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Original article

# Suitability for minimal processing of non-melting clingstone peaches

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**Summary** Clingstone non-melting peach cultivars (*Prunus persica* L. Batsch) are used primarily for canning, but their processing as fresh-cut products is also of interest. Four clingstone peach cultivars ('Andross', 'Babygold 8′, 'Calante' and 'Romea') were evaluated for their suitability for minimal processing (washing, peeling and slicing) followed by storage for 9 days at 4 °C in a modified atmosphere using microperforated films. Romea cultivar, which has low polyphenol oxidase (PPO) enzymatic activity, proved to be the most suitable cultivar for minimal processing, given its lower degree of browning as well as the results from a sensory evaluation. Maturity indicators varied slightly during storage at a different degree depending on cultivars. We have found that PPO activity and browning potential are adequate indicators for surface browning in fresh-cut non-melting peaches.

**Keywords** Modified atmosphere packaging, minimal processing, peaches, phenols, polyphenol oxidase.

## Introduction

The preparation of fresh-cut products is known to accelerate deterioration and shorten their shelf-life when compared to that of the whole product. This results in an increase in respiration rate, ethylene production, softening, susceptibility to enzymatic browning, weight loss and microbial development (Brecht *et al*., 2004). Enzymatic browning is one of the chief factors that influence the shelf-life of several minimally processed fruits, including peaches (García & Barrett, 2002). This change is basically due to the oxidation of phenols to o-quinones that, through non-enzymatic reactions, form the pigments responsible for the brown colouring (Whitaker & Lee, 1995). However, it has been suggested that cut-edge browning is largely a consequence of cellular disintegration below the cells that are directly damaged by the cutting operation rather than the browning of the contents of the damaged cells themselves (Toivonen *et al*., 2005). Susceptibility to browning depends on PPO activity in some products (Rocha & Morais, 2001), on the phenolic content in others (Vámos-Vigyázó & Nádudvari-Márkus, 1982), and in some cases on both parameters (Prabha & Patwardhan, 1985). Therefore, research with regard to cut-edge browning has mainly focused on control of the interaction of PPO with phenolics.

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In peaches and nectarines, the total phenol content varies greatly among cultivars (Kubota *et al*., 2000; Tomás-Barberán *et al*., 2001; Gil *et al*., 2002). Besides, there are substantial variations in PPO activity among cultivars (Chang *et al*., 2000). Therefore, the susceptibility to deterioration of minimally processed peaches and nectarines very much depends on the variety (Gorny *et al*., 1999). In spite of this, there are very few studies relating their sensitivity to browning with phenolic content and/or enzyme activity (Lee *et al*., 1990), unlike the case of other fruits such as apples (Coseteng & Lee, 1987; Rocha & Morais, 2001).

In any event, the rapid deterioration of peaches and nectarines makes essential to find treatments to slow down the browning process and to prolong their shelf-life. Treatment and storage conditions for fresh-cut fruits have been recently reviewed (Rojas-Graü *et al*., 2009). The use of chemical inhibitors acting directly on the PPO enzyme or on the substrates is one of the most widely used methodologies for avoiding browning (Artés *et al*., 1998; Brecht *et al*., 2004). Some anti-browning agents and their derivates such as ascorbic acid, isoascorbic acid, acetyl cysteine, 4-hexylresorcinol, calcium chloride, potassium sorbate and propionate, alone or in combinations at different concentrations, have been found to be effective in retarding browning and reducing decay of fresh-cut fruits such as pear (Sapers & Miller, 1998; Buta & Abbott, 2000; Arias *et al*., 2008), mango (González-Aguilar *et al*., 2000) and apple (Monsalve-González *et al*., 1995) among others.

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There are few studies devoted to the preparation of fresh-cut melting peach (Gorny *et al.*, 1998; Li-Qin *et al.*, 2009) and none concern with non-melting peaches cultivars.

The aim of this work is to analyse the total phenolic content and PPO activity in various non-melting peach cultivars and to study their correlations with the degree of browning and the evolution of the main quality parameters after minimal processing.

## Materials and methods

### Experimental procedure

Four non-melting peach cultivars (*Prunus persica* L. Batch) obtained from the Jalon Valley (Aragón, Spain) were used for the study. The selected cultivars were Romea, Andross, Babygold 8 and Calante. The fruits were harvested at the commercial harvest point established for the cultivars in the region (Carbó & Iglesias, 2002). The harvest parameters, soluble solids content/titratable acidity in ºBrix/(g malic acid $L^{-1}$) and firmness in N $cm^{-2}$ were the following: 1.88 and 35.71 for Romea; 3.10 and 40.91 for Andross; 2.64 and 43.65 for Babygold 8; and 2.28 and 45.1 for Calante. After harvest, they were immediately transported to our laboratory (80 km), sorted to eliminate damaged or defective fruit, and stored at 1 °C until subsequent use ($< 24$ h).

The whole fruits were washed in chilled water containing 100 ppm of sodium hypochlorite (adjusted to pH 6.5 with citric acid) during 5 min and then gravity drained. The peel was removed with an automatic peeler (Orange peeler, Pelamatic, Valencia, Spain) and the fruit was manually stoned. Each unit was cut into 10–12 slices with sharp stainless steel knives (Granton, Sheffield, UK) and washed under running water.

The peach slices (180 g) were packaged in 500 mL polypropylene trays (TS500, Linpac, Knottingley, UK) thermosealed with a microperforated film (Pplus, AM-COR Flexible, Bristol, UK) and stored at 4 °C. The gas transmission rates of the exchange surface of each tray at 4 °C were the following: 3.04 μL $s^{-1}$ for $O_2$, 2.73 μL $s^{-1}$ for $CO_2$ and 3.24 μL $s^{-1}$ for $N_2$. Under the conditions of these experiments, the equilibrium atmosphere reached in the trays was 12–14% $O_2$, 8–10% $CO_2$ and the balance $N_2$. Quality analyses on slices from five trays were carried out just after processing and after 3, 6 and 9 days.

### Determination of PPO activity

Enzymatic activity was assayed following the method proposed by Lopez *et al.* (1994). Fruit slices were homogenised with 0.2 M phosphate buffer with 10 g $L^{-1}$ polyvinylpyrrolidone and 0.1 g $L^{-1}$ Triton X-100. The homogenates were centrifuged at 16 500 × ***g*** for 30 min at 4 °C, the supernatant constituting the enzyme extract. The assay mixture consisted of 10 mM DL-Dopa and 0.05 M potassium phosphate buffer (pH 7.0). The reaction was initiated by adding 100 μL of the enzyme extract to 900 μL of the assay mixture, and the rate of dopachrome formation from DL-Dopa was spectrophotometrically determined by monitoring the absorbance at 475 nm using a spectrophotometer Unicam UV500 (Thermospectronic, Leeds, UK). One unit of enzymatic activity (AU) corresponds to an increase of 0.1 unit of absorbance per minute. All measurements were performed in triplicate.

### Total phenolic content (TP)

Fruit pulp (10 g) was boiled in 30 mL of distilled water for 20 min as described by Kubota *et al.* (2000). After blending with an Ultra-Turrax T-25 (Ika-Werke, Staufen, Germany) and filtering (Whatman No. 4), the mixture was diluted to 250 mL. Total phenolic compounds were determined by Folin-Ciocalteu method (Singleton & Rossi, 1965). Aliquots of 5 mL of Folin-Ciocalteu reagent were added to 5 mL of the resulting solution to measure the total phenolic content. Subsequently, 5 mL of 100 g $L^{-1}$ sodium carbonate solution were added and after 1 h at 25 °C, the samples were centrifuged and the absorbance at 700 nm was measured. D-catechin was used to obtain the standard curve each day of analysis. Total phenolic content was expressed in g $kg^{-1}$ fruit pulp. All measurements were performed in triplicate.

### Browning potential

The browning potential (BP) was determined using the procedure described by Coseteng & Lee (1987). Peach slices (50 g) from each treatment were homogenised for 2 min in an Ultra-Turrax homogeneizer T-25 (Ika-Werke, Staufen, Germany). The homogenates were centrifuged at 800 × ***g*** for 10 min at 4 °C (Du Pont Sorvall RC28S, Wilmington, USA) and filtered through Whatman No. 4 filter paper. The degree of browning of the resulting clear juice was determined by measuring absorbance at 440 nm using a spectrophotometer (Unicam UV500, Thermospectronic, Leeds, UK). All measurements were performed in triplicate.

### Colour measurement

Colourimetric measurements were carried out on ten slices from every batch with a spectroradiometer IS CAS 140 (Instrument System, Munich, Germany) using a TOP 100 probe with a NIKKOR 200 mm f/4 macro lens; the instrument was controlled by the ISCOLOR software installed on a PC. Reflectance spectra were

measured during 5 s on the surface of the slices. Spectra were measured between 380 and 900 nm every 1 nm. From these spectra CIELAB coordinates $L^*$, $a^*$, $b^*$, and $h_{ab}$ were calculated with the standard observer CIE64 and the D65 illuminant. In addition, decreases in coordinates, between beginning and end ($\Delta L^*$, $\Delta a^*$, $\Delta b^*$, $\Delta h_{ab}$) were calculated.

### Texture determination

A texture analyser (TA-XT2i, Stable MicroSystem, Godalming, UK) equipped with a 5 kg load cell was used. Assays were performed with a Volodkevich bite jaws probe acting perpendicularly to the cylinder axis at 0.8 mm $s^{-1}$. Maximum strength, in N, was measured on pulp cylinders of 10 mm diameter obtained with a cork borer at the midpoint of the cut surface between the pit cavity and skin. Ten replications were evaluated from each batch.

### Soluble solids content (SSC) and titratable acidity (TA)

Soluble solids content was determined on ten slices from each batch using an Atago DBX-55A refractometer (Atago CO, Tokyo, Japan) at 20 °C and mean values were expressed in º Brix. Acidity was quantified in 25 mL of juice extracted from 200 g of fruit by potentiometric titration with 0.1 N NaOH to an end point of pH 8.2. Values are expressed in g malic acid $L^{-1}$. Three replications were evaluated from each batch. The maturity index was obtained as the ratio of soluble solids to titratable acidity.

### Sensory analysis

At the start of the experiment and after 3, 6 and 9 days, the fruit slices were evaluated by a semi-trained panel consisting of ten people. A descriptive analysis was conducted to evaluate browning using a numerical scale (0 = Absence to 10 = Total) as well as a hedonic test to estimate the overall quality using a numerical scale (0 = Poor to 10 = Excellent).

### Statistical analysis

The statistical analysis was carried out using the Statistical Package for Social Science (SPSS, software version 12). One-way ANOVA and Tukey post-hoc tests were used for statistical data analysis ($P < 0.05$). Data were also evaluated using a Pearson correlation analysis between physico-chemical and sensorial parameters.

## Results and discussion

Initial PPO activity varied among the cultivars, which can be divided into two groups (Fig. 1). The Andross and Babygold 8 cultivars showed a high degree of activity while the Romea and Calante cultivars displayed a lower degree of activity. Other studies of soft-flesh peaches have revealed substantial differences in PPO activity among different varieties (Lee *et al.*, 1990). Studies of non-melting peaches show that the Andross cultivar has relatively high activity (Chang *et al.*, 2000) while the late Calanda cultivar shows low activity (Ferrer *et al.*, 2005).

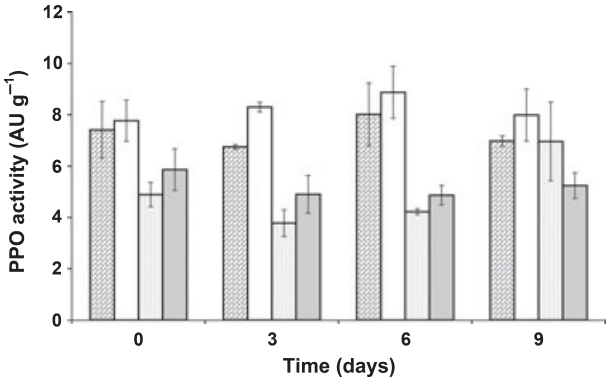


**Figure 1** Evolution of PPO activity (AU $g^{-1}$ fruit) of fresh-cut peach slices during storage at 4 °C: Andross (bricked bars), Babygold 8 (white bars), Calante (dotted bars) and Romea (grey bars). Values are means of three determinations ± SD.

The PPO activity in Andross, Romea and Babygold 8 cultivars did not undergo significant modification ($P < 0.05$) during the storage of the slices at 4 °C. This is also the case in other minimally processed peach varieties such as Spring Belle (Koukounaras *et al.*, 2008). A significant increase in the PPO activity was observed at the end of the storage period only with the Calante cultivar. This increase might be due to the activation of soluble tyrosinase forms existing in a latent state, which would otherwise be masked (Kahn, 1977). The latent forms of the enzyme might be effectively activated during storage by several factors, such as proteolysis, liberated by means of cell disruption and subsequent decompartmentalisation of enzymes, substrates and other substances present in cell vacuoles (Soliva-Fortuny *et al.*, 2002).

Total phenolic compounds also varied among the cultivars (Fig. 2). Andross had the highest total phenolic content followed by the Calante cultivar. Although the Folin-Ciocalteu procedure does not give a full picture of the quantity or quality of the phenolic compounds in the extracts, it is a simple, practical and widely used method which is useful to compare the cultivars. The total phenolic content of the four cultivars is within the range of values given in a peach variety screening carried out by Kubota *et al.* (2000) or for clingstone peach cultivars (Chang *et al.*, 2000; Asami *et al.*, 2003; Cantín *et al.*, 2009). However, Gil *et al.* (2002) found total phenolic

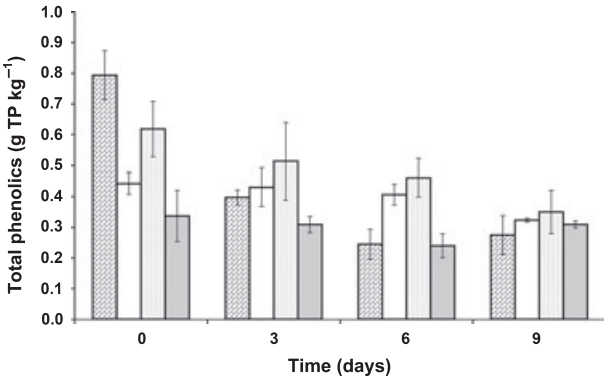


**Figure 2** Evolution of total phenolics content (g kg$^{-1}$ fruit) of fresh-cut peach slices during storage at 4 °C: Andross (bricked bars), Babygold 8 (white bars), Calante (dotted bars) and Romea (grey bars). Values are means of three determinations ± SD.

levels in yellow fresh pulp peach cultivars lower than those obtained for the Andross and Calante cultivars in this study. The total phenolic content decreased during storage time, showing similar values after 9 days at 4 °C for all the cultivars. The degradation of phenolic compounds in peaches could be the result of direct oxidation by polyphenol oxidases and of coupled oxidation, as was described for other fruits. The decrease in the phenolic content was particularly marked for the Andross cultivar, being reduced by as much as 50% during the first three days of storage. This drop could be due to the lower respiration rate of the Andross cultivar when stored at 4 °C after fresh-cut processing (González-Buesa *et al.*, 2009). As we assayed a passive modified atmosphere, the time of exposure in this cultivar to high $O_2$ concentrations is longer, likely leading to greater oxidation of the phenolic compounds on the surface of the slices. Similar behaviour has been described in minimally processed apples, for which the phenolic content has been reported to drop by a similar percentage in only one day (Cocci *et al.*, 2006).

The evolution of the texture is shown in Table 1 for the four cultivars. The Calante cultivar initially had the firmest texture, but it was also the only cultivar that softened significantly ($P < 0.05$) during the storage time, most sharply during the first three days. The other cultivars had lower initial firmness but the values did not change significantly during storage at 4 °C. In a study of various peach varieties carried out by Gorny *et al.* (1999) it was observed that the slices of the Flavorcrest variety maintained their firmness during conservation between 0 °C and 5 °C, while the slices of the nectarine variety Zee Grand suffered significant loss of firmness. These data suggest that an appropriate selection of the cultivar is important for preserving a firm texture in minimally processed peaches.

The initial titratable acidity content of the peach slices showed significant differences among the cultivars (Table 1). The acidity decreased to 25% for all the cultivars during the storage, but the decrease was most significant during the first 3 days for the Andross, Calante and Romea cultivars, and between days 3 and 6 of storage for the Babygold 8 cultivar. The rapid decrease in acidity could be due to the accelerated respiration of wounded tissues (Kim *et al.*, 1993) given that acids are known to be metabolised during respiration faster than other compounds or to the use of acids as antioxidant compounds. Soluble solids content decreased slightly for all cultivars while maturity index increased during the 9 days storage in all cultivars (32.2% for Andross, 12.8% for Babygold, 7.9% for Romea and 20.3% for Calante).

The initial lightness ($L^*$) of the slice surfaces was similar in the four cultivars studied (Table 2). During storage at 4 °C, the lightness did not change in the Calante cultivar, while in the Andross and Babygold 8

**Table 1** Evolution of texture, acidity and soluble solids content of minimally processed peaches. The values are means of ten determinations ± SD

| | | Time *(days)* | | | |
|---|---|---|---|---|---|
| | **Cultivar** | **0** | **3** | **6** | **9** |
| Texture *(kg)* | Andross | 0.42 ± 0.10$^{a}$ | 0.28 ± 0.08$^{b}$ | 0.31 ± 0.10$^{ab}$ | 0.39 ± 0.11$^{ab}$ |
| | Babygold 8 | 0.31 ± 0.12$^{a}$ | 0.3 ± 0.06$^{a}$ | 0.28 ± 0.10$^{a}$ | 0.26 ± 0.09$^{a}$ |
| | Romea | 0.42 ± 0.12$^{ab}$ | 0.42 ± 0.07$^{ab}$ | 0.31 ± 0.07$^{a}$ | 0.48 ± 0.10$^{b}$ |
| | Calante | 0.62 ± 0.10$^{a}$ | 0.36 ± 0.07$^{b}$ | 0.38 ± 0.07$^{b}$ | 0.37 ± 0.06$^{b}$ |
| Acidity | Andross | 3.77 ± 0.42$^{a}$ | 2.92 ± 0.05$^{ab}$ | 3.27 ± 0.05$^{ab}$ | 2.73 ± 0.11$^{b}$ |
| *(g malic acid L$^{-1}$)* | Babygold 8 | 4.52 ± 0.25$^{a}$ | 4.62 ± 0.17$^{a}$ | 3.34 ± 0.08$^{b}$ | 3.31 ± 0.16$^{b}$ |
| | Romea | 7.07 ± 0.70$^{a}$ | 5.18 ± 0.03$^{ab}$ | 5.25 ± 0.02$^{b}$ | 5.56 ± 0.02$^{b}$ |
| | Calante | 4.93 ± 0.31$^{a}$ | 4.10 ± 0.03$^{b}$ | 4.13 ± 0.01$^{b}$ | 3.58 ± 0.21$^{b}$ |
| Soluble solids | Andross | 11.70 ± 0.54$^{a}$ | 11.66 ± 1.68$^{a}$ | 11.06 ± 1.69$^{a}$ | 11.20 ± 1.56$^{a}$ |
| *(° Brix)* | Babygold 8 | 11.94 ± 0.77$^{a}$ | 10.72 ± 1.03$^{b}$ | 10.98 ± 1.40$^{ab}$ | 9.86 ± 0.59$^{b}$ |
| | Romea | 13.26 ± 1.20$^{a}$ | 11.14 ± 0.79$^{b}$ | 11.19 ± 0.43$^{b}$ | 11.25 ± 0.69$^{b}$ |
| | Calante | 11.22 ± 1.81$^{a}$ | 9.87 ± 1.83$^{a}$ | 9.95 ± 1.52$^{a}$ | 9.80 ± 1.12$^{a}$ |

Means in the same row without a common letter show significant differences ($P < 0.05$).

**Table 2** Evolution of lightness ($L^*$) and chromaticity coordinates ($a^*$, $b^*$ and $h_{ab}$) of minimally processed peaches. The values are means of ten determinations ± SD

| | | Time *(days)* | | | |
|---|---|---|---|---|---|
| | **Cultivar** | **0** | **3** | **6** | **9** |
| $L^*$ | Andross | 75.81 ± 0.72$^a$ | 74.17 ± 2.44$^a$ | 72.59 ± 0.95$^{ab}$ | 70.85 ± 1.27$^b$ |
| | Babygold 8 | 75.38 ± 0.34$^a$ | 70.39 ± 1.73$^b$ | 69.87 ± 1.84$^b$ | 68.95 ± 1.22$^b$ |
| | Romea | 76.00 ± 0.77$^a$ | 80.59 ± 1.09$^b$ | 81.94 ± 2.12$^b$ | 79.40 ± 1.03$^b$ |
| | Calante | 73.95 ± 0.85$^a$ | 75.86 ± 1.26$^a$ | 75.09 ± 1.04$^a$ | 74.09 ± 1.07$^a$ |
| $a^*$ | Andross | 17.10 ± 1.80$^a$ | 17.91 ± 1.26$^a$ | 21.73 ± 1.23$^b$ | 21.76 ± 1.91$^b$ |
| | Babygold 8 | 19.14 ± 1.03$^a$ | 20.24 ± 1.26$^a$ | 15.10 ± 3.30$^b$ | 17.15 ± 2.14$^{ab}$ |
| | Romea | 20.88 ± 0.69$^a$ | 22.60 ± 0.56$^b$ | 22.72 ± 1.18$^b$ | 22.19 ± 0.99$^{ab}$ |
| | Calante | 15.10 ± 1.00$^a$ | 12.97 ± 1.75$^a$ | 13.91 ± 0.97$^a$ | 13.52 ± 0.55$^a$ |
| $b^*$ | Andross | 56.52 ± 4.39$^a$ | 62.48 ± 1.20$^b$ | 58.18 ± 3.16$^{ab}$ | 58.25 ± 4.26$^{ab}$ |
| | Babygold 8 | 51.18 ± 1.09$^a$ | 58.69 ± 2.38$^b$ | 51.57 ± 4.26$^a$ | 53.24 ± 1.65$^a$ |
| | Romea | 51.98 ± 0.81$^a$ | 53.56 ± 1.22$^a$ | 53.43 ± 0.92$^a$ | 53.19 ± 1.64$^a$ |
| | Calante | 54.79 ± 2.81$^a$ | 50.18 ± 2.28$^b$ | 47.29 ± 0.66$^b$ | 49.92 ± 1.22$^b$ |
| $h_{ab}$ | Andross | 74.79 ± 0.64$^a$ | 72.60 ± 1.04$^b$ | 69.64 ± 0.59$^c$ | 70.03 ± 0.61$^c$ |
| | Babygold 9 | 70.55 ± 2.08$^a$ | 70.72 ± 1.00$^a$ | 71.11 ± 0.97$^a$ | 71.19 ± 1.28$^a$ |
| | Romea | 67.67 ± 0.91$^a$ | 67.07 ± 0.54$^a$ | 67.09 ± 0.60$^a$ | 67.08 ± 0.60$^a$ |
| | Calante | 75.08 ± 1.29$^a$ | 73.51 ± 1.00$^a$ | 72.57 ± 0.86$^a$ | 72.71 ± 1.71$^a$ |

Means in the same row without a common letter show significant differences ($P < 0.05$).

cultivars a pronounced reduction in this parameter was observed. The reduction in lightness ($L^*$) is generally associated with browning in minimally processed peaches (Wright & Kader, 1997; Sapers & Miller, 1998; Gorny *et al*., 1999). However, in the Romea cultivar there was an increase in the values of this coordinate which could be related to an increase in the brightness of the slice surface due to reversible surface dehydration. Gorny *et al*. (1998) also described this behaviour in mature-green soft-flesh peaches. This discolouration, known as white-blush, is commonly observed in other products such as sliced carrots (Cisneros-Zevallos *et al*., 1995). White-blushing is usually accompanied by moderate hardening, which is also observed in our slices of Romea peaches. Edible coatings could be of interest to prevent dehydration in fresh-cut products (Rojas-Graü *et al*., 2009).

The starting chromaticity coordinates $a^*$, $b^*$ and $h_{ab}$ varied widely in different cultivars (Table 2). Changes in $a^*$ values have been used frequently to monitor browning of fresh-cut products such as pear slices (Sapers & Miller, 1998; Buta & Abbot, 2000; Arias *et al*., 2008). In the case of sliced peach, only one study (Wright & Kader, 1997) associates the increase in this coordinate to the development of browning. In our case it has not been possible to relate the evolution of this coordinate with the browning process: the $a^*$ value in the Romea and Calante cultivars remained constant during storage, increased significantly for the Andross cultivar but decreased moderately in Babygold 8 cultivar.

The sensorial evaluation showed that after 9 days of storage, only the Romea peaches obtained a score for overall quality higher than level 5, the value corresponding to the acceptability limit (Fig. 3a). The high

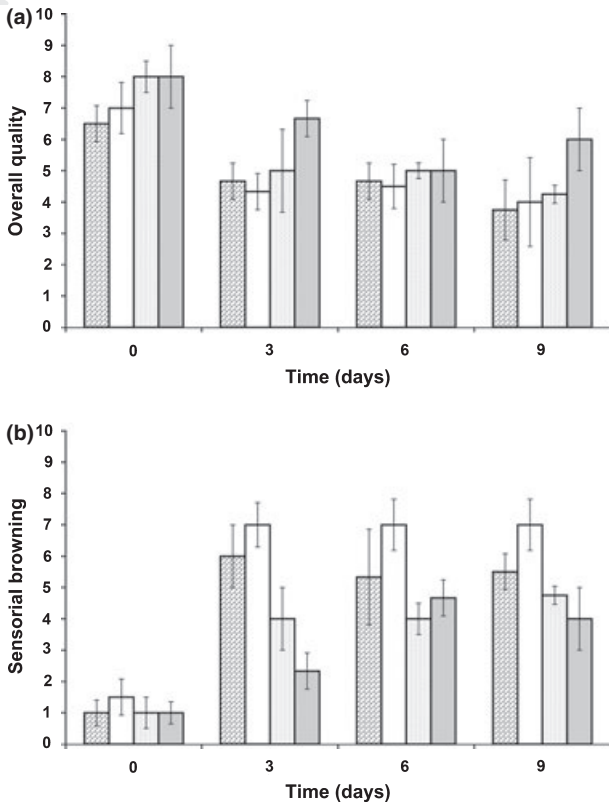


**Figure 3** Sensory evaluation of overall quality (a) and browning (b) of fresh-cut peach slices during storage at 4 °C. (Numerical scale of quality: 0 – poor quality; 10 – excellent quality. Numerical scale of browning: 0 – no browning; 10 – extremely browned). Andross (bricked bars), Babygold 8 (white bars), Calante (dotted bars) and Romea (grey bars). Vertical bars indicate ± SD.

**Table 3** Correlation coefficients between physico-chemical and sensorial parameter results

| | Total phenolics (g kg$^{-1}$) | PPO activity (AU g$^{-1}$) | Sensorial browning |
|---|---|---|---|
| ΔSS/TA (°Brix/g malic acid L$^{-1}$) | NP | 0.598** | NP |
| ΔFirmness (N) | 0.480* | 0.492* | NP |
| Δ $L^*$ | NP | −0.750*** | −0.841*** |
| Δ$a^*$ | NP | NP | NP |
| Δ$h_{ab}$ | NP | NP | NP |
| Sensorial browning | NP | 0.775*** | – |

NP: not significant.
*Significant to 0.05 *P* level.
**Significant to 0.01 *P* level.
***Significant to 0.001 *P* level.

value was a consequence of the lower degree of sensory browning (SB) awarded to this cultivar by the panel of tasters (Fig. 3b). The changes in overall quality and in browning were most marked during the first 3 days of storage. The cultivar that according to the panellists underwent the most browning is Babygold 8, coinciding with the fact that it showed the greatest loss of lightness.

The sensorial evaluation was consistent with the data obtained for the BP measured by spectrophotometry. The Romea cultivar had the lowest BP score, 1.0, as opposed to the values of 2.4, 2.2 and 1.8 assigned to the Andross, Babygold 8 and Calante respectively. Other authors have also reported substantial variations in this index among cultivars (Cheng & Crisosto, 1995).

The interdependence of the various factors governing enzymatic browning has been the object of some study but no firm conclusions have emerged thus far. For example, Vámos-Vigyázó *et al*. (1976) found a correlation between browning and PPO activity in apples, while finding no such correlation between browning intensity and total phenolic content. A similar conclusion was reached by Brandelli & Lopes (2005) in their study of peaches. However, subsequent studies concluded that the browning of apples depended significantly on both the PPO activity and *o*-dihydroxiphenol levels (Vámos-Vigyázó *et al*., 1985). Other authors (Coseteng & Lee, 1987; Lee *et al*., 1990) working with minimally processed apples and peaches have also found good correlations ($r^2 = 0.98$ and $r^2 = 0.67$) between the increase in browning and initial phenolic content.

We have evaluated the suitability of each cultivar for minimal processing by determining correlations between the values of PPO activity, total phenolic content and sensory browning with the variations in the maturity index, firmness and colour coordinates. Pearson correlation analyses were carried out and the results are shown in Table 3. The maturity index showed a positive correlation with PPO activity (significant at $P = 0.01$) and firmness was also correlated with total phenolic content and PPO activity (significant at $P = 0.05$). PPO activity results and sensory browning showed a highly significant correlation with the coordinate $L^*$ (significant at $P = 0.001$). Those cultivars with a high initial BP or PPO activity, such as Babygold 8 and Andross, showed a high degree of browning during storage at 4 °C. Studies on fresh-cut potatoes show that browning is not limited by either the enzymes associated with browning or by polyphenoloxidase substrate concentration (Cantos *et al*., 2002). Further study is required to conclude if the activity of this enzyme determines the browning of non-melting peaches. We can only state at this time that PPO activity and browning are correlated in non-melting peaches but no causal relation has been established. Cantos *et al*. (2002) also suggest that membrane stability is potentially a major factor controlling the rate of browning, as was also observed in peach by Li-Qin *et al*. (2009). We did not find any relation between initial phenolic content and the evolution of the colour or sensory browning (Table 3). This was observed as well by Brandelli & Lopes (2005) who suggested that the lack of correlation is due to the continued availability of phenols throughout the storage period.

## Conclusions

The characterisation of non-melting flesh peach cultivars is essential for achieving a high quality minimally processed product. The main organoleptic change limiting the shelf-life of the product is the alteration in colour associated with enzymatic browning in these peach cultivars. Both the initial BP and the PPO activity provide a good indication of the susceptibility to enzymatic browning of the peach cultivars studied. There is a good correlation between the PPO activity and the sensory evaluation of browning with the reduction in the colour coordinate $L^*$ (significant at $P = 0.001$). Experimental data indicate that the Romea cultivar is more suitable for minimally processed preparation than the other cultivars studied. These data have to be considered for the optimisation of a preserving treatment.

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