Original article

Preconditioning treatment maintains taste characteristic perception of ripe 'September Sun' peach following cold storage

Rodrigo Infante,[1]* Claudio Meneses[1] & Carlos H. Crisosto[2]

1 Department of Plant Science, University of Chile, Santa Rosa 11315, Santiago, Chile
2 Department of Plant Science, University of California, Kearney, CA, USA

Summary   Preconditioning is a thermal treatment that consists in maintaining stone fruits immediately after harvest and prior to cold storage at 20 °C for 24–48 h in special chambers aimed to extend fruit market life reducing chilling injury symptoms. This work investigates whether preconditioned 'September Sun' peaches had better eating quality than control fruit. Commercially harvested peaches were preconditioned and transferred to cold storage for 12, 26 and 40 days and evaluated for sensory characteristic perception after a ripening period at 20 °C. Acceptability of preconditioned fruit was higher than control fruit during this 40-day cold-storage period. Preconditioned and control fruit were also segregated into two clusters by PCA analysis; preconditioned fruit clustered together and show association to acceptability, sweetness and juiciness, while the second cluster was associated with flesh texture, acidity and aroma, suggesting the positive effect of preconditioning on final fruit quality. Preconditioned fruit maintained their sensory characteristics longer than control fruit during this 40-day cold-storage period.

Keywords   Acceptability, cold storage, flesh firmness, fruit quality, Peaches, postharvest, preconditioning, *Prunus persica,* sensory evaluation.

Introduction

The ultimate objective of the production, handling and distribution of fresh peach, is to satisfy consumers. For a favourable purchase decision, the appearance of peach (visible quality) is a primary criterion in making decisions (Kays, 1999). Size, colour and shape correspond to particular cultivar standards, while absence of defects and homogeneity between fruit are common visual quality factors. Visible quality encourages purchase and supports marketing/placement choices. Furthermore, peach acceptance is based on different eating traits that can be studied to develop standard protocols of sensory evaluation (Predieri *et al.*, 2006). These sensory-based protocols can help to understand peach fruit quality and are increasingly used in breeding, in testing new cultivars and in new production and storage practices (Infante *et al.*, 2006).

Preconditioning of stone fruits involves exposing the fruit to warm conditions for 1 or 2 day(s) after harvest before placing them in 0 °C storage; this treatment can extend peach and nectarine storage life (Anderson & Penney, 1975; Lurie & Crisosto, 2005). Scott *et al.* (1969)

reported that holding fruit at 20 °C for 2 days prior to 49 days storage at -0.5 °C reduced chilling injury considerably. It has been reported that two days of delayed storage at 20 °C prior to storage at 0 °C for 42 days prevented chilling injury in 'Flavortop' nectarines (Zhou *et al.*, 2000a). Warm temperatures induce cell wall disassembly which continues slowly during storage, so that at the end of storage the distribution of the pectin between soluble and insoluble fractions and the size of the polymers in the different classes were similar to that of fruit ripened without storage (Zhou *et al.*, 1999, 2000b).

A commercial preconditioning treatment was developed to extend market life of peaches from California and Chile (Crisosto *et al.*, 2004). A 48-h cooling delay at 20 °C was the most effective treatment for extending market life of chilling injury susceptible peaches and nectarines without causing fruit deterioration. This treatment increased minimum market life by up to 14 days in the cultivars tested. Weight loss and softening occurred during the preconditioning treatments, but did not reduce fruit quality after storage. Detailed monitoring of fruit quality changes during the preconditioning period and proper use of fungicides is fundamental for a successful result. Rapid cooling after preconditioning is important to stop further fruit deterioration such as flesh softening, senescence, decay and weight loss (Lurie

*Correspondent: Fax: + 56 2 9785813;
e-mail: rinfante@uchile.cl

& Crisosto, 2005). Preconditioning can also be used to pre-ripen susceptible and non susceptible peaches and nectarines in order to deliver a 'ready to buy' product to the consumer (Crisosto *et al.*, 2004).

The physical and chemical changes that occur to preconditioned peaches enable a high acceptance quality, evidenced as juicier, aromatic and tastier fruit (Crisosto *et al.*, 2004). Nevertheless, if preconditioning is not appropriately monitored, the quality diminishes and excessive flesh softening can occur (Girardi *et al.*, 2005). Further, the relationship between consumer acceptance and quality attributes will be cultivar dependent; thus, the establishment of a minimum quality index based on soluble solids concentration (SSC), or the ratio between SSC and titratable acidity (TA) need to be evaluated for each cultivar (Crisosto *et al.*, 2006).

Considering that peach is the most susceptible species to chilling injury among the stone fruit group and, the increasing need for high quality products on a fresh stone fruit global market, this work is focused on evaluating the sensory quality during a long term postharvest life of a standard type peach after preconditioning.

Materials and methods

Peach (*Prunus persica* (L.) Batsch.) 'September Sun', which originated from 'O'Henry' seedling (Okie, 1998), a traditional late season yellow flesh peach with firm and round-shaped fruit, was used for this study. 'September Sun' peaches were harvested based on ground colour from a commercial orchard in San Bernardo, near Santiago, Chile, during the last week of February 2005. Fruit with similar size that presented a yellow greenish ground colour and at least 60% covering red colour, which was visually estimated and correspond to the common harvest maturity used by the fruit exportation industry, were harvested for this study. The fruit harvest ripe characterisation was determined by the flesh firmness, the SSC, the fruit mass and diameter in a sample of twenty fruits and was expressed as the mean value $\pm$ SD.

Homogeneous fruit were transported to the laboratory. When fruit reached flesh temperature of 20 °C, measured on three fruits with a needle-nose thermometer inserted about 2.0–2.5 cm into the fruit flesh, twenty fruit per replication were used for quality attribute evaluations in order to characterise harvest maturity stage. Furthermore, a batch of forty fruits were kept at 20 °C for monitoring flesh softening and juice content after 2 and 4 days.

Preconditioning treatment

Two cooling temperature handling treatments (CTH) were tested: preconditioning and conventional cooling.

Fruit submitted to preconditioning treatment were washed, sorted, packaged and placed in the preconditioning chamber (18–20 °C and 90% RH) until the flesh firmness reached 48.6–58.3 N on the equator zone (cheeks) and 29.1–38.8 N on the proximal zone (shoulders). Immediately after, the fruit were air cooled using an air forced precooling chamber, until the fruit flesh reached 0–2 °C. Control fruit were also washed, sorted, packaged, air forced cooled. In both groups, fruit were placed in the cold chamber (0 °C and 90% RH) for 12-, 26- and 40-days storage. Quality and sensory evaluations were made after the different storage period on twenty fruit per each of the five replications. Fruits were maintained in a cold chamber (0 °C and 90% RH) and then were removed after 12, 26 and 40 days and transferred to a ripening chamber (20 °C) till the flesh reached an adequate firmness for consumption (9.8–19.6 N) (Infante *et al.*, in press).

Quality attributes evaluations

In order to determine the flesh softening rate, which would be necessary for evaluating fruit at the same firmness on postharvest experiment, fruits recently picked were kept in the ripening chamber at 20 °C for 4 days.

Flesh firmness was measured on both cheeks and shoulders of the fruit, using a portable penetrometre (Effegi, Milan, Italy), with a 7.9-mm probe. Soluble solids concentration (SSC) was measured with a thermobalanced refractometer (Atago, Tokyo, Japan) and titratable acidity (TA) on 10 mL of juice buffered with NaOH 0.1 N and expressed as % (p/v) of malic acid.

Apparent juice content was determined on the supernatant of 3 g of homogenised flesh obtained near the pit and deprived of epidermis, then collected on an Eppendorf tube after centrifugation 12 000 g for 5 min (Lill & Van Der Mespel, 1988).

Sensory evaluations

A quantitative descriptive analysis was carried out at a sensory analysis lab performed on individual conventional cabinets, by a trained judge panel formed of twelve individuals. The same panel was used for the three storage periods considered (12, 26 and 40 days). Due treatments were evaluated at the same flesh firmness range, in each storage period the panel was called twice because preconditioning treatment hastened flesh softening in comparison to the control. In this way, the first evaluation (12 days) was performed after 2 days of ripening for the preconditioned treatment and after 4 days for the control. On the second and third evaluation periods (26 and 40 days) the preconditioned treatment was evaluated after 2 days and the control after 3 days of ripening.

The samples were prepared on a white pottery dish by presenting a slice of one fourth fruit with epidermis, cutted and prepared less than 5 min before testing them, for assuring tenderness and avoiding flesh browning. The dish containing the sample was marked by a three-digid code randomly assigned, which correspond to the same code presented on a separated evaluation guideline. The evaluation guidelines considered a continuous scale for each attribute, ranging from 0 to 15, marked with three anchors, 0 = dislike extremely, 7.5 = neither like nor dislike, and 15 = like extremely, which were used before on stone fruits eating quality evaluation (Heintz & Kader, 1983). The quality attributes evaluated were: aroma, sweetness, acidity, juiciness, flesh texture, and flavour. Degree of liking was determined as the other attributes, but by means of an untrained panel of twenty-four judges. Percentage of acceptance was calculated as the number of assessors liking the sample (score > 7.5) divided by the total number of assessors tasting the sample (Lawless & Heymann, 1998). After fruit were withdrawn from the cold chamber they were kept at 20 °C and 70–80% RH for ripening until they reached 12.6 ± 2.0 N flesh firmness. That corresponds to the optimum level for consumption of most high acid yellow flesh peaches, as has been previously observed in our lab.

Statistical analysis

Data of fruit flesh softening after 4 days at 20 °C were submitted to analysis of variance (ANOVA) for flesh firmness and juice content.

For cold storage trial a factorial design was carried out (2×3) in two CTH (preconditioning and conventional cooling) and three cold-storage periods (CSP) (12, 26 and 40 days). Data were treated by analysis of variance (ANOVA).

After ANOVA, significant differences between means were determined by the nonparametric Student–Newman–Keuls separation test with significance level $P < 0.05$.

In order to determine the association among quality attributes measured on 'September Sun' peaches a principal component analysis (PCA) was performed on the same factorial design (2 CTH × 3 CSP). Statistical analysis was performed with InfoStat (2004).

Results and discussion

The most common criterion, followed by the fresh fruit industry for harvesting peaches, is based on the ground colour of the skin because it is easily visible by harvesters; shows a high correlation with flesh firmness, being an adequate indicator of peach ripe level (Crisosto, 1994; Crisosto & Mitchell, 2000). 'September Sun' peaches harvested with a yellow greenish ground colour reached a mean SSC of 12.0% ± 2.1%, a mean weight of 225 ± 24 g, a mean diameter of 75 ± 0.3 mm and a mean firmness of 67.72 ± 10.12 N. These firmness scores are within commercial standards for long distance shipment for this cultivar grown in Chile, Republic of South Africa and California, USA (Crisosto *et al.*, 2001). Thus, fruit were harvested mature but they will need an extra ripening (softening) period in order to reach the 'ready to eat' stage associated with texture changes (Crisosto *et al.*, 2003, 2006) and higher juiciness (Lill & Van Der Mespel, 1988).

Quality attributes evaluations

During fruit ripening, flesh firmness dropped from a mean of 67.72 N to a mean of 14.99 N within the 4 days of ripening at 20 °C (Table 1), and this level of flesh firmness is considered ideal for yellow peach consumption (Infante *et al.*, in press). Flesh firmness was the parameter that changes the most rapidly at 20 °C, reaching a softening rate of 19.6 N day^{-1}, almost doubling values observed in other yellow fleshed peach cultivars (Crisosto *et al.*, 2001), but coinciding with observed values on white peaches such as 'Snow King' and 'September Snow' (Garner *et al.*, 2001). During this same ripening period, fruit extractable juice increased from 27.1% to 50.6% (Table 1). This result underlines that a softer flesh (12.6 N) would be associated with high apparent juice content (Lill & Van Der Mespel, 1988), thus, potentially with a high degree of liking, and high consumer satisfaction (Predieri *et al.*, 2006). Similar changes during the ripening period have been reported by other researchers on peaches (Altube *et al.*, 2001).

Juiciness and TA were affected by preconditioning treatment and changes during storage period (Table 2). Preconditioning and cold storage significantly reduced TA and increased SSC:TA ratio but did not affect SSC. The SSC remained constant during this cold-storage period. Preconditioned fruit evaluated after 40-days storage had the lowest TA (0.34%) and the highest SSC:TA (34.5), while untreated fruit evaluated after 12 days had the highest TA (0.55%) and the lowest SSC:TA. Fruit from the other treatment combinations ended with TA within 0.34–0.55, and SSC:TA within 20–35. The TA decrease throughout cold-storage period

Table 1 Apparent juice content and flesh firmness of 'September Sun' peaches assessment on fruit maintained at 20 °C

Time (day)	Flesh firmness (*N*)	Juice content (%)
0	67.72a	27.10a
2	47.82b	35.60b
4	14.99c	50.60c

Different letters on the same column indicate statistical differences 5%.

Table 2 Effect of preconditioning on 'September Sun' peach quality parameters assessed on fruit maintained in cold storage

	Titratable acidity (%)	Soluble solids concentration (%)	SSC:TA	Juiciness (%)
Cooling temperature handling treatment (CTH)				
Preconditioned	0.43a	12.1a	29.3b	40.61b
Untreated	0.60b	11.8a	26.5a	32.96a
Cold storage period (CSP) (days)				
12	0.51c	12.0a	24.5a	49.46b
26	0.45b	12.3a	27.7b	29.62a
40	0.37a	11.6a	31.6c	31.27a
CTH × CSP				
Preconditioned × 12	0.48c	12.3a	27.4b	52.08d
Preconditioned × 26	0.48c	12.3a	26.0a, b	35.64c
Preconditioned × 40	0.34a	11.7a	34.5c	34.10b, c
Control × 12	0.55d	11.8a	21.6a	46.83d
Control × 26	0.42b	12.3a	29.4b	23.59a
Control × 40	0.40b	11.4a	28.6b	28.45a, b

Different letters on the same column indicate statistical differences 5%.

was more evident on preconditioned fruits, as it had been reported previously for peach and nectarine (Crisosto & Crisosto, 2005).

Sensory evaluations

Degree of liking (acceptability) determined by our untrained panel was only affected by the CTH. Degree of liking showed that preconditioned fruit had significantly higher scores (9.1) than control fruit (6.2). There was no significant effect of CSP and interaction between CTH and CSP on degree of liking (Table 3). Further-

Table 3 Effect of preconditioning on September Sun' peach on the degree of liking assessed on fruit maintained in cold storage

|	Degree of liking (score)	Satisfied assessors (%)	Indifferent assessors (%)	Unsatisfied assessors (%)
Cooling temperature handling treatment (CTH)				
Preconditioned	9.14b	61.1	5.6	33.3
Control	6.22a	28.1	1.4	70.4
Cold-storage period (CSP) (days)				
12	7.61a	45.8	2.1	52.1
26	8.14a	48.9	8.5	42.5
40	7.29a	39.5	0	60.4

Different letters on the same column indicate statistical differences 5%.

more, the percentage of panelists liking the sample measured on ripe fruit was 64% on preconditioned fruit while control reached only 28% (Table 3). The percentage of panelists that disliked the sample was 33% for preconditioning treated and 70% for control fruit which confirmed the acceptability data. There were a low number of indifferent panelists (∼1–5%).

PC1 and PC2 explained 84.3% of the score's plot total variation (Fig. 1). PC1 explained 65.3% of the total variation and is represented by sweetness ($r = 0.97$), juiciness ($r = 0.99$), aroma ($r = 0.92$) and texture ($r = -0.76$). On the other hand, PC2 explains 19% of the variance, being acceptability ($r = 0.82$) the principal attribute that represent it. Fruit after 12 days in cold storage showed higher scores for sweetness, juiciness and aroma compared with fruits kept for 26 and 40 days in postharvest, which are better associated to stronger texture, particularly those of the control treatment. Probably chilling injury symptoms such as leathering, mealiness and 'off flavour' were responsible for the poor sensory evaluation of these fruit.

Acceptability, associated with PC2, showed the potential for discriminating both CTH, showing the preconditioning treatment higher liking degree than the control.

Significant correlations were observed between sweetness and texture ($r = -0.88$), sweetness and juicinesss ($r = 0.96$), and sweetness and aroma ($r = 0.82$); however, their association with acceptability was low, as it has been observed in other studies on peaches (Giacalone *et al.*, 2006; Predieri *et al.*, 2006). The fact that ripe 'September Sun' peaches showed a moderately low TA that varied from 0.34%
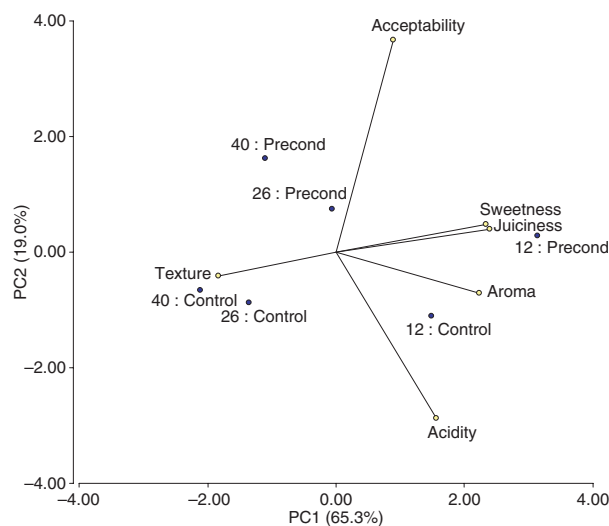
Figure 1 Principal component analysis of sensorial attributes of preconditioned 'September Sun' peaches assessment on fruit maintained in cold storage.

to 0.55% may explain the poor association between other sensory attributes and acidity. Our previous sensory work indicated that consumers are sensitive to ripe titratable acidity when values are ≥0.8% (Crisosto & Crisosto, 2005). Fruit preconditioning positively affected texture and juiciness, in agreement with Crisosto *et al.* (2004), confirming that this treatment maintains a better eating quality than untreated fruits. Preconditioned fruits had lower acidity, and higher sweetness, aroma, and acceptability than untreated fruits, when tested at the same firmness range. Peaches submitted to preconditioning treatment showed that the fruit cell wall components began the process of cell wall disassembly which continued slowly during cold storage, so that at the end of storage the distribution of the pectin between soluble and insoluble fractions and the size of the polymers in the different classes was similar to that of fruit ripened without storage (Zhou *et al.*, 1999, 2000b; Brummell *et al.*, 2004).

Conclusions

Preconditioned 'September Sun' peaches had a higher degree of liking and percentage of satisfied assessors than control after 40 days in cold storage at 0 °C. At the same time, preconditioned fruit maintained their sensory characteristics for longer periods during cold storage compared with control when evaluated on ripe fruit. Thus, preconditioning treatments can be used to maximise market life based on flavour perception for long distance markets or storage period. Furthermore, selection of the proper cultivar and its market life potential should be considered in the final decision to protect peach sensory quality.

Acknowledgments

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