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Effect of harvest maturity stage on the sensory quality of 'Palsteyn' apricot (*Prunus armeniaca* L.) after cold storage

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SUMMARY

Fresh apricots (*Prunus armeniaca* L.) are in high demand, but are available for only a short period during the Spring and the beginning of the Summer. There is no information on the correct harvest maturity stage that should be chosen to ensure a long post-harvest life and high sensory quality. The objective of this study was to evaluate the effect of maturity stage at harvest on the sensory quality of 'Palsteyn' apricots after 14, 28, or 42 d in cold storage. Sourness, flavour, and acceptability showed major changes during cold storage. Ripe fruit (orange-yellow skin colour) showed the highest acceptability, as assessed by a "mini-consumer test" (i.e., an untrained panel; n = 36). Fruit harvested at an intermediate stage of maturity (light yellow skin colour) reached an average acceptability, while unripe fruit (greenish skin colour) were not acceptable. After 28 d of cold storage, fruits were still acceptable; but, after 42 d, fruits reached the "dislike" zone. On a principal component analysis, acceptability was shown to be positively associated with sweetness, flavour, juiciness, and aroma, and negatively associated with sourness. After 28 d and 42 d of cold storage, unripe fruit appeared to have low acceptability and quality attributes. 'Palsteyn' apricot harvested with an orange-yellow skin colour, as the least ripe fruits, showed that they could reach high sensory quality standards and were able to withstand long periods of cold storage.

Apricots are stone fruits with a limited post-harvest life. They remain fresh for only 1 – 4 weeks, depending on cultivar, when stored at –0.5º to 0ºC and 90 ± 5% relative humidity (Fan *et al*., 2000). Apricots are climacteric fruit and undergo rapid ripening, including flesh softening and loss of overall flavour. Furthermore, since apricots do not have a waxy skin to help reduce moisture loss, they are considered highly susceptible to dessication and shrivelling (Manolopoulou and Mallidis, 1999). During storage, apricots develop two main types of physiological disorder: internal browning and internal breakdown, which usually reduce their storage potential (Manolopoulou and Mallidis, 1999).

Among the quality parameters that define the eating quality of apricot, important traits such as texture and flavour influence final acceptance. Flavour has been defined as a complex attribute of quality in which a mixture of sugars, acids, and volatile compounds play a primary role (Baldwin, 2002). Fruit shape, colour intensity, aroma, sweetness, sourness, flesh firmness, and juiciness are all basic sensory descriptors for apricot (Infante *et al*., 2006).

In order to attain an acceptable, pleasant flavour, apricots should generally be harvested when they are ready-to-eat. Nevertheless, for long-term storage or transport, fruits are harvested at the pre-climacteric stage, before they attain their full flavour and colour, but are more tolerant to handling and prolonged cold storage (Aubert and Chanforan, 2007). This commercial practice affects their eating quality attributes, resulting in fruits with an unpleasant taste and aroma (Manolopoulou and Mallidis, 1999; Dong *et al*., 2002).

As apricots are generally expensive, their sensory quality attributes should be high enough to attract consumers and to create confidence in the product (Infante *et al*., 2006). The development of efficient and reliable protocols to evaluate and control fruit sensory quality while in the marketing chain, is a primary objective of the industry. The aim of this study was to evaluate the effect of harvest maturity on the sensory qualities of 'Palsteyn' apricots kept in cold storage for periods up to 42 d.

MATERIALS AND METHODS

Plant material

'Palsteyn' apricots were harvested from a commercial orchard located in the Central Valley of Chile during December 2005. Fruits were picked according to skin ground colour and sorted into three levels of maturity: E1 = greenish; E2 = light yellow; and E3= orange-yellow. At harvest, a 12-fruit sample for each level of maturity was submitted to flesh firmness (N), soluble solids content (SSC) (%), titratable acidity (TA) (%), and fruit weight (g) evaluations.

Post-harvest trials

After harvest, fruit from E1, E2 and E3 (Table I) were kept in a ripening chamber at 20ºC and 65% relative humidity for 5, 3, or 2 d, respectively, until sensory evaluations were performed. Sensory quality, flesh firmness, SSC, TA, and fruit weight where evaluated

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TABLE I
Characterisation of harvest maturity in 'Palsteyn' apricots at three stages of maturity

Maturity stage[†]	Weight (g)	Diameter (mm)	SSC (%)	TA (%)	Flesh firmness (N)	SSC:TA	Skin colour (h°)
E1	104.5 a[§]	5.0 a	7.9 a	2.2 b	47.5 c	3.6 a	85.14 a
E2	124.7 b	5.0 a	9.7 b	2.2 b	38.2 b	4.5 b	73.09 b
E3	134.2 c	5.4 b	12.4 c	2.1 a	21.8 a	5.9 c	70.60 b

[§]Means values (n = 12) followed by a different lower-case letter indicate statistically significant differences at $P \leq 0.05$.
[†]E1= greenish; E2= light yellow; and E3= orange-yellow skin.

when the flesh reached consumption firmness (i.e., 13.8 ± 5.8 N). Flesh firmness was estimated on samples of six fruits showing a visually uniform skin colour. Fruit firmness was measured on the equatorial area using a FT-327 penetrometer (Effegi, Milan, Italy), with an 8-mm diameter probe.

Fruit destined for cold storage were sorted and transferred to plastic trays, wrapped with perforated polyethylene bags, packaged in 6 kg cartons, and transferred to a cold chamber at 0ºC and 90% relative humidity.

Evaluations of samples in cold storage were performed after three storage periods: (i) 14 d in cold storage plus 4 d in a ripening chamber; (ii) 28 d in cold storage plus 2 d in a ripening chamber; and (iii) 42 d in cold storage plus 1 d in a ripening chamber. As with fruit not placed in cold storage, all samples were tested at consumption flesh firmness.

Quality parameters

The weights, flesh hue angle (hº), SSC, TA, and flesh firmness of 20 fruit were determined for each treatment. Flesh colour components were measured on both sides (cheeks) using a CR-200 colorimeter (Minolta, Tokyo, Japan), recording the L*, a* and b* values (McGuire, 1992). Fruit firmness was measured using a FT-327 penetrometer (Effegi) with an 8-mm diameter probe on opposite sides of each previously peeled fruit. A longitudinal wedge, from the stem end to the calyx end, was then removed from each fruit and pressed through cheesecloth. The SSC (%) of the juice was measured using a temperature compensated ATC-1 refractometer (Atago, Tokyo, Japan). The juice from three fruit was pooled to form a composite sample and its TA was measured by titration of 2 ml juice with 0.1 M NaOH and expressed as % (w/v) of malic acid equivalent, using an automatic Easyline titrator (Schott, Mainz, Germany).

Sensory evaluations

Each sample was prepared on a white pottery dish by presenting a slice of one quarter of the fruit, with its epidermis, cut and prepared less than 5 min before sensory testing, to ensure a glossy aspect and to avoid flesh browning. The dish containing each sample was marked with a 3-digit code, assigned at random, which corresponded to the code presented on a separate evaluation guide. The evaluation guide provided a continuous scale for each sensory attribute, ranging from 0 to 15, and marked with two anchors (Aroma: 0 = no aroma, 15 = very aromatic; Sweetness: 0 = not sweet, 15 = very sweet; Juiciness: 0 = juiceless, 15 = very juicy; Texture: 0 = very soft, 15 = very hard; Sourness: 0 = low sour and 15 = high sour; Flavour: 0 = no flavour, 15 = high flavour). These scales had been used previously to evaluate stone fruit eating quality (Heintz and Kader, 1983). A quantitative descriptive analysis (QDA) was then performed for all attributes by a panel of 12 trained assessors.

A "mini-consumer" test by 36 untrained assessors was used to determine fruit acceptability following the same procedures used for the QDA. A hedonic scale ranging from 0 to 15 (0 = I dislike the sample, and 15 = I like the sample very much) was used. The percentage acceptance was calculated as the number of assessors who like the sample (> 7.5) divided by the total number of assessors who tasted the sample (Lawless and Heymann, 1998).

Statistical analysis

To characterise fruit maturity stage at harvest, a completely random design was used with analysis of variance (ANOVA) for the three sample stages (E1, E2, and E3).

For the storage trial, a 3 × 4 factorial model, corresponding to the three levels of maturity (E1, E2, and E3), and four evaluation periods (0, 14, 28, and 42 d) was used for analysis of variance (ANOVA). Following ANOVA, significant differences between means were determined by the Student–Newman–Keuls separation test, at a significance level of $P \leq 0.05$ (InfoStat, 2004).

To determine associations between quality attributes, a principal component analysis (PCA) was performed with the same factorial design (InfoStat, 2004).

RESULTS AND DISCUSSION

Characterisation of harvest maturity

Fruit corresponding to three stages of harvest maturity were segregated using the common harvest indices employed by the stone fruit industry: namely, fruit weight, SSC, and flesh firmness. Following multivariate analysis, Brown and Walker (1990) concluded that flesh firmness, TA, and juice viscosity were good indicators of physiological maturity in 'Moorpark' apricots. Fruit diameter and TA were not suitable indices to distinguish between E1 and E2 (Table I). The SSC:TA ratio appeared to be rather low for fresh apricots at all maturity stages studied. However, as this fruit would be subjected to cold storage and ripening, this ratio might be expected to increase, reaching values associated with satisfactory eating quality. Fruit skin hº changed as expected. For E1 fruit, a green colour was predominant (hº = 85.14); whereas, for the ripest fruit (E3), an orange colour predominated (hº = 70.60). It should be emphasised that the fruit used in this trial had an unusually large size, considering that even each of the least mature fruit (E1) weighed ≥ 100 g. Large-sized apricots normally fetch a better price, so fruit harvested at all maturity levels in this trial could be classified as high standard quality fruit. In the fresh fruit industry, there is no unique or standardised criterion of maturity

TABLE II
Soluble solids content (SSC), titratable acidity (TA), flesh firmness, and skin colour (h°) evaluated when the flesh reached consumption firmness in 'Palsteyn' apricots harvested with greenish (E1), light yellow (E2), or orange-yellow skin (E3)

Parameter	SSC (%)	TA (%)	SSC:TA ratio	Firmness (N)	Colour (h°)
Maturity level (M)					
E1	9.4 a[§]	2.1 c	4.5 a	28.1 c	86.16 c
E2	10.5 b	1.9 b	5.8 b	23.3 b	75.96 b
E3	13.2 c	1.7 a	7.9 c	11.3 a	68.66 a
Post-harvest cold storage period (PH) (d)					
0	10.0 a	2.1 c	4.9 a	16.7 a	79.71 c
14	12.0 b	2.1 c	5.9 b	22.4 b	74.39 a
28	11.9 b	1.7 a	7.5 c	21.7 b	77.43 bc
42	10.4 a	1.7 b	6.2 b	22.8 b	76.19 ab
M × PH					
E1 × 0	7.9 a	2.1 f	3.8 a	21.7 bc	91.75 e
E1 × 14	10.9 cd	2.4 g	4.6 abc	27.8 cd	77.64 d
E1 × 28	10.0 bc	1.9 de	5.2 bcd	32.0 d	88.10 e
E1 × 42	8.6 ab	1.9 de	4.5 ab	30.8 d	87.17 e
E2 × 0	9.7 bc	2.1 ef	4.7 abc	17.6 ab	77.61 d
E2 × 14	11.2 cde	2.1 f	5.4 bcd	28.9 cd	75.39 cd
E2 × 28	12.1 def	1.6 b	7.4 e	21.1 bc	77.53 d
E2 × 42	9.8 bc	1.7 bc	5.8 cd	25.8 cd	73.31 bcd
E3 × 0	12.4 def	2.0 ef	6.2 d	10.8 a	69.75 abc
E3 × 14	13.8 f	1.8 cd	7.6 e	10.6 a	70.14 abc
E3 × 28	13.7 f	1.4 a	9.8 f	12.0 a	63.65 a
E3 × 42	12.8 ef	1.6 ab	8.2 e	11.7 a	68.08 ab
Significance					
M	*	*	*	*	*
PH	*	*	*	*	*
M × PH	ns	*	*	*	*

[§]Mean values followed by different lower-case letters indicate statistically significant differences at $P \leq 0.05$.
ns, not significant. *, significant at $P = 0.05$.

for harvesting fresh apricots for the fresh market. Companies normally use unripe fruit when the product is to be kept in a cold chamber for a long period.

Post-harvest performance

An interaction between maturity level and storage time was observed (Table II). A higher SSC:TA ratio was observed in E3 fruit than in E2 and E1 fruit. This was mainly due to a reduction in organic acids and a higher SSC. The increase in SSC during fruit development is normally linked to changes in fruit colour and ethylene production (Gouble *et al*., 2005; Table I). A reduction in TA, from 2.1% to 1.7%, was observed after cold storage, and was more evident after 42 d. In contrast, no major changes were observed in SSC during cold storage (Table II). Post-harvest behaviour of apricot TA and SSC have been described in different varieties (Botondi *et al*., 2003; Aubert and Chanforan, 2007). Skin colour h° was higher on unripe fruit (E1), than on E2 and E3, confirming the higher presence of chlorophyll in E1 samples. Also, after cold storage, h° continued to decrease, reaching the lowest scores after 42 d (Table II).

After 42 d in cold storage, dehydration reached 1.6% and 3.7% (w/w) for E3 and E1 fruit, respectively. These values are considered moderate, and no visual symptoms of shrivelling were registered.

Sensory performance

Unripe fruit (E1) had a low acceptability score (6.98), which was below the acceptance threshold for ≤ 50% of satisfied assessors. In contrast, E3 fruit attained the highest acceptability score (9.98) and 78.8% of assessors scored samples as being over the acceptance threshold (Table III). E2 fruit reached an average acceptability score (8.5) and satisfied 67.7% of consumers.

No difference in acceptability was observed between recently picked fruit (0 d) and fruit kept in cold storage for 14 d. Up to 28 d of cold storage, the acceptability score (7.97) was above the acceptance threshold, and 59% of assessors scored samples as acceptable. 'Palsteyn' apricots could maintain an adequate eating quality only after 28 d in cold storage plus 2 d of ripening. After 42 d in cold storage plus 1 d of ripening, neither the acceptability score (7.08), nor the number of satisfied assessors (48.6%) reached suitable levels (Table III). These results emphasise the importance of selecting an adequate harvest maturity stage in apricots when consumer satisfaction is the objective.

The acceptability scores of fruit submitted to up to 28 d in cold storage were above the acceptance threshold, and resulted mainly from a reduction in TA, which was high at harvest (Table I) and, in consequence, favoured a balanced SSC:TA ratio (Infante *et al*., 2006).

TABLE III
Acceptability scores and acceptance (%) of 'Palsteyn' apricot fruit harvested with greenish (E1), light yellow (E2), or orange-yellow (E3) skin and evaluated by a "mini-consumer" test (n = 36)

Parameter	Acceptability score[†]	Acceptance (%)[#]
Maturity level (M)		
E1	6.98 a[§]	45.8
E2	8.50 b	67.7
E3	9.98 c	78.8
Post-harvest period (PH)		
0	9.72 c	80.6
14	9.18 bc	75.0
28	7.97 ab	59.0
42	7.08 a	48.6
Significance		
M	*	
PH	*	
M × PH	ns	

[†]0 = dislike extremely, to 15 = like extremely.
[#]Number of assessors who evaluate the sample as > 7.5, divided by the total number of assessors.
[§]Mean values followed by different lower-case letters indicate statistically significant differences at $P \leq 0.05$.
ns, not significant; * significant at $P = 0.05$.

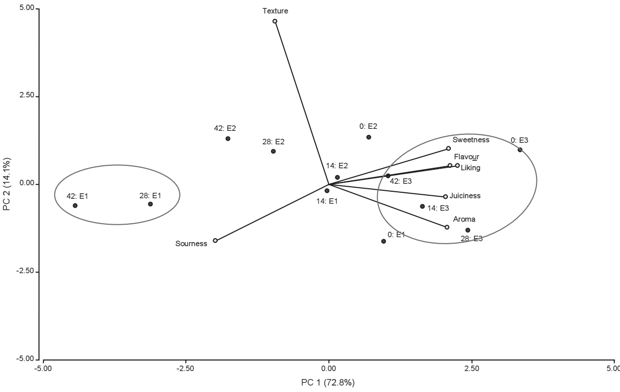

FIG. 1
Principal component analysis of sensory attributes of 'Palsteyn' apricots harvested with greenish (E1), light yellow (E2), or orange-yellow (E3) ground skin colour, after 0, 14, 28, or 42 d in a cold chamber (0ºC and 90% RH) followed by a ripening period until the flesh firmness reached 13.8 ± 5.8 N.

These high acid fleshed stone fruit cultivars behave, in some way, like late-season pears or apples which need to be kept in cold storage to express their full sensory potential, even if there was any increase in SSC, as occurs in pomes (Infante *et al.*, 2008).

Principal component 1 (PC1) and principal component 2 (PC2) explained 86.9% of the total variation of the plot (Figure 1). PC1 (72.8%) was associated with aroma, sweetness, sourness, juiciness, flavour, and acceptability, while PC2 (14.1%) was linked to texture.

Significant and positive correlations were observed between acceptability scores and sweetness (r = 0.93), flavour (r = 0.93), juiciness (r = 0.84), and aroma (r = 0.80). In contrast, acceptability was significantly and negatively correlated with sourness (r = –0.84), and no correlation was observed with texture (r = –0.32). Other studies on peach have shown positive correlations between acceptability and flavour, sweetness, and aroma (Giacalone *et al.*, 2006). In other fleshy fruits (e.g., peaches and nectarines) juiciness is one of the most relevant attributes that define the degree of liking (Infante *et al.*, 2008). Consumers assume that apricot fruit need not be as juicy as peaches to be good (i.e., acceptable). Rather, they expect apricots to taste sweet or flavoured.

For all storage periods, the ripest fruit (E3) was associated with greater acceptability. E3 treatments clustered together and were associated with quality attributes. There was a second cluster located in the negative area of PC1, which contained unripe fruit (E1) tested after 28 d and 42 d of cold storage. These fruit showed high texture scores, but lacked the other quality traits associated with acceptability (Figure 1).

E2 fruit was not associated with quality attributes, but appeared associated with texture, particularly after 28 d and 42 d. Neither chilling injury, nor 'off flavours' were observed in any fruit, even after 42 d of cold storage.

Peaches, nectarines, and plums kept in cold storage for a long period, have achieved better sensory levels by temperature manipulation either during storage (e.g., by intermittent warming; Zhou *et al.*, 2001), or before storage (e.g., by pre-conditioning; Nanos and Mitchell, 1991; Zhou *et al.*, 2000). It would be advisable to study the effects of these temperature regimes on apricot. However, adequate harvest maturity should be considered as a basic pre-requisite for each apricot genotype when high eating quality is required after cold storage.

The results obtained here are promising because they show that 'Palsteyn' apricots, even when harvested as least mature (E1) fruits, with an orange-yellow skin colour, are able to withstand 28 d in cold storage and retain a satisfactory eating quality. In most industries, fresh apricots are packaged by hand. No automatic fruit packaging occurs as happens with other stone fruits, so the risk of mechanical damage is minimised. This careful fruit handling could allow the use of more mature fruit to attain its full flavour potential, either immediately after harvest or after cold storage. Previous studies showed that the highest acceptability scores could only be reached at harvest, and that cold storage only negatively affected sensory quality. In this study, acceptability scores remained unchanged after up to 14 d of cold storage and, after 28 d, fruits were still acceptable.

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