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Overall quality of 'Rich Lady' peach fruit after air- or CA storage. The importance of volatile emission

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ABSTRACT

In this work, 'Rich Lady' peach fruit picked at three different dates were stored at 2 °C under air or controlled atmosphere (CA) conditions for 3 or 15 days with the purpose of assessing the effects of the different factors considered on some variables (standard quality parameters and emission of volatile compounds) potentially having an impact on sensory acceptance after storage. Extending cold storage under air resulted in lowered acceptance scores, which were improved by CA storage. Multivariate analysis of results revealed that acceptance of 'Rich Lady' peach fruit was related closely to the perception of the characteristic flavour, which in turn was related to soluble solids content and to the emission of specific volatile compounds. Observed differences in alcohol o-acyltransferase (AAT) activity as affected by factors considered in this work did not appear to be large enough to explain differences in ester production after storage. Data suggest that observed differences in the emission of volatile esters arose mainly from modifications in the activity of enzymes located upstream of AAT, causing changes in the supply of precursors for ester biosynthesis in 'Rich Lady' peach fruit.

1. Introduction

Ripening-related events in climacteric fruit, including softening and volatile ester production, are coordinated by ethylene. Handling and commercialization of peach (*Prunus persica* (L.) Batsch.) fruit are limited by rapid softening and overall ripening, which results in short shelf life potential. If harvested before optimal maturity, firm enough to withstand handling and marketing, peach fruit do not reach full flavour. Novel post-harvest technologies have often neglected this attribute too, as they have focused mainly on appearance and decay resistance of fruit, notwithstanding flavour is one of the most important characteristics consumers use to judge quality of peaches (Bruhn, 1995).

Refrigerated storage of peaches and nectarines preserves fruit firmness and delays the incidence of fungal infections, but this practice often leads to a range of chilling-induced disorders (reviewed in Lurie & Crisosto, 2005), which can be alleviated through storage under controlled atmospheres (CA), particularly with high CO_2 levels (Anderson, Parsons, & Smith, 1969; Roig, Vendrell, & Lara, 2003; Streif, Retamales, Cooper, & Kania, 1992). Moreover, it has been reported that 'Fantasia' nectarines stored in 10–20% CO_2 for 4 weeks were juicier and had better flavour after storage than those kept in cold air (Burmeister & Harman, 1998).

The understanding of the fundamental mechanisms that control changes in flavour is limited, and many biochemical pathways determining this quality trait are still unknown (Song, 2007). These pathways are influenced by many pre- and post-harvest factors, including harvest maturity and post-harvest handling and storage. Intensive research has been conducted on flavour-related volatiles emitted by peach fruit, and more than 100 compounds have been identified (reviewed in Aubert & Milhet, 2007). Important variations have been shown in the volatile profile of peaches as determined by cultivar or maturity stage (see, for instance, Horvat et al., 1990; Lavilla, Recasens, López, & Puy, 2002; Visai & Vanoli, 1997). Similarly, the effects of storage temperature have also been the subject of a number of reports (Anderson, 1979; Robertson, Meredith, Horvat, & Senter, 1990), and it has been shown that the production of volatiles generally decreases during cold storage. However, to our best knowledge no previous research papers have reported the effects of CA storage on the aroma volatile profile of peaches.

Therefore, the objective of this work was to assess whether CA storage could be a suitable means of preserving overall quality of 'Rich Lady' peach fruit during the post-storage period at 20 °C, with especial emphasis focused on the emission of volatile compounds. The combination of instrumental and sensory analysis should help

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defining the role of particular volatile compounds or quality attributes in the perception of flavour by consumers. The information thus obtained would broaden current understanding of changes in this attribute during post-harvest handling and hence facilitate clues for the enhancement of the post-harvest preservation of peach fruit.

2. Materials and methods

2.1. Plant material

Peach (*P. persica* (L.) Batsch.) fruit of the melting flesh cultivar 'Rich Lady' were picked at a commercial orchard in Aitona (Segrià, NE Spain) at commercial maturity according to the usual standards in the producing area (diameter $\geq$ 70 mm; 100% red surface). Fruit were picked at three different dates (29th June, 3rd July, 6th July 2006; henceforth P_1, P_2 and P_3, respectively) within one week in order to simulate the usual practice by the local growers. Standard quality parameters of fruit at each picking date are shown (Table 1) as a reference. After harvest, samples were stored at 2 °C and 92% relative humidity under air or CA (3 kPa O_2: 10 kPa CO_2) for 3 or 15 days, and subsequently kept in air 1 day at 7 °C to simulate refrigerated transport (henceforth, 3 + 1 and 15 + 1 fruit, respectively). After cold storage, samples were placed at 20 °C, and analyses were carried out 0 and 3 days thereafter.

2.2. Analysis of standard quality parameters

Twenty fruit per each combination of factors (picking date × storage atmosphere × storage period at 2 °C × shelf life period at 20 °C) were analysed individually for flesh firmness, soluble solids content (SSC) and titratable acidity (TA). Flesh firmness was measured on two opposite sides of each fruit with a penetrometer (Effegi, Milan, Italy) equipped with an 8-mm diameter plunger tip; results were expressed in N. SSC and TA were assessed in juice pressed from the whole fruit. SSC was determined using a digital hand refractometer (Atago, Tokyo, Japan), and results were expressed as °Brix. TA was measured by titration of 10 ml of juice with 0.1 mol/l NaOH to pH 8.1; data are given as g malic acid/l.

2.3. Sensory evaluation

Fruit were analysed after 3 days at 20 °C following cold storage. Twenty peaches per each combination of factors were used. Each fruit was divided into four pieces, which were evaluated separately by four different judges included in a consumer panel comprised of 50 judges. Two pieces (one per storage atmosphere) were placed on white plates and immediately presented to each panellist. A total of six analysis sessions were conducted (three picking dates × two storage periods). All participating judges were every-day stone fruit consumers from the UdL-IRTA campus, and were the same for all six sessions. Each piece was identified by a random three-digit code, and the order in which pieces were presented to each judge was randomised. Mineral water was used as a palate cleanser between samples. The judges were asked to rate overall fruit acceptability according to a hedonic test (1: dislike very much; 9: like very much). Sensory sourness, sensory sweetness, sensory juiciness, and intensity of peach flavour were also evaluated with a test in which the judges were requested to order the samples from weaker to stronger perception of each attribute considered, and data were parametrised as −0.56 (weaker perception) or 0.56 (stronger perception) according to Anzaldúa-Morales (1994). The samples could be retested as often as desired. All evaluations were conducted in individual booths under white illumination and at room temperature.

2.4. Analysis of volatile compounds

The extraction of volatile aroma compounds from a sample (2 kg × 4 replicates) of intact fruit was performed at ambient temperature according to the method of dynamic headspace. Each fruit sample was placed in a 8-l Pyrex glass container, and an air stream (900 ml/min) was passed through for 4 h; the effluent was then passed through an ORBO-32 adsorption tube filled with 100 mg of activated charcoal (20/40 mesh), from which volatile compounds were desorbed by agitation for 40 min with 0.5 ml of diethyl ether. Identification and quantification of volatile compounds were achieved on a Hewlett Packard 5890 gas chromatograph equipped with a flame ionisation detector and a cross-linked free fatty acid phase (FFAP; 50 m × 0.2 mm i.d. × 0.33 μm) as the capillary column, where a volume of 1 μl from the extract was injected in all the analyses. Helium was used as the carrier gas (42 cm/s), with a split ratio of 40:1. Both the injector and the detector were held at 240 °C. The analysis was conducted according to the following programme: 70 °C (1 min); 70–142 °C (3 °C/min); 142–225 °C (5 °C/min); 225 °C (15 min). Volatile compounds were identified by comparing retention indices with those of standards and by enriching peach extract with authentic samples. The quantification was made using butylbenzene (assay > 99.5%) as the internal standard. A GC–MS system (Hewlett Packard 5890) was used for compound confirmation, onto the same capillary column as in the GC analyses. Mass spectra were obtained by electron impact ionisation at 70 eV. Helium was used as the carrier gas (42 cm/s), according to the same temperature gradient program as described above. Spectrometric data were recorded (Hewlett Packard 3398GC Chemstation) and compared with those from the

Table 1
Standard quality parameters of 'Rich Lady' peaches at harvest and 3 days after removal from storage.

At harvest	P_1	P_2	P_3
Firmness (N)	47.0 a	42.5 b	41.2 b
SSC (°Brix)	11.1 a	11.9 a	11.2 a
TA (g/l)	10.1 a	9.8 a	9.4 a
°Brix/TA ratio	1.11	1.21	1.19

After storage	P_1				P_2				P_3			
Period[a]	3 + 1		15 + 1		3 + 1		15 + 1		3 + 1		15 + 1	
Parameter	Air	CA	Air	CA	Air	CA	Air	CA	Air	CA	Air	CA
Firmness (N)	6.33 a	6.45 a	<5	<5	1.08 b	6.05 a	<5	<5	<5	<5	<5	<5
SSC (°Brix)	11.49 bc	11.71 b	10.63 d	11.55 bc	11.34 c	10.53 d	11.35 c	11.39 c	12.83 a	12.00 b	11.20 c	11.54 c
TA (g/l)	5.09 b	6.08 a	5.29 b	5.87 a	5.71 ab	5.92 a	4.98 cd	5.39 b	4.29 d	6.16 a	4.70 cd	5.10 b
°Brix/TA ratio	2.26	1.93	2.01	1.97	1.99	1.78	2.28	2.11	2.99	1.95	2.38	2.26

Values represent means of twenty replicates. Means within the same row followed by different letters are significantly different at $p \leq 0.05$ (LSD test).
[a] 3 + 1: 3 days at 2 °C + 1 day at 7 °C; 15 + 1: 15 days at 2 °C + 1 day at 7 °C.