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Postharvest Behavior of Clonal Selections of 'Periana' Peaches

Nachernteverhalten selektierter Klone von 'Periana'-Pfirsichen

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Summary

Four clonal selections of peaches (*Prunus persica* L., cultivar 'Periana') were stored at 0 °C for 4 weeks followed by a 3 day shelf life at 20 °C in two consecutive seasons and three selections studied in only one season. Ethylene production decreased during cold storage to a minimum value after 3–3.5 weeks. In the first season, particularly in fruit from the first harvest, flesh scald developed in the outer part of the mesocarp and to a lesser extent, a radiating form of internal browning. In the second season low sensitivity to chilling injury in 'Periana' peaches was associated with advanced fruit maturity stage at harvest. Development of selection P16 for long-term cold storage is recommended on basis of its quality parameters and chilling resistance.

Zusammenfassung

Vier selektierte Klone von Pfirsich (*Prunus persica* L., Sorte 'Periana') wurden 4 Wochen bei 0 °C gelagert und anschließend 3 Tage auf ihre Lagerfähigkeit bei 20 °C in zwei und drei Selektionen in nur einer Saison geprüft. Die Ethylenproduktion nahm während der Kühllagerung auf einen Minimalwert nach 3–3,5 Wochen ab. In der ersten Saison, besonders bei Früchten der ersten Ernte, entwickelte sich in äußeren Teilen des Mesocarps Fleischbräune und in geringerem Ausmaß eine strahlenförmige innere Verbräunung. In der zweiten Saison zeigte eine bessere Fruchtreife bei der Ernte eine geringere Kälteempfindlichkeit. Der Anbau der Selektion P16 für Langzeit-Kühllagerung wird aufgrund ihrer Kälteresistenz, der Fruchtfleischfestigkeit, dem Gehalt an löslichen Stoffen, der titrierbaren Säure oder dem süßen Geschmack nach der Lagerperiode empfohlen.

Introduction

Recommended storage temperatures for peaches are between –0.5 and 1°C, freezing point being reached around –1.5°C. Below 8 to 10°C temperatures, however, peaches develop chilling injury (CI) symptoms such a radiating form of internal browning and woolliness (CRISOSTO et al. 1995, HALL and SCOTT 1989, LUZA et al. 1992, FERNÁNDEZ-TRUJILLO et al. 1998a, b). CI symptoms are evident in 1 to 6 weeks depending on cultivars sensitivity to injury and the storage temperature used (CRISOSTO et al. 1995). Clingstone cultivars suffer irreversible metabolic changes around 2–3 weeks at 0°C, particularly after an additional ripening period (ARTÉS et al. 1996, FERNÁNDEZ-TRUJILLO et al. 1998b).

CI particularly affects the onset of ethylene production and to a lesser extent respiration rate in peaches at the same time that fruit quality deteriorates (BEN-ARIE and LAVEE 1972, FERNÁNDEZ-TRUJILLO and ARTÉS 1998a, FERNÁNDEZ-TRUJILLO et al. 1998a, b, VON MOLLENDORFF and DE VILLIERS 1988).

A breeding program has been developed in Spain, which has used native plant material (RODRÍGUEZ-NAVARRO and FRUTOS 1992). However, little information about storage quality of these selections is available. Here, we report a study of these selection over 2 years and a further on a single season.

Materials and methods

Plant material and experimental design

The peach fruit (*Prunus persica* L. Batsch) of the selections 'Periana' used in this study were grown at the experimental research station Hacienda Redonda (Abarán, Murcia) managed by the Centro de Investigación y Desarrollo Agrario (CIDA) between 1993 and 1994 (season I and II thereafter). Flower bloom in 'Periana' occurs in the first three weeks of March and optimum harvest is in September, depending on cultivars and climactic conditions. 'Periana' selections are clingstone, non-melting flesh yellow-fleshed peaches useful for immediate consumption or for processing, depending on selections. The selections analyzed followed a genetic protocol (RODRÍGUEZ-NAVARRO 1989, Rodríguez-NAVARRO and FRUTOS 1992).

More than 30 selections were available in the station, although not all of them were analyzed in each of the two seasons and/or the harvest date used per season. The two harvest dates for the selections studied in each season, respectively, were September 20 and 29 (season 1) or September 16 and 23 (season 2). Fruit were harvested according to ground color (green to red Hue angle around 83±2.3° and 78.5±2.4° in 1993 and 1994) and flesh firmness (around 50–60 N in season 1 and 60–75 N in season 2), depending on the selections and harvest date. P4 and P16 selections in season I were also harvested in an immature stage (Hue angle around 5 to 10° higher, flesh firmness around 26 N higher). Fruit were transported to the laboratory at Murcia and selected for uniform size and appearance and freedom from defects. In order to determine respiration and ethylene production, three fruit per selection were treated with iprodione (2 g/L a.i. for 3 min. at 23.6 °C) and ripened at 18 °C (season I) or 20°C (season II). The remaining fruit were stored at 0 °C and 85 % RH for 18 h prior to

Table 1. Weight loss, decay, internal browning and flesh scald after 4 weeks of cold storage at 0 °C and 95% RH plus 3 days at 20 °C and 75% RH (first season) of diverse clones of 'Periana' peaches.
Gewichtsverlust, Fäulnis, innere Verbräunung, Fleischbräune, nach 4 Wochen Einlagerung bei 0 °C und 95% RH und 3 Tagen bei 20 °C und 75% RH (1. Saison) verschiedener Klone von Periana-Pfirsichen.

Selection	Weight loss (% fresh weight)	Decay	Internal browning	Flesh scald
First harvest				
P4 [y]	2.6	0	14[z]	55.6
P16 [y]	2.5	5.0	9.8	59.7
P16	2.9	0	14.4	56.6
P17	3.5	5.1	21.8 [z]	35.8
P18	3.8	30.8	21.6	43.7
P26	2.6	6.9	6.8	71.6[x]
Second harvest				
P17	2.3	36.8	0	5.2 [x]
P18	1.9	0	0	18.0 [x]
P26	2.2	4.5	0	29.7[x]

[z] 5.3% internal browning at the pit.
[y] Immature fruit.
[x] *Alternaria* spp. associated with flesh scald [3.8% and 19.9% in P26 (first and second harvest, respectively)]. All scalded fruit in P17 and P18 (second harvest) were affected by *Alternaria* spp.

random divided into batches and storage in molded plastic trays perforated (ø 2 mm). In the season I, fruit were kept at 0 °C and 95% relative humidity (RH) in gas-tight chambers of 128 L with humidified air-renewal of 120 l/h. After storage fruit were then held at 20 °C and 75–80% RH. P4 and P16 selections were also examined immediately after 4 weeks of storage. In the season II, fruit were stored at 0 °C and 90% RH in a humidified cold room and were subjected to the same shelf life period as in season I.

Quality analysis

Quality analysis were assessed in one replicate of 15 to 27 fruit in season I and in three to five replicates of 24 fruit in season II. Weight loss was evaluated weekly during storage and after 3 days of shelf life period at 20°C and 75% RH and results based on a fresh weight at harvest. Physiological disorders and senescence (over-ripeness, shriveling) were evaluated in a four degree scale. Moderate to severe injured fruit were not commercial since browning or scald affected more than 20% of the mesocarp surface (particularly at the pit) or the outer part of the mesocarp, respectively. Very slight to slight symptoms affected less than 10% or 20% or the mesocarp surface, respectively.

Flesh firmness, soluble solids, titratable acidity, pH, ground and flesh color were measured on three replicates of five fruits at harvest, after 4 weeks at 0 °C (season I) and after 3 days of additional shelf life period according to FERNÁNDEZ-TRUJILLO and ARTÉS (1998b). The chroma (C^*) $[(a^{*2} + b^{*2})^{1/2}]$ and Hue angle [arcsin tan $(b^* \cdot a^{*-1})$] indices were also calculated from the CIE-LAB parameters. Taste (sweetness, astringency) was evaluated in season II after the shelf life period by an informal panel of three people. A 1–10 scale and fresh-cut sound flesh of fruit used for losses inspection were used and results recorded as the mean ± standard deviation (n = 3).

Respiration rate and ethylene production

In season I, three fruit was held at 18±1 °C in chambers of 1.5 L under a 0.5–3 L/h continuous humidified and airflow. In season II, three replicates of individual fruit were held in sealed 620 mL jars for 1–2 h at 0 °C or 25 to 30 min at 20 °C prior to analysis. The samples collected were 1 mL for CO_2 and 5 mL for C_2H_4. Both samples were analyzed by gas chromatography (FERNÁNDEZ-TRUJILLO et al. 1998a, b).

Statistical analysis

A 2-way analysis of variance (ANOVA) was carried out on quality parameters with clonal selections and inspection time (storage and shelf life periods) as factors (season I). LSD tests were used to compare treatment means. When appropriated, losses were transformed to arcsin and analyzed using the same ANOVA model. Weight loss trend was modeled by linear regression forced through the origin.

Table 2. Soluble solids (mean ± SD), weight loss, decay, internal browning and flesh scald after 4 weeks of cold storage at 0°C and 90% RH plus 3 days of shelf-life (3 d at 20 °C) in diverse clones of 'Periana' peaches (second season).
Lösliche Bestandteile und Fruchtfleischfestigkeit (Mittelwert ± SD), Gewichtsverlust, Verbräunung und Fruchtfleischbräune nach 4 Wochen Einlagerung bei 0 °C und 90% RH und weiteren 3 Tagen bei 20 °C von verschiedenen Klonen der Periana-Pfirsiche (2. Saison).

Clon	Shelf-life (3 days at 20 °C)				Storage at 0 °C	
	Soluble solids (°Brix)	Weight loss (% fresh weight)	Chilling injury (%)	Senescence (*%)	Total weight loss in 4 weeks	Average weight loss/week[y]
P16	18.5 ± 0.5	6.7 a	0 a	0 a	4.8 a	1.24
P17	18.1 ± 0.1	7.2 a	0 a	0 a	5.4 a	1.39
P18	18.9 ± 0.5	10.4 b	1[z] a	1 a	6.8 b	1.69
P19	18.5 ± 0.3	4.7 c	0 a	0 a	3.5 c	0.89
P20	15.3 ± 0.1	10.5 b	5[y] b	0 a	6.8 a	1.69
P26	14.8 ± 0.4	11.0 b	6[x] b	13 b	7.5 b	1.86

[z] Internal browning.
[y] 1% internal browning and 3.7% flesh scald.
[x] 4.4%% internal browning at the pit and 1.2% radiating form of the internal browning.
[v] Calculated by linear regression forced through origin ($r^2 > 0.99$).

Results and discussion

Physiological disorders

Chilling injury symptoms included flesh scald in the outer part of the mesocarp and to a lesser extent internal browning at the pit (Tables 1 and 2). Flesh scald particularly affected more immature part of the fruit (greenish to yellowish skin, Hue angle higher than 85). Fruit showing translucent skin also developed scald down this apparently darker skin. Flesh scald prevailed on internal browning particularly in the season I (Tables 1 and 2). Scald has been included as a chilling injury symptom called cold storage breakdown or simply internal breakdown (HALL and SCOTT 1989, SONEGO et al. 1995). Flesh scald has been proposed as a different chilling injury symptom (ARTÉS et al. 1998, FERNÁNDEZ-TRUJILLO et al. 1998a).

The second harvest in season I resulted in no internal browning and a strong decrease in flesh scald (Table 1). In season II, scald showed slight to very slight scald symptoms (11% in P16, 2% in P17 and 1% in P19). In general, scalded fruit were more sensitive to decay produced by *Alternaria* sp., especially in the second harvest of season I (20 and 18% after the shelf life period in fruit from P26 and P18, respectively; data not reported in Table 1). Because of scald and internal browning with or without associated decay, conventional cold storage of 'Periana' cultivars should not be extended longer than 3 weeks at 0°C.

In the season II, fruit from selections with soluble solids content lower than 16°Brix showed higher incidence of CI than selections with lower soluble solids (Table 2). Very slight to slight CI symptoms were also higher in that fruit (8% in P18, 22% in P20 and 14% in P26). In the season I, soluble solids content were lower than 15°Brix (data not shown) and fruit showed serious CI (Table 1). In fruit subjected to different irrigation treatments, CRISOSTO et al. (1994) found differences of soluble solids ranging from 10.7 to 13.3°Brix unrelated to the incidence of internal browning or mealiness during storage.

Environmental conditions affected CI susceptibility between both seasons. Season II was very warm and dry during the summer probably with associated water stress and consequently smaller fruit size (70–80 mm in season I, 62–70 mm in season II), increased soluble solids content and some astringency. KUBOTA (1995) and CRISOSTO et al. (1995) reported the delay of the onset of CI under these conditions. Under these climate conditions usually the onset of CI is often delayed (HALL and SCOTT 1989). Furthermore, CRISOSTO et al. (1997) reported earliest CI development in than medium and small size peaches.

Weight loss, senescence and decay

Weight loss in both seasons followed a linear trend during storage ($r^2 > 0.98$, $P < 0.01$, Table 2). In season I, CI after the shelf life period was lower in the selections that showed reduced weight loss during storage or after a shelf life period (Table 1). However, this result was not confirmed in season II probably because CI incidence was lower (Table 1).

Selection P26 considerably developed shriveling after shelf life in season II (Table 2), and ground color in these fruit as measured by Hue angle increased by 2°.

Main fungi species isolated from rotted fruit (no decay in season II) were *Alternaria* spp. and *Botrytis* sp., *Monilia* spp. and *Cladosporium* sp. only developed after a shelf life period. (Table 1).

Influence of physiological disorders on fruit quality

CI and changes in soluble solids, acidity or L*C* ground and flesh color parameters were not related statistically (data not shown). The lack of correlation between the onset of CI and the loss of firmness in season I could be related to higher CI incidence in this season in all the selections (Table 1). In the season II, P20 and P26 showed CI (Table 2) and flesh firmness after the shelf life period was around 5–10 N compared with other selections as it has been reported in other cultivars (FERNÁNDEZ-TRUJILLO and ARTÉS 1997, FERNÁNDEZ-TRUJILLO et al. 1998b). After the shelf life period in season I, a slight increase in pH (around 0.4 units in P17, P18 and P26) was related to CI.

In general skin ground values were lower than flesh values (data not shown), indicating more orange color in the skin than in the flesh and some gradient in color development. Hue angle value in season I was around 3-4° higher in the flesh compared with the skin (around 79°).

The sweetest fruit from the selections was P16 (7.6±1.1 ud.), P17 (7.7±0.5 ud.) and P18 (8.8±0.5 ud.). Fruit from selections P20 and P26 reached the lowest flesh firmness in season II (5–10 N lower) and were tasteless (6.0±1.5 and 5.8±0.5 ud., respectively). The selection P19 presented astringent taste at harvest that barely decreased after the shelf life period. The selections P19 and P16 showed slight flesh bleeding, particularly at the pit, compared with its absence in other selections, this color at times slightly turning into slightly brown color as a result of CI after shelf life.

Respiration rate and ethylene production

All selections showed climacteric pattern of respiration and C_2H_4 production during ripening (Figs. 1 and 2, Table 3). Respiration rate and ethylene production values at harvest were similar to those found during the shelf life period (Figs. 1 and 2). In season I, all the clones showed the highest C_2H_4 production accompanying the climacteric onset in the first harvest except P16 (Table 3). However, this maximum was undetectable or low in the second harvest of season II. This pattern could be associated with different CI susceptibility between harvest date in season I and between seasons, because the highest C_2H_4 in season I (preclimacteric fruit), the greatest incidence of CI (Tables 1 and 3).

C_2H_4 production gradually decreased in the fruit during storage to minimum values around 21 to 25 days (Figs. 1 and 2). Other peach cultivar, more sensitive to CI, showed depletion in C_2H_4 production during storage before 2 weeks at 0°C (FERNÁNDEZ-TRUJILLO and ARTÉS 1998b, FERNÁNDEZ-TRUJILLO et al. 1998b). In 'Periana' C_2H_4 production did not increase much after this minimum, an observation consistent with low CI symptoms in season II (Figs. 1 and 2). Other cling-

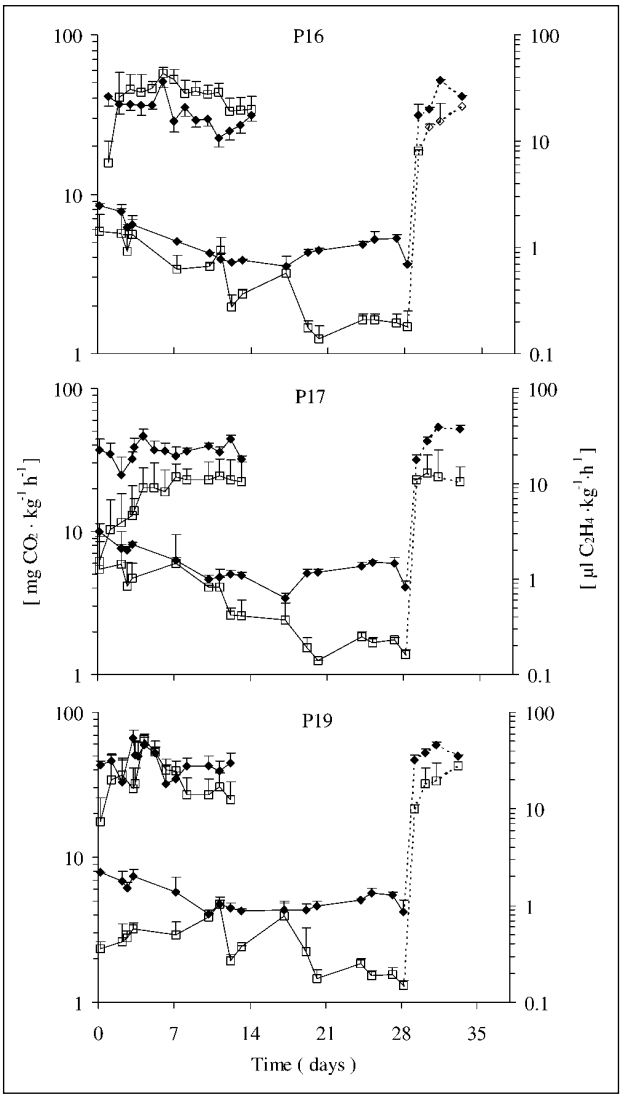


Fig. 1. Respiration rate (◆) and ethylene production (□) at 20 °C and during storage at 0 °C plus an additional shelf life at 20 °C (dashed lines) in diverse selections of 'Periana' peaches (second season, first harvest). Bars represent SE (n=3).
Atmungsrate (◆) und Ethylenproduktion (□) bei 20 °C und während der Einlagerung bei 0 °C und anschließender Lagerung bei 20 °C (---) von verschiedenen Selektionen der Periana-Pfirsiche (Zweite Saison, erste Ernte), n=3.

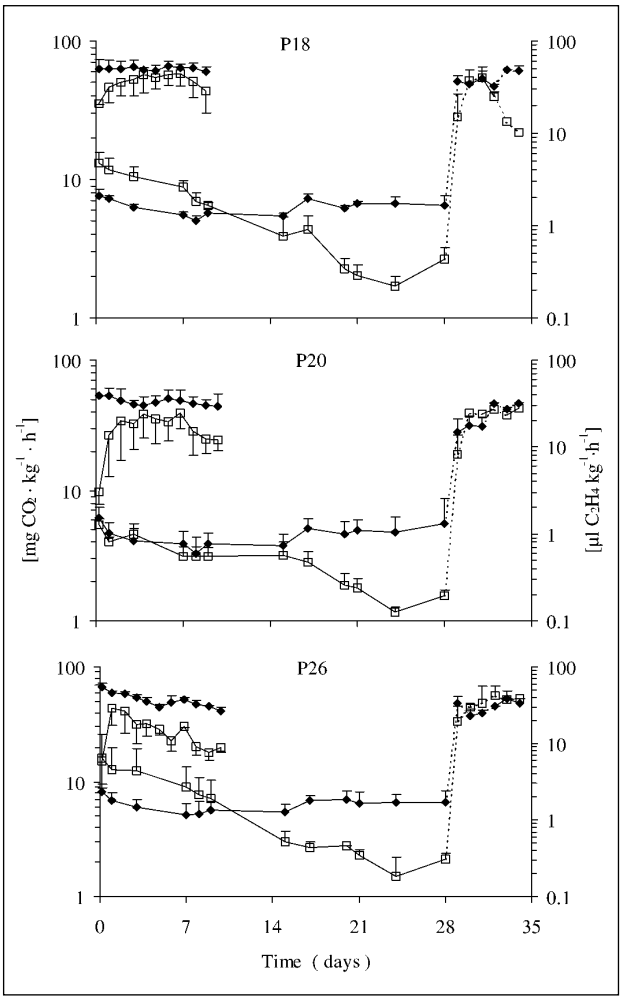


Fig. 2. Respiration rate (◆) and ethylene production (□) at 20 °C and during storage at 0 °C plus an additional shelf life at 20 °C (dashed lines) in diverse selections of 'Periana' peaches (second season, second harvest). Bars represent SE (n=3).
Atmungsrate (◆) und Ethylenproduktion (□) bei 20 °C und während der Einlagerung bei 0 °C und anschließender Lagerung bei 20 °C (---) von verschiedenen Selektionen der Periana-Pfirsiche (Zweite Saison, zweite Ernte), n=3.

stone cultivars showed increased C_2H_4 production after the minimum with the onset of flesh browning (FERNÁNDEZ-TRUJILLO et al. 1998b). An intermittent warming treatment of 1 day at 20°C every 6 days of storage of known effectiveness against CI also stimulated C_2H_4 production in P19 during the warming periods with a residual effect thereafter (data not shown). Stimulation of ethylene production was detected in the cultivar 'Paraguayo' and CI was strongly delayed by 1 to 2 weeks (FERNÁNDEZ-TRUJILLO and ARTÉS 1998a). Collectively, these results suggest a possible relationship between the depletion in C_2H_4 production and the induction of the different CI symptoms.

In summary, 'Periana' clones could be resistant to CI during storage avoiding the storage of immature fruits. The maximum storage life advised is 3 weeks at 0 °C

Table 3. Maximum value of respiration and ethylene production at the climacteric during 8-11 days in two successive harvests of 'Periana' peaches over two years.
Zweijährige Ergebnisse der maximalen Atmungsrate und Ethylenproduktion von Periana-Pfirsichen mit klimakterischem Atmungsanstieg nach 8-11 Tagen bei zwei Ernten pro Jahr.

Selection	Respiration rate (mg $CO_2 \cdot kg^{-1} \cdot h^{-1}$)		Ethylene production ($\mu L\ C_2H_4 \cdot kg^{-1} \cdot h^{-1}$)	
	First harvest	Second harvest	First harvest	Second harvest
Season I (18 °C)				
P4	37.4	53.6	4.7	2.0
P16	34.5	52.4	2.5	1.4
P17	28.0	88.2	10.7	2.6
P18	24.2	52.2	7.5	2.2
P26	23.5	64.5	4.5	3.1
Season II (20 °C)				
P18	45.2	54.1	22.3	44.0
P20	47.5	39.2	48.5	23.8
P26	57.3	54.9	16.3	28.7

without using coadjutants. P16 selection was recommended according to panel tests and its relative tolerance to CI and particularly to internal browning.

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