom) and the fruit of ‘Sweet Dream^{cov}’ (SD) and ‘Venus’ (VE) (mid-season cultivars) were harvested on July 31st, 2010 (140 and 145 d, respectively, after full bloom). The four varieties were grown in commercial orchards at Alcarràs, Lleida, Catalonia (northeastern Spain). The four cultivars used in this study were yellow-flesh nectarines and peaches. ‘Big Top’ is a regular, rounded, mid-sized nectarine (≈180 g) with deep red skin and sweet taste. ‘Venus’ is a bicolour, mid-sized nectarine (≈210 g) with acid taste. ‘Sweet Dream^{cov}’ is a large-sized peach (250 g) with a high full red skin and sweet taste, and ‘Early Rich’ is a mid-sized peach (≈200 g) with a high full red skin and acid taste. Immediately after harvest, five lots were selected from each cultivar on the basis of uniformity and the absence of defects. One 25 kg lot was analyzed at harvest and the other four 75 kg lots were stored at −0.5 °C and 92–93% RH in cold storage chambers. Four different storage atmospheres were tested: a normal atmosphere: 21 kPa O_2/0.03 kPa CO_2, (AIR); and three controlled atmospheres: 2 kPa O_2/5 kPa CO_2, (2/5), 3 kPa O_2/10 kPa CO_2, (3/10) and 6 kPa O_2/17 kPa CO_2 (6/17). O_2 and CO_2 concentrations of the experimental chambers (21 m^3) were continuously monitored and automatically corrected using N_2 from a tank and scrubbing off CO_2 excess with a charcoal system. Samples were removed from cold storage after 20 (S20), or 40 (S40) d and held at 20 °C to simulate commercial ripening. Analysis of physicochemical parameters and volatile compounds were carried out at harvest, after remaining 0 and 3 d at 20 °C, and after each period of cold storage, after allowing the fruit to reach 20 °C (labeled 0 d at 20 °C, SL0) and also after a further three (SL3) d at 20 °C. Sensory measurements were only carried out after 3 d of storage at 20 °C to simulate the period to reach consumers.

2.2. Analysis of physicochemical parameters

Twenty fruit either at harvest or after each storage atmosphere × storage time at −0.5 °C × ripening time at 20 °C were individually assessed for flesh firmness, soluble solids content (SSC), titratable acidity (TA), and skin color. Flesh firmness was measured on opposite sides of each fruit with a digital penetrometer (Model. 53205; TR, Forlí, Italy) equipped with an 8-mm diameter plunger tip; the results were expressed in N. SSC and TA were measured in juice pressed from whole fruit. SSC was determined with a Palette-10 hand refractometer (Atago PR-32, Tokyo, Japan) and the results were expressed as % sucrose equivalents. TA was determined by titrating 10 mL juice with 0.1 M of NaOH to pH 8.1 and the results were given as % malic acid equivalents.

2.3. Sensory measurements

Nine panelists (trained according to ISO 1993) assessed and evaluated the sensory attributes of the peach and nectarine samples. The panel evaluated the intensity of the following attributes: crispness (Cr), ease of breakdown (Eb), flavor (Fv), fibrousness (Fi), hardness (hs), juiciness (Ju), sourness (So) and sweetness (Sw). The intensity of each attribute was recorded on 150 mm unstructured line scales, anchored at 0, absent and 150, extreme, with the exception of firmness, which was anchored at 10, low and 140, high.

2.4. Analysis of volatile compounds

The measurement of volatile compounds was carried out as described Cano-Salazar et al. (2012). The extraction of compounds from a sample (2 kg × 3 per replicates) of intact fruit was performed by the method of dynamic headspace. The compounds were desorbed into an Agilent 7890A gas chromatograph (Agilent Technologies, Inc., Barcelona, Spain) using an automated UNITY Markes thermal desorption system (Markes International Ltd., Llantrisant, United Kingdom). Identification and quantification of volatile compounds were achieved on an Agilent 7890A gas chromatograph (Hewlett-Packard Co., Barcelona, Spain) equipped with a flame ionization detector and a cross-linked free fatty acid phase (FFAP; 50 m × 0.2 mm × 0.33 μm) as the capillary column. Compounds were identified by comparing their respective retention index with those of standards and by enriching peach extract with authentic samples. Quantification was performed using individual calibration curves for each identified compounds while the concentrations of volatile compounds were expressed as ng kg^{-1}. Compound confirmation was performed in an Agilent 6890N gas chromatograph/mass spectrometer (Agilent Technologies, Inc.), using the same capillary column as in the GC analyses. Spectrometric data were recorded (Hewlett-Packard 3398 GC Chemstation) and compared with those from the original NIST HP59943C library mass spectra.

All of the standards for the volatile compounds studied in this work were analytical grade or the highest quality available. Ethyl acetate, 2,3-butanodione, eucalyptol, butyl acetate, pentyl acetate, acetophenone, and γ-hexalactone were obtained from Fluka (Buchs, Switzerland). 2-Methylpropyl acetate was obtained from Avocado Research Chemicals, Ltd. (Madrid, Spain). 2-Ethyl-1-hexenal, Z-3-hexenyl acetate, methyl octanoate, and decanoic acid were obtained from SAFC Supply Solutions (St. Louis, MO, USA). The rest of the compounds (up to 43) were supplied by Sigma–Aldrich (Steinheim, Germany).

2.5. Statistical and multivariate analyses

A multifactor design was used for statistical analysis of the results. The factors considered per cultivar were: atmosphere, storage time at −0.5 °C, and ripening time at 20 °C. All data were tested using analysis of variance (GLM-ANOVA procedure) with the SAS program package (SAS Institute Inc., 2004). Means were separated by the least significant difference (LSD) test at $p \leq 0.05$. Correlations between experimental variables were made using Spear-man's Rank Correlations and, if required, presented as Spear-man's