Monitoring the sensorial quality and aroma through an electronic nose in peaches during cold storage

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Abstract

BACKGROUND: The poor eating quality of fresh peaches transported to far markets is one of the main problems that fresh-fruit exporting countries have to face. This research is focused on the evaluation of the sensorial quality, with emphasis on aroma, of four peach cultivars kept in long-term storage, through maturity parameters, sensorial attributes and electronic nose (e-nose) assessments. Fruits were stored at 0 °C and 90% elative humidity, for 14, 28 and 42 days. Evaluations were carried out after the fruit was taken out of cold storage and after a variable period of ripening at 21 °C, until flesh firmness reached 1–2 kgf.

RESULTS: On fruit recently harvested, the e-nose was suitable for discriminating among cultivars, even if it corresponded to an early pre-climacteric phase. As cold storage proceeded, liking degree, and specially aroma, declined for each cultivar tested. Cultivars showed different behavior patterns for liking degree and especially aroma during cold storage. Flavor showed significant correlation with sweetness ($r = 0.92$), juiciness ($r = 0.92$) and texture ($r = 0.93$), but not with aroma and acidity, being these last ones being independent from each other.

CONCLUSION: Post-harvest storage life of peaches is limited by loss of quality. 'Tardibelle' peaches showed the highest quality attribute scores after 42 days of cold storage. This evidences the availability of commercial peach cultivars which are able to withstand long-term storage periods, allowing far markets to be reached with high quality standards.

INTRODUCTION

Peaches submitted to long-term cold storage are subject to serious quality decay, detected at final consumer level, the symptoms of which include the lack of flavor associated with unripe fruit,[1] and development of chilling injury,[2] evidenced as mealiness and internal browning,[3,4] among the most common. Peach quality has always been measured in terms of the attributes of the products, mainly through the evaluation of the physical and chemical properties that better explain maturation and ripening. Flesh firmness, ground color, soluble solids content (SSC) and titratable acidity (TA) are the commonly used parameters for defining fruit quality because they provide a common language among researchers, industry and consumers.[5] When quality is measured from the consumers' perspective, these parameters do not match with what consumers take into account for deciding whether the quality is good or poor; it is therefore of relevant importance to define quality on the basis of consumer expectations.[6]

The characteristic aroma of fruits results from the existence of volatile compounds present in their skin and pulp, which produce a complex mixture of organic components strongly related to the ripening phase, genetic background,[7] storage conditions, maturity stage and/or ripening conditions.[8] Traditionally, the aroma of horticultural products is measured by means of sensory panels. Alternatively, gas chromatography, which separates volatiles into their individual components,[10] is used to quantify the different volatiles constituting fruit aroma.[9]

Other techniques that could easily determine aroma in fruits are being investigated. Among these is electronic nose (e-nose) technology, defined as a chemical sensor matrix with different sensibilities, capable of recognizing simple or complex aromas. When the sensors are exposed to volatiles, adsorption occurs and electronic resistance of each sensor changes.[9] The e-nose offers a fast and non-destructive alternative to evaluate fruit aroma,[11] with easier analysis and less data-processing time,[12] being suitable for segregating ripe peach varieties.[13]

Considering the fundamental importance of the sensorial quality of peaches subjected to long-term cold storage, it becomes necessary to carry out new

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investigations and to use novel tools to determine objectively quality changes during this phase. This research is focused on the evaluation of the sensorial quality and aroma, using an e-nose, of four peach cultivars kept in long-term cold storage.

MATERIALS AND METHODS
Materials
Yellow-fleshed peach cultivars 'Ryan Sun', 'Autumn Red', 'September Sun' and 'Tardibelle' were picked from a germplasm bank near Santiago, Chile. For each cultivar, homogeneous-looking fruits were harvested; choosing those with green-yellow ground color was associated to 6–7 kgf flesh firmness.

Fruit characterization
In order to characterize the fruit used in this experiment, immediately after harvest 12 fruits per cultivar were evaluated through maturity parameters and by using an e-nose.

Those fruits destined for cold storage were sorted and transferred to plastic trays, wrapped with fenestrated polystyrene bags, and kept in 8.2 kg boxes containing two trays each. Fruits were maintained in a conventional cold chamber (0 °C and 90% relative humidity (RH)) and taken out of cold storage after 14, 28 and 42 days. Afterwards, fruits were held under ripening conditions (21 °C), until flesh firmness reached 1–2 kgf. For each cold storage period, 24 fruits were used for maturity parameter determination and sensorial quality attributes, whereas for e-nose evaluations 12 samples were used.

Maturity parameters
On an individual fruit base, weight and ground color, using a Minolta chromometer (model CR-300, Minolta, Osaka, Japan), were determined. Lightness (L) was measured directly and, additionally, a and b parameters were measured, expressed as chroma (C^*) values and as hue angle (H_{ab}), where $C^* = (a^2 + b^2)^{1/2}$ and $H_{ab} = \tan^{-1}(b^*/a^*)$. Flesh firmness was measured on both fruit cheeks using a penetrometer (Effegi, Milan, Italy) with a 7.9 mm diameter probe. A wedge-shaped slice of flesh was taken longitudinally from each fruit and was pooled and juiced. SSC was determined using a digital refractometer (Atago, Tokyo, Japan). TA was determined through titration of 10 mL juice with 0.1 mol L^{-1} NaOH to pH 8.2 and was expressed as % malic acid.

Sensorial quality
A quantitative descriptive analysis was carried out at a sensory analysis laboratory, performed in individual conventional cabinets, by a trained judge panel formed of 12 individuals (ten men and two women, aged 25–55). The training period of the panel on fresh fruit evaluation, for a total of 12 h, was carried out during the same harvest season. Six sessions were executed for discussing and standardizing the criteria and definition of quality parameters. The same panel was used for the three storage periods considered (14, 28 and 42 days). After fruits were withdrawn from the cold chamber they were kept at 21 °C and 70–80% RH for ripening until they reached 1–2 kgf flesh firmness.

The samples were prepared on a white pottery dish by presenting as a quarter slice of fruit with epidermis, cut and prepared less than 5 min before testing, for assuring tenderness and avoiding flesh browning. The dish containing the sample was marked with a randomly assigned three-digit code, corresponding to the same code presented on a separate evaluation guideline. The evaluation guidelines considered a continuous scale for each attribute, ranging from 0 to 15, marked with three anchors: 0 = lowest level for that specific attribute; 7.5 = medium level for that specific attribute; and 15 = highest level for that specific attribute, as used before in evaluation experiments on stone fruit eating quality.[14] The quality attributes evaluated were liking degree, aroma, sweetness, acidity, juiciness, flesh texture and flavor.

Aroma evaluation
The e-nose EOS 835 (SACMI, Imola, Italy) was used to determine the first two principal components that determine the aroma of each cultivar at harvest, as well as after cold storage. Each fruit was placed in a glass-tight container (1500 mL) for 10 min at 22 °C and each sample was obtained from the headspace. The instrument, equipped with six electrochemical sensors, was configured with the following program: pre-acquisition phase 30 s; acquisition phase 180 s; post-acquisition phase 30 s, waiting phase 180 s and chamber-cleaning phase 100 s. The gas carrier used was an instrumental synthetic air. In all determinations the same flow (150 mL s^{-1}), chamber temperature (22 °C) and relative humidity (80%) were used. The e-nose registers, during the acquisition phase, a set of data (values of electric resistance in ohms) for each one of the six sensors. These data were subjected to the 'single point' algorithm (SACMI) based on the average of the highest electrical resistance scores registered. Each measurement was then identified by a six-component vector and presented in a two-dimensional plot.

Experimental design and statistical analysis
Fruit maturity at harvest was characterized on 12 fruits which were used as replicates for weight, flesh firmness, SSC and ground and cover color. TA and pH were determined on four replicates composed of three fruits each. Data were subjected to ANOVA and, afterwards, significant differences between means were determined by Student–Newman–Keuls separation test with a $P < 0.05$ significance level,[15] under a completely random scheme.

For cold-storage fruit, a completely randomized 4 × 4 design was used (cultivar × storage period). The number of replications used in sensorial evaluation was 12, corresponding to each assessor. For data

registered with the e-nose, a principal components analysis (PCA) was performed, using the Nose Patters Editor program (SACMI; Imola, Italy).

RESULTS AND DISCUSSION
Harvest characterization
Cultivars showed similar flesh firmness, with values ranging between 6.0 and 6.5 kgf, corresponding to the recommended harvest firmness for fruit that will be kept in cold storage.[16] Ground color hue values indicated homogeneity between cultivars, expressed by the prevalence of yellow color, highlighting the similar maturity stage among fruits (Table 1).

The first two principal components (PC1 and PC2) explained 96.8% of the total variance in the score plot (Fig. 1). The PCA results form a model which considers as classification variables the scores obtained by each of the six sensors of the e-nose. Each cultivar was separated in an independent cluster at harvest, indicating that there are genetically based differences in the proportions of volatile compounds and constituents.[8,17] Even at this early pre-climacteric phase, the e-nose was suitable for discriminating among cultivars. In another study Benedetti et al.[13] determined that the first two principal components (99.43% of the total variance) of the score plot produce a clear separation of four peach cultivars into four independent clusters. The cultivars evaluated by Benedetti et al.[13] were 'Earlymaycrest', a yellow melting peach, an early mutation of 'Springcrest'; 'Maycrest', a yellow very firm melting peach, a mutation of 'Springcrest'; 'Springcrest', a yellow very firm melting peach; and 'Silver Rome, a white nectarine, rich in epicarp and mesocarp polyphenols.[13] In our study the tested cultivars shared a common progenitor, the well-known 'O'Henry' peach, a fact that reduces the genetic distance among the cultivars

tested, even though each cultivar was undoubtedly clustered separately. The typical aroma of peach is not abundant in unripe fruits, but develops after flesh softening,[1] which, in this case, occurred at 21 °C. Aromatic composition of fruits has been found to be dependent on the cultivar, ripeness as well as post-harvest treatments.[18]

Quality attributes after cold storage
Ripening involves changes that transform the mature fruit into one that is ready to eat. As the fruit ripens, it softens, its acidity declines, changes occur in color,[19] flavor and texture, and certain volatile compounds, which give the characteristic aroma for each genotype,[20] are produced. No remarkable variation in the SSC was observed throughout storage, differences observed at harvest stayed unchanged because there is no further sugar accumulation in
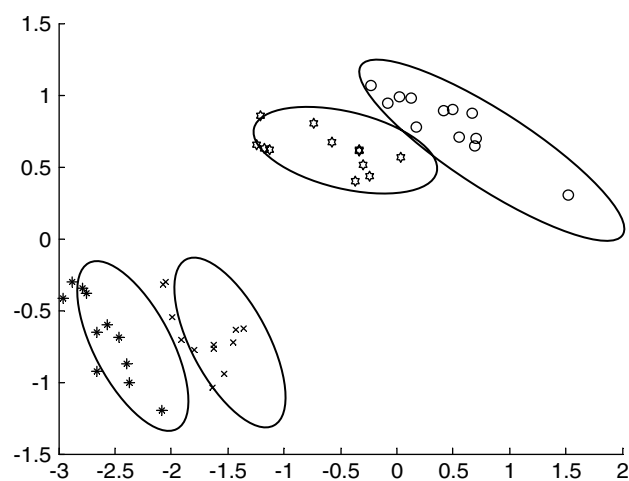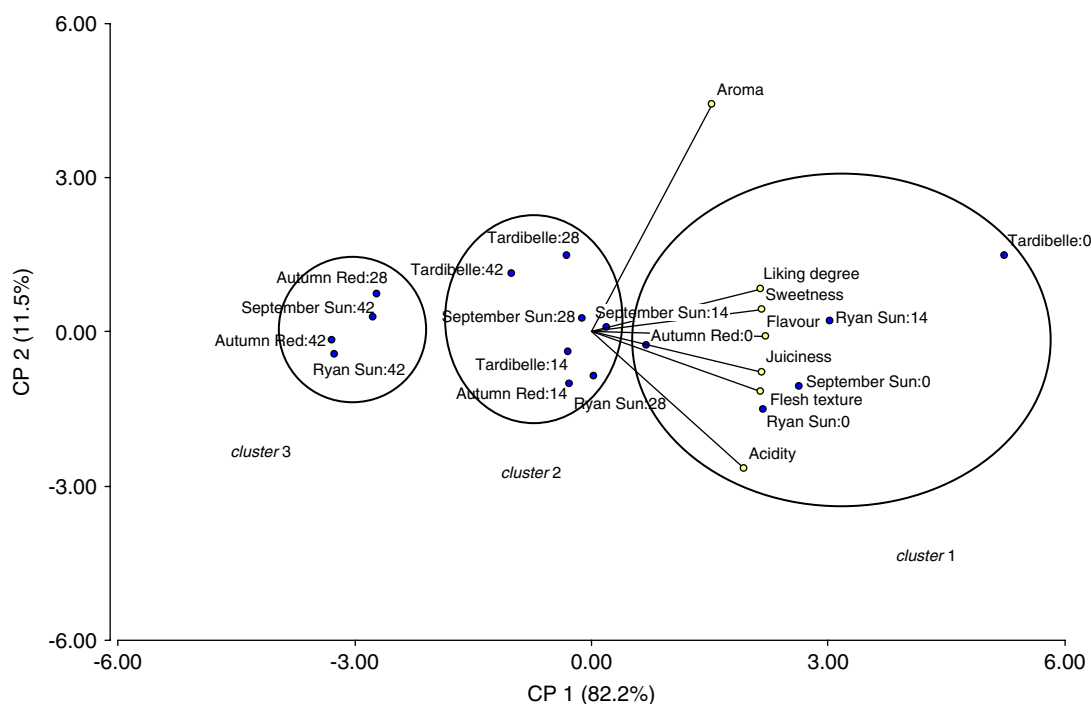

Figure 1. Principal component analysis determined with the electronic nose system EOS 835, at harvest, for 'Ryan Sun' (○), 'Autumn Red' (✿), 'September Sun' (×), and 'Tardibelle' (∗) peach cultivars.

Table 1. Maturity parameters measured in 'Ryan Sun', 'Autumn Red', 'September Sun' and 'Tardibelle' peach cultivars, at harvest

Maturity parameter	Cultivar (harvest date)			
	'Ryan Sun' (1 Feb.)	'Autumn Red' (7 Feb.)	'September Sun' (13 Feb.)	'Tardibelle' (14 Feb.)
Weight (g)	226.8b[Z]	191.8a	303.3c	228.4b
Flesh firmness (kgf)	6.0a	6.2a	6.2a	6.5a
SSC (%)	11.0a	11.3ab	12.9c	12.1bc
TA (% malic acid)	0.7b	0.5a	0.8c	0.7b
SSC:TA	16.6ab	21.2c	15.8a	17.9b
pH	3.9b	3.9b	3.7a	3.7a
Ground color				
L	68.6ab	69.0ab	66.5a	71.3b
C^*	41.0a	41.7a	42.9a	45.7b
Hue	94.0b	85.4a	80.2a	91.4b
Cover color				
L	40.4b	41.7b	36.4a	39.3b
C^*	27.5a	25.6a	21.5a	24.8a
Hue	37.6a	35.0a	30.6a	33.6a

Different letters in the same column show statistical differences (5%), independently for each parameter.

Figure 2. Principal components analysis for the sensorial attributes determined through a trained sensorial panel of 'Ryan Sun', 'Autumn Red', 'September Sun' and 'Tardibelle' peach cultivars after 0, 14, 28 and 42 days of cold storage, plus a variable ripening period at 21 °C (cultivar: days on cold storage).

stone fruits after harvest.[21] Other authors found no significant changes in SSC during cold storage, but reported a slight increase in SCC during shelf-life, upon removal from cold storage, attributable to fruit shriveling.[22]

TA decreased throughout cold storage (data not shown) due to the oxidation of organic acids, as reported previously.[23] The SSC:TA ratio increased through storage, as observed before in 'Harvester' peaches;[24] the authors of that study stated that this ratio shows a closer relationship with eating quality than TA or SSC, separately.[19]

In regard to sensorial quality, determined by the trained panel, PC1 and PC2 explained 93.9% of the score's plot total variation (Fig. 2). Flavor showed significant correlation with sweetness ($r = 0.92$), juiciness ($r = 0.92$) and texture ($r = 0.93$), but not with aroma and acidity, these last two being independent from each other. Other studies on peaches presented positive correlations between flavor, sweetness, and aroma[25] and particularly between aroma and flavor.

Three clusters were formed, the first one constituted by fruit not subjected to cold storage, which presented the highest values for all sensorial attributes evaluated by the trained panel, especially sweetness, flavor, juiciness and texture. 'Ryan Sun', after 14 days of storage, was also included in Cluster 1. Treatments gathered in Cluster 2 did not show particular association with any quality attribute and presented lower values for all of them. This cluster was mainly constituted by all the cultivars after 14 and 28 days of cold storage and by 'Autumn Red' not submitted

to cold storage, a cultivar that never reached high scores for the measured quality attributes. The third cluster was constituted by all the cultivars kept for 42 days in cold storage and by 'Autumn Red' after 28 days of cold storage. At this cold storage period all cultivars showed the lowest values for all the sensorial parameters evaluated, coinciding with the results of Infante *et al.*,[22] who stated that peach long-term cold storage affects sensorial quality negatively, due to the appearance of soft and juiceless fruit.

Even if no evident symptoms of chilling injury were observed at any storage period tested, this disorder could become a limiting factor for the shelf-life of peaches stored at low temperatures[2] and is expressed by symptoms such as mealiness and flesh browning.[26] Chilling injury determines peach post-harvest storage/shipping potential, because its occurrence reduces consumer acceptance.[3]

Aroma after cold storage

Volatile composition varied considerably, both quantitatively and qualitatively, over time and among cultivars.[27] In this study, each post-harvest period was segregated into an independent cluster for each one of the four evaluated cultivars. PC1 and PC2 explained over 85% of the score plot's total variance, evidencing the capacity of the instrument to sort peaches subjected to different storage periods, as well as genetic differences among unripe peaches (Fig. 1). The formation of volatiles during fruit ripening is a dynamic process, so the aromatic composition changes both qualitatively and quantitatively, a process that in peaches continues after harvest, owing to their climacteric nature.[17]
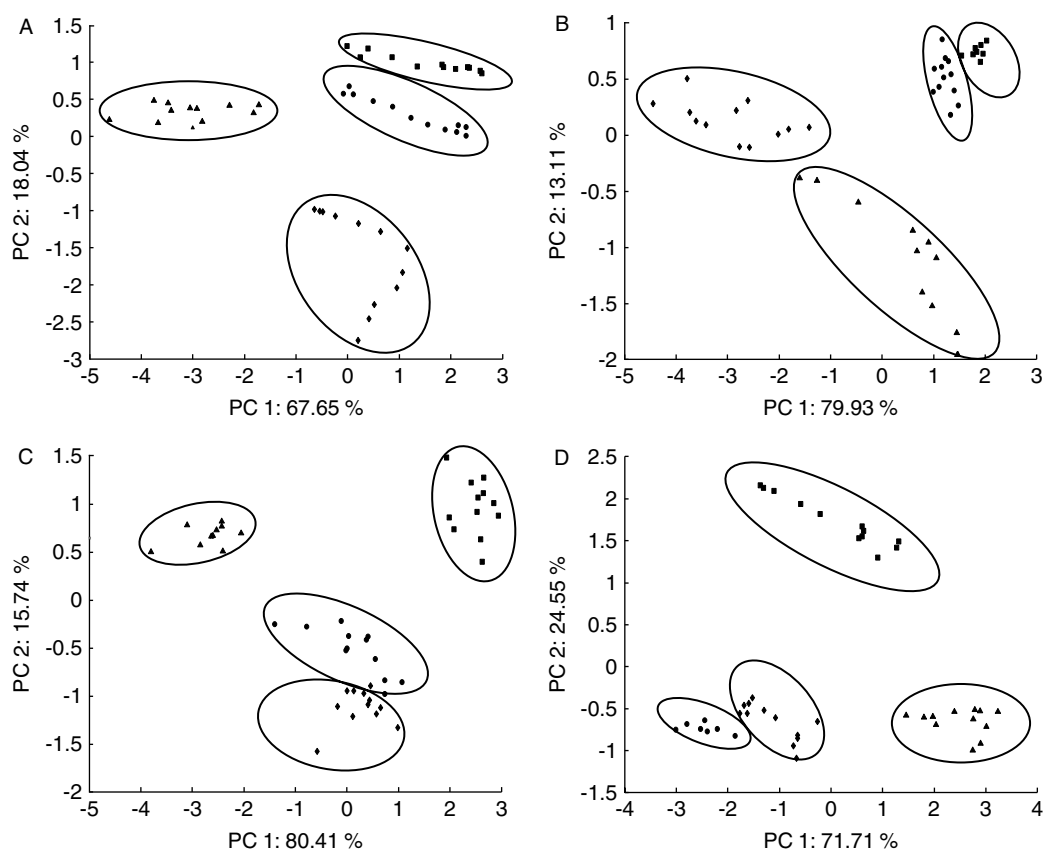
Figure 3. Principal components analysis determined with the electronic nose EOS 835, for (A) Tardibelle, (B) Ryan Sun, (C) September Sun and (D) Autumn Red peach cultivars after different cold storage evaluation periods plus a variable period at 21 °C. Storage periods: 0 days at 0 °C + 4 days at 21 °C (■), 14 days at 0 °C + 3 days at 21 °C (●), 28 days at 0 °C + 2 days at 21 °C (▲) and 42 days at 0 °C + 2 days at 21 °C (♦).

The constitution of four clusters was observed, corresponding to each of the post-harvest periods evaluated (Fig. 3). In general, for all cultivars, those fruits not submitted to cold storage (0 days at 0 °C + 4 days at 21 °C) were clustered far away from the others in an independent and upper quadrant (Fig. 3(C) and (D)) or near to fruit kept 14 days at 0 °C + 3 days at 21 °C (Fig. 3(A) and (B)). The highest scores for the sensorial attributes were observed for fruit not submitted to cold storage (Fig. 2) and these treatments were also clustered independently by the e-nose. In the case of 'Ryan Sun', those fruits not submitted to cold storage and those after 14 days of cold storage were clustered almost in the same cluster according of their quality attributes (Fig. 2), and aroma determined through the e-nose (Fig. 3(B)). Aroma changes throughout cold storage; in fact, Robertson et al.,[28] on 'Cresthaven' peaches, reported that volatiles decreased after 4 weeks of cold storage.

The results of this study confirm that post-harvest storage life of peaches is limited by quality loss.[22,26] As cold storage proceeded, sensorial attributes, and especially aroma, seem to be affected by a natural declination. 'Tardibelle' peaches showed the highest quality attribute scores after 42 days of cold storage. This evidences the availability of commercial peach cultivars able to withstand long-term storage periods retaining aroma in a better way than others.

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