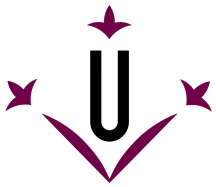


Universitat de Lleida

Optimización de las tecnologías de conservación en diferentes variedades de melocotón y nectarina para la mejora de su calidad.

Jaime Andrés Cano Salazar

Universidad de Lleida

Escuela Técnica Superior de Ingeniería Agraria

Departamento de Tecnología de Alimentos

Optimización de las tecnologías de conservación en diferentes variedades de melocotón y nectarina para la mejora de su calidad.

Memoria presentada por:

Jaime Andrés Cano Salazar

Para optar al grado de Doctor en Ciencia y Tecnología de Alimentos

Directora: Dra. María Luisa López Fructuoso

Directora: Dra. Gemma Echeverría Cortada

Lleida, Abril 2012

La presente memoria con título“Optimización de las tecnologías de conservación en diferentes variedades de melocotón y nectarina para la mejora de su calidad.” es presentada por **Jaime Andrés Cano Salazar**, estudiante del departamento de Tecnología de Alimentos de la Universidad de Lleida, para optar al grado de Doctor. La parte experimental se ha realizado en el Centro UdL-IRTA de Lleida bajo la dirección de la **Dra. María Luisa López Fructuoso** y la **Dra. Gemma Echeverría Cortada**. Ambas autorizan la presentación de esta memoria de tesis debido a que reúne las condiciones necesarias para su defensa

Directores de Tesis

Dra. María Luisa López Fructuoso

Dra. Gemma Echeverría Cortada

Jaime Andrés Cano Salazar

Doctorando

Lleida, Abril de 2012

Lo único que interfiere en mi aprendizaje….., es mi educación.

Albert Einstein

Este trabajo se ha realizado en el laboratorio de Tecnología y Aromas del Departamento de Post-cosecha del Centro UdL-IRTA, financiado por el Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria, y l'Agència de Gestió d'Ajuts Universitaris i de Reserca.

AGRADECIMIENTOS

Después de este "corto" tránsito por el mundo de la ciencia y la investigación ha llegado el momento de dar por terminada una etapa más en la vida. Considero que este periodo me ha permitido ver, aclarar, analizar y tomar decisiones que espero sean las correctas para así re-encaminar los pasos de cara a mi futuro, tanto a nivel personal como profesional. De este modo y teniendo en cuenta lo trascendental de la situación seria ingrato y descortés no agradecer a todas aquellas personas que me han arropado y aportado tanto en estos últimos años.

Primeramente, agradecer a las personas que dirigieron la presente tesis, Dra. Gemma Echeverría C y Dra. María Luisa López F, agradezco la implicación que cada una aporto para la realización de esta.

En cuanto a las instituciones involucradas, agradecer, especialmente a la Universidad de Lleida por la concesión de la beca predoctoral, al AGAUR (Agencia de Gestión de Ayudas Universitarias y de Investigación) por el apoyo económico y al IRTA (Instituto de Investigación y Tecnología Agroalimentaria) por facilitar sus espacios físicos. Estas entidades han permitido que se lleve a buen fin este trabajo de investigación.

En cuanto a las estancias académicas, agradecer el apoyo del departamento de poscosecha de el Plant and Food Research Center en Nueva Zelanda, particularmente al Dr. Allan Wolff en Aukland y a los doctores Darryl Rowan y Adam Mitch en Palmerstone North. Así mismo agradecer al Dr. Víctor Hugo Escalona y el Dr. Javier Obando Ulloa del CEPOC (Centro de estudios de Poscosecha) en Chile.

Así mismo, agradezco la posibilidad que me brindo la vida de coincidir y compartir con personas grandiosas, de las que he aprendido mucho y con las que me he

quejado, llorado y reído. Me refiero a personas como la Dra. Matilde Izaguirre, Dra. Carmen López, Dr. Ignasi Iglesias, Dra. Wendy Scotchman, Dr. Jordi Gine, Carlos Calvo, Meritxell, Ferrán, Anabel, Eli, David, Joan, Erika, demás becarios y trabajadores de los grupos de fisiología, patología, entomología, genética porcina y otros departamentos del IRTA. Muchas gracias por los buenos momentos!!!!.

Particular agradecimiento, a la familia Rowan (Darryl, Linda e hijos), quienes me abrieron las puertas de su casa en Nueva Zelanda y de modo más que especial me acogieron como uno mas de su familia.

En cuanto a los "momentos históricos" -como los llama mi madre-, situaciones tales como la hora de comer del día a día tomaron en su momento gran valor, ya que en compañía de Giuseppe, Miguel, Diego, Raziel, Fanny y Ariadna se podía acariciar cualquier tema, haciendo de ese rato un placentero periodo de tiempo en el que se podían tener conversaciones agradables, inteligentes, personales, actuales y frívolas (si era del caso); la verdad es que esto dio sazón a la rutina de vida. Del mismo modo quedara en la memoria, nuestro querido equipo de futbol del ETSEA (Parchelona F.C) el cual fue otra gran alegría; donde Rogelio, Harry, Sergi, Edinson, Ramiro, Diego, Miguel y demás estudiantes predoctorales de turno dejamos nuestro limitado aporte al futbol.

Como no podía ser de otra manera, entre mis más gratos agradecimientos esta mi familia en Colombia (el eje fundamental de mi vida). Considero poco lo que puedo escribir para todo lo que se podría decir. Somos una familia de seis hijos donde cada uno tiene una historia de éxitos académicos y personales, donde además fuimos premiados por la vida con unos padres que nos han enseñado el valor por el trabajo con pasión y dedicación, un hogar donde no hay sitio para las actitudes derrotistas ni el

desanimo; a todos los que integran la familia Cano Salazar, mil y mil gracias. Particular merito doy a mi mamá, quien me merece la mayor admiración y será eterno ejemplo de resistencia a todo nivel, para ti mi pequeño esfuerzo y mil gracias por luchar contra el cáncer y sucesivas dificultades físicas, entendemos que quieres vivir más y con amor día tras día porque tu interés es poder estar presente y de ese modo hacer que nuestros triunfos sean completos.

Del mismo modo, a mi familia en España: Alba, Carlos y Naty T, mil gracias por querer verme como me veo hoy, por el ánimo, por aguantarme y lo incondicional que han sido a cada momento.

Finalmente, es de ley y no menos importante el agradecer a el bastión principal de esta experiencia, mi Sandrita, quien siempre está ahí, dándolo todo y mas, espero entiendas que este logro tiene muchísimo de ti y por lo tanto sabrás, que has sido más que fundamental para que esto llegue a buen fin. Te reitero y reiterare mi mas eterno agradecimiento por tu comprensión, ayuda y silencios oportunos, así mismo por quererme, soportarme, escucharme, entenderme y más que nada por siempre motivarme a cada paso, gracias por tu sincero, afectivo y efectivo amor. Gracias de todo corazón. Te quiero.

A quienes he dejado en el tintero y que han colaborado con esta tesis, gracias y espero que la vida sea justa con todos y cada uno de ustedes.

RESUMEN

El objetivo principal de la presente tesis doctoral ha sido evaluar la influencia que ejerce el periodo de pre-acondicionado previo al almacenamiento frigorífico a -0.5 ºC , diferentes combinaciones gaseosas de la atmósfera de conservación frigorífica y su posterior vida útil a 20 ºC, sobre la producción de compuestos volátiles emitidos, los parámetros físico-químicos y la evaluación sensorial en cuatro variedades de melocotón (Early Rich®, Royal Glory®, Sweet Dream^{cov} y Elegant Lady®) y siete variedades de nectarina (Big Top®, Honey Blaze^{cov}, Venus®, Honey Royale^{cov}, August Red®, Nectagala^{cov} y Nectalady^{cov}). Para ello se han realizado cuatro estudios: caracterización varietal en recolección, potencial de conservación, efecto del pre-acondicionado a 20 ºC previo a la conservación frigorífica e influencia de la atmósfera gaseosa durante el almacenamiento. Teniendo en cuenta que las variedades utilizadas en cada estudio variaron y que ellos se realizaron durante los años 2009, 2010 y 2011.

En cosecha, el mayor grado de satisfacción por parte del panel de consumidores se asoció con las variedades que presentaron superior contenido en sólidos solubles y altas emisiones de ésteres, especialmente acetatos y lactonas. Concretamente, estas fueron las variedades dulces Honey Royale^{cov}, Nectalady^{cov} y Nectagala^{cov}. En cambio las variedades ácidas Royal Glory®, Elegant Lady® y Venus® obtuvieron menor aceptación.

Con relación al potencial de conservación en frío, se obtuvo un descenso de la firmeza en las variedades de melocotón, debido al periodo de conservación y posterior permanencia a 20 ºC. En cuanto a las nectarinas, variedades Big Top® y Honey Blaze^{cov} conservadas durante 20 y 40 días en frío obtuvieron una valoración más alta por parte de los consumidores. Esta mayor aceptación se asoció con frutos más firmes y con

mayores emisiones de algunos compuestos volátiles provenientes de la familia de los ésteres.

En relación al efecto del periodo de pre-acondicionado aplicado a las variedades Big Top® y Early Rich®, los resultados indicaron que este provocó un incremento en la emisión de algunos compuestos volátiles, aunque su efecto dependió del periodo de conservación frigorífica y comercialización posterior a 20 ºC. El pre-acondicionado acentúa el descenso de firmeza a lo largo de la conservación en mayor medida en melocotón que en nectarina.

En cuanto a la influencia de las atmósferas controladas y periodo de conservación sobre los atributos sensoriales, los resultados mostraron que el periodo de conservación fue el factor que más influyó en la percepción del sabor, siendo los frutos procedentes de largos almacenamientos los que obtuvieron inferior valoración. La composición de la atmósfera también produjo una variación en la percepción de este atributo, disminuyendo a medida que aumentaban los niveles de O_2 y CO_2. Este efecto también se puede extender a los atributos de dulzor y jugosidad, ya que todos ellos se mostraron altamente correlacionados.

RESUM

L'objectiu principal d'aquesta tesi doctoral ha estat avaluar la influència que exerceix el període de pre-acondicionat previ a l'emmagatzematge frigorífic a -0.5 º C, les combinacions gasoses de l'atmosfera de conservació frigorífica i la seva posterior vida útil a 20 º C, sobre la producció de compostos volàtils, paràmetres fisicoquímics i avaluació sensorial en quatre varietats de préssec (Early Rich®, Royal Glory®, Sweet Dream^{cov} i Elegant Lady®) i set de nectarina (Big Top®, Honey Blaze^{cov}, Venus®, Honey Royale^{cov}, August Red®, Nectagala^{cov} i Nectalady^{cov}). Per això s'han realitzat quatre estudis: caracterització varietal en recol·lecció, potencial de conservació, efecte del pre-acondicionat a 20 ºC previ a la conservació frigorífica i influència de l'atmosfera gasosa durant l'emmagatzematge. Tenint en compte que les varietats utilitzades en cada estudi van variar i que ells es van realitzar durant els anys 2009, 2010 i 2011.

En collita, un major grau de satisfacció per part del panel de consumidors es va associar amb les varietats que van presentar major contingut en sòlids solubles i altes emissions d'esters, especialment acetats i lactones. Concretament, aquestes van ser les varietats dolces Honey Royale^{cov}, Nectalady^{cov} i Nectagala^{cov}. En canvi les varietats àcides Royal Glory®, Elegant Lady® i Venus® van obtenir menor acceptació.

En relació amb el potencial de conservació en fred, es va obtenir un descens de la fermesa, en les varietats de préssec, a causa del període de conservació i posterior permanència a 20 º C. En quant a les nectarines, les varietats Big Top® i Honey Blaze^{cov} conservades durant 20 i 40 dies en fred van obtenir una valoració més alta per part dels consumidors. Aquesta major acceptació es va associar amb fruits més ferms i amb majors emissions d'alguns compostos volàtils provinents de la família dels esters.

En relació a l'efecte del període de pre-acondicionat aplicat a les varietats Big Top® i Early Rich®, els resultats van indicar que aquest va provocar un increment en l'emissió d'alguns compostos volàtils, encara que el seu efecte va dependre del període de conservació frigorífica i comercialització posterior a 20 º C. El pre-acondicionat accentua el descens de fermesa al llarg de la conservació en major mesura en préssec que en nectarina.

Respecte a la influència de les atmosferes controlades i període de conservació sobre els atributs sensorials, els resultats van mostrar que el període de conservació va ser el factor que més va influir en la percepció del sabor, sent els fruits procedents de llargs emmagatzemaments els que van obtenir inferior valoració. La composició de l'atmosfera també va produir una variació en la percepció d'aquest atribut, disminuint a mesura que augmentaven els nivells d'O_2 i CO_2. Aquest efecte també es pot estendre als atributs de dolçor i sucositat, ja que tots ells es van mostrar altament correlacionats.

SUMMARY

The main objective of this thesis was to evaluate the influence of the pre-storage treatment prior to cold storage at -0.5 ° C and the effect of different atmosphere gas combinations during cold storage and subsequent shelf life (20ºC) conditions, on the production of volatile compounds, physicochemical parameters and sensory evaluation in four peach varieties (Early Rich ®, Royal ® Glory, Sweet Dream^{cov} and Elegant Lady ®) and seven nectarine varieties (Big Top ®, Honey Blaze^{cov}, Venus ®, Honey Royale^{cov}, August Red ®, and Nectalady^{cov} Nectagala^{cov}). Accordingly, four different experiments were carried out over the years 2009, 2010 and 2011 using different fruit varieties. First, we evaluated and characterize varietal differences upon harvest, then we investigated the storage potential, and finally we assessed the effect of pre-storage at 20ºC prior to cold storage and the influence of the atmosphere during storage.

Immediately after harvest, the greatest consumer satisfaction degree was associated with those varieties having higher soluble solids contents and greater esters emissions, mainly acetates and lactones. In detail, this was the case for fruits from the sweet varities like Honey Royale^{cov}, Nectagala^{cov} and Nectalady^{cov}. In contrast, acid varieties such as Royal Glory ®, Elegant Lady ® and Venus ® were less appreciated by the consumers.

Regarding the cold-storage potential, peach firmness tend to decrease both during cold storage and subsequent shelf life at 20 ° C. However, some nectarine varieties like Big Top ® and Honey Blaze^{cov} preserved better their firmness for up to 20 and 40 days in cold and generally obtained a better consumer acceptance. This higher acceptance was in most cases associated with firmer fruit as well as increased emissions of certain volatile compounds from the esters family.

Regarding the effect of pre-storage treatment applied to the Big Top ® and Early Rich ® varieties, the results revealed that this caused an increase in the emission of some volatile compounds but dependent on the length of cold storage and subsequent shelf life at 20 ° C. The pre-storage treatment prior to cold storage favored the loss of firmness during postharvest handling being this trend more accentuated in peaches than in nectarines.

As for the influence of controlled atmospheres and shelf life on the sensory attributes of peaches and nectarines, the results showed that the storage length was the most prominent factor in the perception of flavor by the consumer, with longer periods resulting in fruits less appreciated by the consumers. The composition of the atmosphere also influenced the consumer perception of flavor, decreasing at the same time as O_2 and CO_2 levels increased in the storageatmosphere. A similar trend was noticed for other sensory attributes like sweetness and juiciness since all of them appeared to be highly correlated.

ABREVIATURAS

AC: Atmósferas controladas.

AN: Atmósfera Normal.

AGAUR: Agència de Gestió d'Ajuts Universitaris i de Recerca.

AN: Atmósfera normal.

ANOVA: Análisis de varianza.

AT: Acidez titulable.

CE: Cara expuesta.

CS: Cara sombreada.

CSS: Contenido de sólidos solubles**.**

ddpf: Días después de plena floración.

D-HS: Dynamic head space.

DMS: Diferencia mínima significativa.

EDS: Extracción por destilación simultánea.

ELL: Extracción líquido–líquido.

FID: Flúor ionization detector.

GC: Gas Chromatography.

GC-MS: Cromatografía de gases-espectrometría de masas.

HR: Humedad relativa.

HS: Head space.

IRTA: Institut de Recerca i Tecnologia Agroalimentàries.

LO: Low oxygen.

MAPYA: Ministerio de Agricultura, Pesca y Alimentación.

MARM: Ministerio de Medio Ambiente y Medio Rural y Marino.

MEFS: Micro-extracción en fase sólida.

OCVV: Oficina Comunitaria de Variedades Vegetales.

PCA: Principal component analysis.

PIB: Producto interior bruto.

PLSR: Partial least square regression.

ppb: Partes por billón.

ppm: Partes por millón**.**

S-HS: Static head space.

TD: Termal desorption.

UdL: Universidad de Lleida.

UE: Unión Europea.

ULO: Ultra low oxigen.

ÍNDICE

Resumen I

Resum II

Summary III

Abreviaturas IV

1. Introducción 1

1.1 Situación del sector de melocotón y nectarina 6

1.2 Caracterización varietal 9

1.2.1 Características físico-químicas 10

1.2.2 Características aromáticas 15

1.2.3 Características sensoriales 21

1.3 Tecnología de la conservación 27

1.3.1 Almacenamiento frigorífico en atmósfera normal 29

1.3.2 Almacenamiento frigorífico en atmósfera controlada 33

1.3.3 Pre-acondicionado previo al almacenamiento frigorífico 38

1.4 Bibliografía 41

2. Objetivos 57

3. Diseño experimental 61

3.1 Plan de trabajo 63

3.2 Material vegetal 72

3.3 Datos climatológicos 73

4. Resultados 75

CAPÍTULO I 77

Influence of volatile compound emissions and standard quality on consumer acceptance of peaches and nectarines.

CAPÍTULO II.1 95

Cold storage potential of four yellow-fleshed peach cultivars defined by their volatile compounds emissions, standard quality parameters, and consumer acceptance.

CAPÍTULO II.2 133

Cold storage of six nectarine cultivars: Consequences for volatile compounds emission, physicochemical parameters, and consumer acceptance.

CAPÍTULO III 173

Relationships between instrumental and sensory characteristics of four peach and nectarine cultivars stored under air and CA-Atmospheres.

CAPÍTULO IV 209

Volatile compound emissions and sensory attributes in 'Big Top' nectarine and'Early Rich' peach fruits in response to pre-storage treatment before cold storageand subsequent shelf life.

5. Discusión general 237

5.1 Estudio 1: Caracterización varietal de melocotón y nectarina en cosecha 239

5.2 Estudio 2: Efecto del sistema de conservación frigorífica en atmósfera normal 240

5.3 Estudio 3: Efecto del sistema de conservación frigorífica en atmósfera controlada 244

5.4 Estudio 4: Efecto del sistema de pre-acondicionado previo a la conservación frigorífica 246

5.5 Bibliografía 247

6. Conclusiones 249

1. Introducción

Con el objeto de aumentar la satisfacción del consumidor de melocotón y nectarina, el sector productor ha propiciado en los últimos años un incremento en el cultivo y comercialización de nuevas variedades con diferentes características de color de epidermis, contenido en sólidos solubles y acidez titulable. Sin embargo, una de las principales quejas de los consumidores y mayoristas es la pérdida de sabor y la excesiva firmeza del fruto. Diversos estudios llevados a cabo en California (Crisosto y Crisosto, 2002) han aportado información interesante sobre las principales razones de los consumidores a la hora de explicar la habitual insatisfacción que le merecen determinados melocotones en el momento de ser consumidos. Los principales motivos de queja de los consumidores hacen referencia a algunos de los siguientes aspectos: frutos muy firmes, pulpa harinosa y pardeamiento interno, falta de sabor y una deficiente capacidad para madurar correctamente en el hogar. Este menor sabor y excesiva firmeza son causados principalmente por un inadecuado estado de madurez del fruto en el momento de la recolección y por la tecnología de conservación utilizada. Durante la maduración del fruto fuera del árbol se produce ablandamiento, modificación del aroma, reducción de la acidez e incremento de los azúcares. Estos cambios, que pueden continuar en mayor o menor extensión a lo largo de la fase poscosecha, determinan la calidad con que un fruto es percibido por los consumidores.

Los frutos de hueso son productos extremadamente perecederos, lo que conduce a mayores valores de pérdidas en el proceso poscosecha en comparación con otras frutas (como manzanas, peras, naranjas,…). Según Tonini y Caccioni (1990), estas pérdidas son causadas principalmente por factores como: elevado metabolismo que en breve tiempo lleva a los frutos a la madurez adecuada para su consumo, inmediatamente después a una maduración excesiva y rápida, y como consecuencia a la senescencia;

recolección en épocas estivales, alta sensibilidad al desarrollo de infecciones fúngicas y elevadas pérdidas de agua por transpiración que conducen a pérdidas de tipo cuantitativo (pérdidas de peso) y de tipo cualitativo (marchitamiento). Para reducir la velocidad de maduración de dichos frutos es muy eficaz la pre-refrigeración rápida (generalmente por aire frío) y el almacenamiento a bajas temperaturas. Éstas son consideradas tecnologías "blandas" y "limpias", que implican la variación de factores como la temperatura, junto con otros como la composición gaseosa de la atmósfera que rodea al producto, tratamientos térmicos, etc., que permiten restringir el deterioro cualitativo del fruto (Vendrell y Carrasquer, 1994). La conservación de melocotones y nectarinas con unos valores de temperatura entre 0 y 10 ºC conduce a la aparición de diversos síntomas de alteración en los frutos, que en conjunto se llaman daños por frío "chilling injury" o "internal breakdown" y que se manifiestan en una textura harinosa de la pulpa "mealiness", pardeamiento interno "flesh browning" y presencia de sabores atípicos "off flavours" (Crisosto y col., 1999b). Entre las variedades más susceptibles de melocotón, se observa que el rango de temperatura que mayor incidencia de la alteración en los frutos es entre 2,2 y 7,8 ºC; este intervalo de temperaturas críticas se ha denominado como "killing range" (Crisosto y Labavitch, 2002). En cambio, a una temperatura de 0 ºC el desarrollo de los daños es menos intenso. En variedades sensibles, se observa que su vida comercial se reduce drásticamente cuando los frutos se ven expuestos a las temperaturas críticas. Por desgracia, algunas partidas y lotes comerciales de melocotón están sometidos al mencionado rango térmico en las cámaras de almacenamiento de las centrales frutícolas, así como durante el transporte frigorífico y en las cámaras de los centros comerciales en destino.

Hasta hace pocos años, los programas de mejora genética han centrado su trabajo en la mejora de aspectos pomológicos como el color y calibre. Esta mejora del color de los frutos se ha traducido en la obtención de variedades con mayor coloración incluso en estados muy avanzados de madurez, lo cual ha provocado en muchos casos que el productor anticipé su recolección aunque en algunos casos los frutos todavía no han alcanzado su madurez de consumo conduciendo de esta manera a una decepción por parte del consumidor, con la consiguiente disminución del consumo. La recolección en base a dicho carácter implica en muchos casos una pérdida de calidad. Se han de intentar equilibrar las necesidades del consumidor con las características genéticas de cada variedad para de este modo se logre cumplir con las expectativas sensoriales demandadas por el consumidor. En base a las consideraciones respecto al fruto anteriormente expuestas y de cara al receptor final se perfila un nuevo tipo de consumidor, es el consumidor que considera la "fruta de calidad" como aquella que tiene un buen aspecto, textura, sabor y alto valor nutritivo (Brücker, 2008).

Existe un evidente descenso del consumo de melocotones y nectarinas en los últimos años, siendo alguna de las principales razones el incumplimiento de las exigencias del consumidor en cuanto a preferencias, la calidad final y el estado de madurez de los frutos en destino. Como alternativa a esto en los últimos años se han investigado diversos tratamientos para limitar el desarrollo de daños por frío y la pérdida de la calidad aromática. En cuanto a la tecnología de conservación el uso de atmósferas controladas y el pre-acondicionado suelen ofrecer resultados beneficiosos, siempre que se apliquen correctamente y de forma adaptada al comportamiento fisiológico de cada variedad en una zona de cultivo determinada (Crisosto y col., 2000). De cara a la calidad aromática las mismas tecnologías se han utilizado teniendo en

cuenta que es muy poca la información técnica y científica sobre como generar, mantener y/o incrementar la producción de compuestos aromáticos en melocotones y nectarinas.

1.1 Situación del sector de melocotón y nectarina

Actualmente, la producción de melocotones y nectarinas en el mundo asciende a aproximadamente 11 millones de toneladas, siendo China, Italia y USA los tres principales países productores en el hemisferio Norte, Chile, Sudáfrica y Australia en el hemisferio Sur. En el transcurso de los últimos años al contrastar la producción de especies de fruta de hueso en la Unión Europea y el mundo, podemos ver que España ocupa el segundo o tercer lugar respecto a la producción mundial, junto a Estados Unidos, si se exceptúa China. Actualmente España es el segundo país en el ranking de la producción europea de melocotón (figura 1), Italia sigue liderando la producción de la Unión Europea con más del 40% de la producción, mientras que Francia ocupa el cuarto lugar. La producción anual media de melocotón en España es de alrededor de un millón de toneladas, lo que convierte a esta especie en la más importante (figura 2), dentro de las especies consideradas como fruta dulce. La mejora tecnológica y la innovación varietal han propiciado un incremento progresivo y mayoritario de sus producciones durante los últimos quince años, y esto se ha derivado en un notable incremento y diversificación de la oferta.

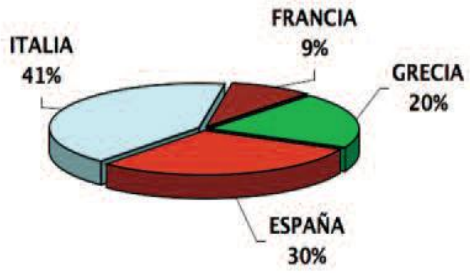


Figura 1. Aportación de los principales países productores a la producción de melocotón en la Unión Europea. Valores medios del período 2008-2010 (Europech'10, junio 2010).

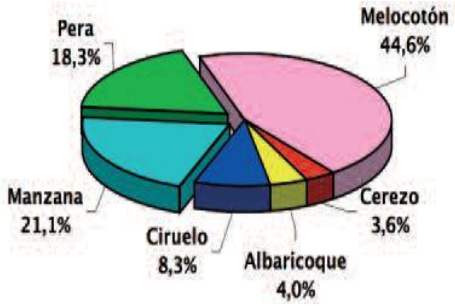


Figura 2. Distribución de la producción de fruta dulce en España por especies. Valores medios del período 2008-2010 (Europech'10, junio 2010).

El interés por la producción de especies frutales de hueso es lógico, dada su mejor adaptación a climas secos y calurosos que caracterizan la mayor parte de las zonas frutícolas de España, en particular el Valle del Ebro donde destacan Cataluña y Aragón. En la última década se ha dado una ampliación de las zonas de producción hacia el Levante y sur del país, destacando Murcia (15.800 ha), la Comunidad Valenciana y Andalucía con cerca de 17.000 ha cultivadas entre ambas.

El melocotonero es actualmente la especie de fruta dulce más producida en España. La superficie de melocotonero cultivada actualmente en España es de 78.000 ha

con una producción de 1.091.000 t en 2010, de la cual se exportó el 51%, principalmente a Alemania, Francia, Holanda y Polonia. En Cataluña la superficie total plantada de melocotonero (incluyendo melocotón, nectarina y pavía) es de 19.100 ha con producciones de 138.000 t para el melocotón y de 133.200 t para nectarina. Dichas producciones representan el 12 % de la producción final agraria catalana.De este modo los frutales de mayor importancia en Cataluña son los de hueso, con una producción estimada en 2009-2011 de 115.118 t de nectarina y melocotón por año. En cuanto a la tipología del fruto y en base a las producciones en España en el período 2008-2010, la nectarina es el grupo más importante con el 38% de la producción, seguida por la pavía (34%) y el melocotón rojo que junto al paraguayo representa el 28%. La evolución según tipología de fruto en el período 1991-2010, denota un notable incremento de la producción de nectarina y un aumento moderado del melocotón rojo (Europech'10, junio 2010). En el caso de la nectarina el 76% corresponde a variedades de pulpa amarilla y el 24% a variedades de pulpa blanca, mientras que para el melocotón estos porcentajes son del 86% y del 14%, respectivamente. Las nectarinas se han consolidado en las principales áreas de producción y consumo de Europa, a lo que ha contribuido su buena respuesta a la exportación hacia países del norte y del este, principalmente de variedades de pulpa amarilla, alta coloración y sabor dulce, como ejemplo se encuentra la variedad `Big Top®´ con un notable impacto en el sector productor.

El consumo medio en la actualidad se sitúa en valores de 5 kg per cápita y año, muy por debajo de otras frutas como manzanas y peras, que alcanzan valores de 11 ó 7 kg per cápita y año, respectivamente (MARM, 2011). El descenso de consumo repercute negativamente sobre los intereses económicos de un sector que representa un gran porcentaje del PIB regional tanto de Cataluña como de Extremadura. Los

consumidores mencionan la falta de calidad de la fruta como la principal causa de su insatisfacción, que puede estar motivada por la recolección anticipada para evitar mermas en el proceso de comercialización. Este hecho ha sido común en muchos países productores como Italia, Francia o Estados Unidos (Crisosto y Crisosto, 2001).En Francia, el 80% de los consumidores encuestados estaban insatisfechos con la calidad de los melocotones comprados (Clareton, 2000).El desconocimiento de las preferenciasdel consumidor y la insuficiente calidad principalmente debida a una recolección de los frutos en un estado inmaduro se han identificado como las principales causas del incesante descenso en el consumo. Sin embargo, el cada vez mayor conocimiento de los beneficios de su consumo para la salud humana y la creciente demanda por alimentos saludables, unido a la mejora de la calidad ofertada, son aspectos alentadores de cara al futuro de estas especies en España.

1.2 Caracterización varietal

El melocotonero es originario de China, donde las referencias de su cultivo se remontan a 3000 años. Desde China fueron introducidos en Persia (actual Irán) a través de diversas rutas comerciales abiertas entre montañas. Hacia el año 330 a.c. los melocotoneros llegaron a Grecia, desde donde su cultivo se extendió por toda Europa. En el siglo XX se constata que el melocotonero aparece ya como cultivo en expansión. A principios del siglo XX se empezaron a seleccionar genotipos de melocotonero a partir de poblaciones procedentes de semilla y se fijaron por medio de injerto. El fruto es una drupa de gran tamaño con una epidermis delgada, un mesocarpio carnoso y endocarpio de hueso que contiene la semilla. La aparición de huesos partidos es un carácter varietal. Existen dos grupos de melocotones según el tipo de fruto; los de pulpa

blanda y sin adherencia al endocarpio, con destino a comercializar en fresco, y los de pulpa dura y fuertemente adherida, con destino en fresco e industria. En cuanto a las nectarinas son frutales derivados por mutación de los melocotoneros comunes. El fruto es una drupa (pericarpio membranoso, mesocarpio pulposo, endocarpio leñoso), de forma más o menos globosa con una línea de sutura y una cavidad alrededor del pedúnculo. Su piel es lisa, de coloración atrayente, pulpa muy sabrosa y el hueso no está adherido a la pulpa.

1.2.1 Características fisicoquímicas

El concepto de la calidad se ha definido como el conjunto de características químicas y físicas que ofrecen al consumidor un producto con buena apariencia y un alto grado de aceptación (Kramer y Twigg, 1966). Para conseguir esta calidad se buscan los mejores índices, para cada especie y variedad, que la definan tanto en pre-cosecha como en cosecha. Habitualmente los índices de calidad utilizados para determinar la fecha óptima de recolección en melocotones y nectarinas son: el calibre, el color de la piel, la firmeza de la pulpa, el contenido en sólidos solubles (CSS) y la acidez titulable (AT). Del mismo modo, la mejora genética de melocotón y nectarina persigue la obtención de variedades con buen calibre, ausencia de fisiopatías, un intenso y extenso color rojo en toda la epidermis y finalmente, gusto de tipo dulce o sub-ácido (lo que exige un contenido de azúcares moderado-alto acompañado por un contenido de ácidos bajo) según la variedad y el tipo de consumidor. En cambio, no tienen éxito aquellas variedades con frutos poco coloreados o de gusto excesivamente ácido. En este sentido, son útiles para los investigadores y técnicos la clasificación elaborada por Iglesias y Echeverría (2009), la cual permite agrupar variedades en función de los valores de

acidez; de este modo se agrupan en variedades sub-ácidas (0-4 g ácido málico/L), dulce-semidulces (4-9 g ácido málico/L), equilibradas (9-15 g ácido málico/L) y finalmente ácidas (> 15 g ácido málico/L). La acidez del melocotón está controlada por varios factores tales como la variedad, las condiciones climáticas, la posición del fruto en la copa, la carga de cosecha, el estado de madurez (Crisosto y col., 1996) y el patrón de donde provengan (De Jong y col., 2005).

Diversos estudios realizados con melocotones, han asociado una mayor calidad del melocotón, y consecuentemente una superior aceptación sensorial por parte del consumidor, con un mayor CSS (Parker y col., 1991; Mitchell y col., 1990). Algunas de las nuevas variedades semi-precoces proporcionan valores superiores a los 13 ºBrix y en algunos casos se superan los 16 ºBrix. Del mismo modo, diferentes estudios realizados en el sur de Francia, indican que para variedades de sabor dulce como `Big Top®´, la satisfacción del consumidor aumenta al incrementarse los valores del CSS, obteniéndose altas valoraciones en cuanto a la aceptación (> 70% de consumidores satisfechos) a partir de 10 ºBrix (Hilaire y Mathieu, 2004). Es por ello que con el objetivo de incrementar el consumo se recomiendan valores de CSS > 10 ºBrix y de firmeza < 49 N (para variedades de recolección a partir de principios de julio), para no penalizar la calidad gustativa y satisfacer al consumidor (Hilaire y Giauque, 1994; Hilaire y col., 2000). En cuanto a la relación de contenido en sólidos solubles-acidez titulable (CSS:AT), una opinión general es que cuanto más alta sea la relación CSS:AT mayor será la aceptación del consumidor. Sin embargo, la misma relación CSS:AT se puede alcanzar con un CSS alto o un CSS bajo pero con una AT más baja. Así, AT baja puede compensar un CSS bajo obteniéndose la misma CSS:TA. Crisosto y col. (2003), sugirieron que la aceptación de consumidor de melocotón era más sensible a la relación

CSS:AT que al CSS, pero solamente dentro de una gama aceptable de AT y dependiendo de la variedad.

La calidad de melocotón y nectarinas se puede determinar mediante análisis químico y depende principalmente del contenido en compuestos tales como sacarosa, ácido cítrico y ácido málico, así como de carotenoides, lactonas, polifenoles y sustancias pécticas. El contenido en sólidos solubles y ácidos puede inducir cambios en la calidad, ya que los cambios sensoriales están a menudo relacionados con los cambios en la concentración de ácidos y azúcares. La composición en azúcares puede influenciar el dulzor del fruto, pero altos contenidos de azúcares no son sinónimo de frutos dulces debido a que el contenido de ácidos orgánicos en el equilibrio del fruto es muy importante en la percepción final que se tenga de este, por esto se ha establecido que la aceptabilidad del consumidor está relacionada con los contenidos de ácidos y azúcares, y el ratio entre estos (Iglesias y Echeverria, 2009). Génard y col. (1994), notaron que la sacarosa estaba estrecha y positivamente correlacionada con el ácido málico, pero negativamente correlacionada con el ácido cítrico en melocotones. También determinaron una correlación negativa entre el ácido málico y el ácido cítrico. Génard y col. (1999) y Wu y col. (2003), establecieron que existe una elevada correlación entre la glucosa y la fructosa, pero detectaron una menor relación entre el ácido málico y el ácido cítrico.

La firmeza de la pulpa es un indicador básico de la calidad de melocotón y nectarina, así mismo se considera como el mejor indicador del potencial de vida útil (conocido como “shelf life”) en melocotones y nectarinas. Los valores que se obtienen de firmeza proporcionan una alta información del estado de madurez del fruto y deben

mantenerse entre unos valores óptimos desde la cosecha hasta el consumo; estos valores deben ser reforzados por otras medidas tanto sensoriales como instrumentales (Fillon y Kilcast, 2002). Según Crisosto y col. (2001) frutos con firmeza por debajo de 27 N son susceptibles a daños durante la manipulación en poscosecha. De este modo, los frutos fueron clasificados según su firmeza en frutos "ready to buy", aquellos que alcanzan valores de firmeza entre 26,5 y 35,3 N y frutos "ready to eat" con valores de firmeza entre 8,8 y 13,2 N (Crisosto y Labavitch, 2002). Se podría indicar entonces que el final de la maduración está determinado por los valores de firmeza. Crisosto (2002), sugiere transferir tanto melocotones como nectarinas a los puntos de venta antes de que estos hayan alcanzado el estado denominado como "ready to buy", de esta manera se logrará reducir los potenciales daños físicos que se producen desde los almacenes a las tiendas de venta al por menor y a su vez durante la manipulación en estas últimas. En melocotones y nectarinas la firmeza de la pulpa disminuye lentamente desde el comienzo de la maduración para posteriormente sufrir una pérdida de firmeza más rápida. Nuestro grupo en experiencias previas con melocotones `Royal Glory®´ y nectarinas `Big Top®´ estableció correlaciones de determinados compuestos volátiles aromáticos con parámetros de madurez como son la acidez titulable (AT) y la firmeza, estos resultados posibilitan la determinación de frutos inmaduros y maduros por métodos no destructivos (Lavilla y col., 2002).

El color de fondo de la piel de un fruto es uno de los parámetros que los consumidores utilizan para identificar su estado de madurez ya que es de fácil medida (Wills y col., 2007). Sin embargo, la obtención de nuevas variedades de melocotón y nectarina completamente coloreadas dificulta esta determinación visual de la madurez. Es conocido que el color se debe cambios bioquímicos, como la degradación de la

clorofila por acción de la enzima clorofilasa (Dangl y col., 2000), que en las variedades de pulpa amarilla, provocan la presencia de otros pigmentos como los carotenoides. Tanto en melocotón como en nectarinas la concentración de clorofilas tiende a descender con la maduración, dando paso a un aumento en el contenido de carotenos, flavonoides y antocianos. El resultado de estos constituyentes son el cambio de color de la piel y pulpa, y coloraciones amarillo-rojizas. La rapidez de este cambio dependerá de la variedad y condiciones ambientales teniendo en cuenta que el color del fruto está influenciado por el estado de madurez. Entre las coordenadas usadas para medir el color, los valores de a* parecen ser los mejores indicadores de cambios de color durante la madurez tanto en melocotones como nectarinas, mientras que los valores L*, b*, hue y el croma cambian ligeramente. A medida que avanza la madurez, los valores de a* en variedades como `Dixieland´ y `Flameme Prince´ incrementaron, del mismo modo los valores de L* y b* no cambiaron significativamente (Nunes y Emond 2002). Melocotones y nectarinas en menor estado de madurez muestran un gran incremento en valores de a* durante el periodo de almacenamiento (particularmente frutos almacenados a 20 ºC), en comparación con frutos de mayor estado de madurez (Nunes y Emond, 2002).La variedad de melocotón `Flame Prince´ almacenados durante 7 días a 5 °C muestra pocos cambios en el color de fondo respecto a la misma variedad conservada a temperaturas más altas (Shewfelt y col., 1987; Nunes y Emond, 2002).

En relación con algunas alteraciones fisiológicas que afectan a melocotones y nectarinas, se puede decir que su aparición es debida al efecto de la temperatura de almacenamiento. El control de la temperatura es una de las principales herramientas utilizadas para reducir el deterioro poscosecha de frutas. Sin embargo, la aparición de los desórdenes fisiológicos conocidos genéricamente con el nombre de daños por frío se

debe principalmente al uso de un rango de temperatura que varía entre 2,2 y 7,8 ºC durante la conservación frigorífica (Crisosto y Labavitch, 2002). Según Lill y col. (1989) y Lurie y Crisosto (2005) los daños por frío en melocotones y nectarinas son conocidos también con el nombre genérico de descomposición interna ("internal breakdown").

1.2.2 Características aromáticas

En la fruta, el aroma es una compleja mezcla de un gran número de compuestos volátiles cuya composición es específica de cada especie y variedad (Sanz y col., 1997). La formación de estos compuestos es un proceso dinámico, ya que su biosíntesis es continua a lo largo del crecimiento y maduración del fruto, así la composición volátil cambia cuantitativa y cualitativamente. Las concentraciones de los compuestos volátiles en melocotones y nectarinas dependen esencialmente del grado de madurez de los frutos (Bayonove, 1973; Bayonove, 1974; Engel y col., 1988a,b; Meredith y col., 1989; Horvat y col., 1990b; Chapman y col., 1991; Visai y col., 1997; Lavilla y col., 2001). Estudios realizados sobre los compuestos volátiles en distintas variedades de melocotón y nectarina han identificado aproximadamente 100 compuestos, incluidos alcoholes, aldehídos, alcanos, ésteres, cetonas, lactonas y terpenos (Jennings y Sevenant, 1964; Sevenant y Jennings, 1971; Maga, 1976; Horvat y Chapman, 1990; Visai y Vanoli, 997; Derail y col., 1999; Aubert y col., 2003; Riu-Aumatell y col., 2004, 2005; Wang y col., 2009; Eduardo y col., 2010).

El aroma no está determinado sólo por los compuestos presentes en mayores proporciones en el fruto, dado que para poder contribuir al aroma del fruto la

concentración de un compuesto debe ser superior a su umbral de percepción (Buttery, 1993).Cada compuesto volátil está caracterizado por un umbral olfativo (que varía de ppb a ppm), dependiendo del cual (además de la concentración en que es emitido dicho compuesto) un compuesto contribuye más o menos al aroma. Las lactonas juegan un papel importante en el aroma del melocotón: γ- y δ-decalactonas y γ- y δ-dodecalactonas representan los compuestos impacto, pero ellos actúan en asociación con otros volátiles, como C_6-aldehídos, alcoholes y terpenos, los cuales son responsables del aroma fresco, floral y afrutado característico del melocotón (Spencer y col., 1978; Engel y col., 1988a; Rizzolo y col., 1995).En melocotones inmaduros, C_6-aldehídos y alcoholes (hexanal, *trans*-2-hexenal, hexanol, *trans*-2-hexenol) son los compuestos mayoritarios. Sin embargo, durante la maduración la concentración de estos compuestos disminuye y aumenta la concentración de γ-decalactona, δ-decalactona y linalool, alcanzando las mayores concentraciones en frutos maduros (Engel y col., 1988b; Horvat y Chapman, 1990a; Robertson y col., 1990a; Chapman y col., 1991).Además, los cambios en la composición aromática durante la maduración una vez el fruto es recolectado han sido motivo de estudios los últimos años. Aubert y col., 2003, trabajando con nectarinas de pulpa blanca y amarilla, analizaron los cambios producidos en los compuestos volátiles durante la maduración en árbol y una vez recolectados. En ambos casos, las lactonas presentaron mayores concentraciones en los frutos madurados tras su recolección con respecto a los correspondientes en el árbol. Además, las variedades de carne blanca presentan una concentración significativamente mayor en δ-decalactona que aquellos frutos de pulpa amarilla.

El perfil de compuestos volátiles en melocotón es dependiente de la variedad (Engel y col., 1988a; Horvat y col., 1990), de factores agronómicos (Derail y col., 1999;

Sumitani y col., 1994), de las condiciones de almacenamiento (Robertson y col., 1990a), del estado de madurez y/o de las condiciones de madurez (Aubert y col., 2003; Lavilla y col., 2001). La importancia de cada compuesto volátil dentro del perfil aromático depende de la actividad de las enzimas implicadas y de la disponibilidad del substrato (Sanz y col., 1997). Los compuestos volátiles que en mayor proporción contribuyen al aroma del fruto son sintetizados a partir de los lípidos, aminoácidos y carbohidratos siendo los ésteres la fracción mayoritaria en melocotón y nectarina (Wang y col., 2009). La biosíntesis de ésteres volátiles durante la maduración de los frutos climatéricos está bien establecida (Sanz y col., 1997). No obstante, los factores que controlan la composición tanto cualitativa como cuantitativa en el perfil de ésteres no están totalmente determinados. Varios estudios demuestran que el descenso en la capacidad de sintetizar ésteres a lo largo del periodo de permanencia a 20 ºC se podría atribuir a una reducción en la disponibilidad de sustrato (Robertson y col., 1990a; Ortiz y col., 2009; Ortiz y col., 2010; Zhang y col., 2010).

Las vías de biosíntesis de compuestos volátiles han sido objeto de estudio por su contribución al aroma (Croteau y Karp., 1991). La gran mayoría de compuestos volátiles son originados a partir de ácidos grasos saturados e insaturados, formados por β-oxidación y a través de la ruta de la lipoxigenasa (Schawab y Schreier, 2002). Entre las moléculas aromáticas obtenidas a partir de los ácidos grasos, están las γ-y δ-lactonas que son de gran interés en melocotones y nectarinas (Figuras 3-4). Las lactonas de mayor contribución aromática suelen ser de 10-12 átomos de carbono, por poseer umbrales de percepción menores respecto a las de menor número de átomos de cabono (Engel y col., 1988b). Además, sus concentraciones de incrementan significativamente durante los estadios finales de la maduración de melocotones y nectarinas (Engel y col.,

1988a, b; Horvat y col., 1990; Horvat y Chapman, 1990; Chapman y col., 1991; Wang y col., 2009).

Las aplicaciones de diferentes disciplinas científicas en el campo de la biosíntesis de compuestos volátiles han permitido la identificación de nuevas rutas metabólicas. La correlación de estos conocimientos con los que se dispone a nivel molecular ha permitido caracterizar la proteína utilizada en la ruta de biosíntesis de compuestos de tipo éster (Pérez y col., 1993), identificar el gen que controla la síntesis de algunos ésteres (Aharoni y col., 2000) y proponer al acetato de cis-3-hexenilo como un posible marcador genético para el aroma de melocotón (De Santis y Mencarelli, 2001). La utilización de la biología molecular, aplicada para estudiar la biosíntesis de compuestos volátiles aromáticos en frutas es considerada como una herramienta de gran utilidad en el futuro (Friedman y col, 2005).

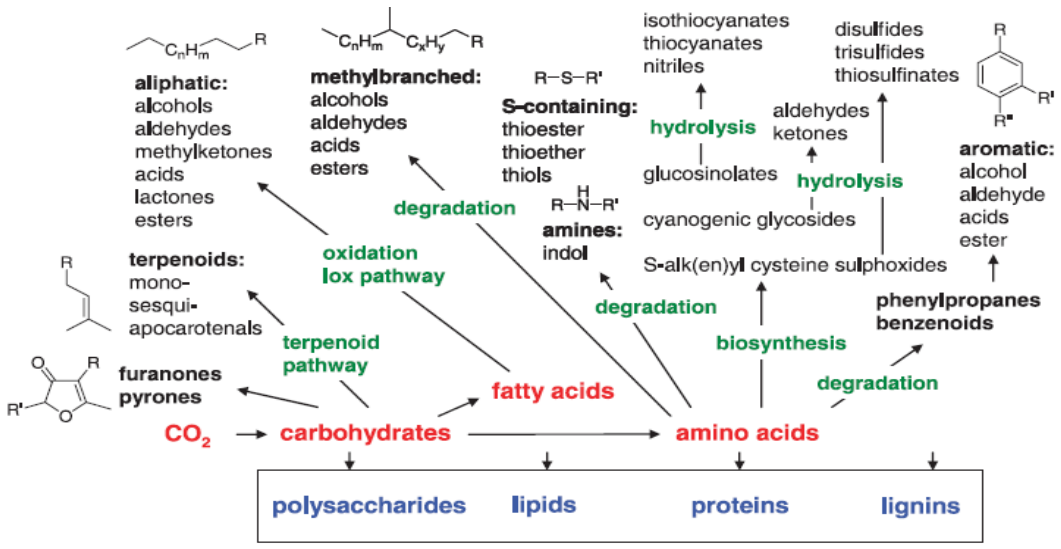


Figura 3. Producción de compuestos volátiles y sus rutas metabólicas (Schwab y col., 2008).

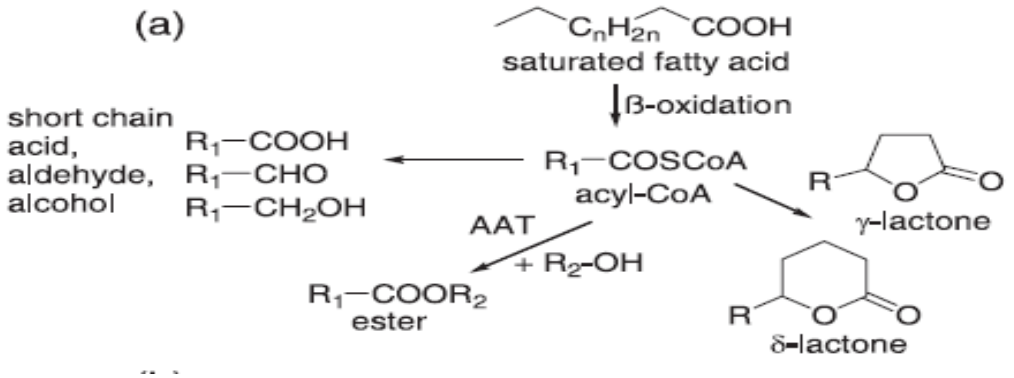


Figura 4. Biosíntesis de ácidos de cadena corta, aldehídos, alcoholes, ésteres y lactonas (Schwab y col., 2008).

Existen diversos métodos de extracción y cuantificación de compuestos volátiles en melocotones y nectarinas. La extracción líquido-líquido se utiliza como método de extracción directa en el que la muestra líquida y disolvente orgánico, y posterior separación de éste por destilación a vacío. Esta técnica es la más antigua y su utilización se justifica por la mayor extracción de lactonas con respecto los métodos de extracción por espacio de cabeza (Takeoka y col., 1988). La técnica de micro-extracción en fase sólida permite el análisis semi-cuantitativo de compuestos volátiles, este método se ha convertido en uno de los métodos de extracción de compuestos aromáticos volátiles más utilizados en manzana, melocotón, nectarina y albaricoque, debido a su corto tiempo de extracción, sencillez, alta selectividad y sensibilidad (Arthur y Pawliszyn, 1990). El método de extracción por espacio de cabeza, tanto dinámico como estático es la técnica de extracción que mejor preserva las condiciones iníciales del fruto. Además, es probablemente uno de los métodos de muestreo en fase gaseosa más ampliamente empleados, como consecuencia de su flexibilidad tanto en volumen de muestra, como en el número de posibles trampas y material que permitan optimizar los diferentes problemas sometidos a estudio.

En los últimos años, se están desarrollado nuevas tecnologías que consigan predecir la calidad del fruto y de algún modo permitan explorar la información de la última etapa de maduración de la fruta. En la última década, los estudios llevados a cabo en relación con los sistemas de olfato electrónico han abierto un nuevo camino para hacer esto posible (Burtlett y col., 1997). Los trabajos llevados a cabo en este sentido se han enfocado en monitorear los componentes volátiles de las frutas, proporcionando información a tiempo real. Estos sistemas de olfato electrónico están equipados con un conjunto de sensores, específicos de amplio espectro, con los que se intenta imitar la percepción olfativa humana y al mismo tiempo proporcionan una huella digital de los compuestos volátiles que puedan ser analizados finalmente con un software apropiado (Shaller y col., 1998). Hay un creciente interés no sólo en el desarrollo de sensores electrónicos cuyas mediciones se puedan relacionar con algunas características de calidad del fruto en la etapa de madurez y/o deterioro, sino también para detectar la presencia de frutos podridos en cámaras de frío o en líneas de envasado, ya que la presencia de hongos o los daños causados por insectos y/o manipulación del fruto producen un aumento significativo de la emisión de algunos compuestos volátiles (Molto y col., 1999). Otros equipos se han desarrollado en el fin de continuar con la detección a tiempo real de compuestos aromáticos, esto ha promovido el uso de equipos diseñados para medir la reacción de transferencia de protones en la detección de compuestos volátiles en plantas (Tholl y col., 2006).

Finalmente, el descubrimiento del genoma humano asociado al reconocimiento en los receptores humanos de los compuestos volátiles permitirá profundizar en nuestra comprensión de cómo los humanos perciben los compuestos volátiles, esto ampliará el

conocimiento sobre los olores y sabores que las frutas nos proporcionan (Zozulya y col., 2001).

1.2.3 Características sensoriales

Los diferentes agentes participantes en la cadena productiva y comercial (producción, manipulación y distribución) de frutas frescas, incluidos los melocotones y nectarinas, tienen como objetivo final satisfacer al consumidor (Oude y Van Trijp., 1996; Pecore y col., 2002) y por tanto, buscan una decisión de compra favorable. Un atributo fundamental en la decisión de compra por parte del consumidor es la apariencia externa de la fruta, en la cual se incluyen el tamaño, el color y la forma particulares de cada variedad, así como la ausencia de defectos y la homogeneidad. La calidad sensorial de un fruto, se corresponde con aquella percibida por los sentidos (gusto, olfato, vista, tacto y oído) en el momento de su consumo y que es expresada en forma de diversos atributos sensoriales. Dichos atributos pueden agruparse en tres categorías principales: apariencia, sabor y textura. El aspecto exterior es el primer criterio de calidad y por tanto, constituye el objetivo básico de los programas de mejora genética de melocotón. Sin embargo, no es suficiente para garantizar la satisfacción del consumidor y el consumo. Los atributos sensoriales de calidad y el valor nutritivo en melocotones y nectarinas juegan un papel importante en la satisfacción de los consumidores y a su vez influyen en el consumo (Hudina y Stampar, 2000). La calificación sensorial de la fruta por parte de panelistas entrenados y su correlación con las medidas físicas de las propiedades de la fruta nos permiten evaluar la calidad de la fruta (Aubert y col, 2003; Sturm y col, 2003). El sabor, la textura y la apariencia se consideran en general como los atributos sensoriales más importantes. El sabor engloba componentes relacionados

con el olor y el gusto. En el caso de melocotón y nectarina incluye los compuestos volátiles aromáticos característicos de estas especies y los gustos dulce y ácido que vienen dados principalmente por los contenidos de azúcares y ácidos orgánicos. El gusto está relacionado con los compuestos solubles en agua. El dulzor es atribuible a lo monosacáridos y disacáridos. La acidez está vinculada a ácidos orgánicos y al pH (Shepard y col., 1993).

La evaluación sensorial mediante paneles entrenados ofrece la posibilidad de obtener la descripción de un perfil completo de la fruta, siendo este a su vez válido para la comparación de productos, la vigilancia de la vida útil y la predicción de la aceptación por parte del consumidor. Crisosto y col. (2006), evaluaron sensorialmente distintas variedades de melocotón y nectarina, los atributos sensoriales analizados fueron el dulzor, la acidez, el aroma y el sabor. En este mismo año, Pedrieri y col. (2006) realizaron una evaluación sensorial más detallada en la cual se incluyeron diversas características tales como firmeza, jugosidad, dulzor, acidez, aroma y astringencia. El dulzor es conocido como uno de los rasgos más importantes de la calidad del melocotón y su percepción está relacionada con el contenido en sólidos solubles y con la acidez titulable. Respecto a la acidez se sabe que también afecta al grado de satisfacción del consumidor de melocotones y nectarinas, mientras que la astringencia no es un atributo a destacar en melocotón y se considera como una característica sensorial negativa, indicando de alguna manera un estado inmaduro en los frutos (Ozawa y col., 1987). Robertson y col. (1989) determinaron que la astringencia obtuvo una baja correlación con el sabor a melocotón (en las variedades `Bailey´ y `Boone Country´). La astringencia es una percepción sensorial muy compleja que en algunas ocasiones muestran ciertas interacciones con la acidez (Lawels y col., 1996, Thomas y Lawless, 1995). Pedrieri y col. (2006), determinaron que las variedades `Big

Top®´ y `Royal Glory®´ tienen una alta correlación lineal entre el gusto y la astringencia. Estudios realizados por Cascales y col. (2005) determinaron la calidad sensorial del melocotón `Catering´ durante la maduración y identificaron diferencias significativas entre los diferentes grados de madurez. Entre las características sensoriales más importantes, la intensidad de sabor y dulzor se incrementó significativamente entre frutos maduros y semi-maduros y luego disminuyó al llegar a la madurez total; de este modo se determinó para esta variedad cual era el momento más adecuado para la recolección y el consumo. El perfil sensorial del melocotón semi-verde alcanzó resultados óptimos en cuanto a la intensidad de aroma en la etapa que se recomienda para su cosecha comercial, ya que los melocotones siguen madurando hasta el momento del consumo. Colaric y col. (2005) estudiaron los atributos sensoriales y composición química de nueve variedades diferentes de melocotón y nectarina, y encontraron interesantes correlaciones entre los parámetros sensoriales y los bioquímicos. Entre los resultados más destacados se determino que la percepción de dulzor estaba influenciada por la cantidad de ácido cítrico, ácido shiquímico y la relación entre azúcares/ácidos orgánicos; el aroma percibido correlacionó con la concentración de ácidos orgánicos totales, sacarosa, sorbitol y ácido málico. El sabor entonces se relaciona con el valor obtenido entre ácido málico/cítrico, azúcares totales, sacarosa, sorbitol y ácido málico. Crisosto y col. (2006), también utilizó la evaluación sensorial, mediante un panel entrenado, para establecer los índices mínimos de calidad en 49 cultivares (23 melocotones y 26 nectarinas). Los datos obtenidos de este trabajo fueron sometidos a análisis de componentes principales, y con ellos se lograron clasificar las variedades en grupos según sus características sensoriales. El enfoque de este estudio podría ser de ayuda en los programas de mejora genética de selección de nuevas variedades. La evaluación sensorial ha permitido dilucidar que existe una

relación entre el contenido de ácido málico y el grado de satisfacción o de aceptación obtenido por parte del consumidor (Monet., 1979). Así, la variedad `María Dolce´ (nectarina sub-ácida) presentó una mayor aceptabilidad por parte del consumidor que la variedad `Venus®´ (nectarina ácida) (Infante y col., 2006). Los genotipos sub-ácidos son interesantes porque pueden ser cosechados en etapas más tempranas de maduración, asegurando un precoz y adecuado balance en la relación azúcar/ácidos orgánicos junto con la firmeza de la pulpa adecuada para soportar la manipulación y el transporte.

En un estudio realizado por Bassi y Selli (1990), en el cual se analizó el contenido en azúcares totales, ácidos y compuestos fenólicos, así como se determinaron distintos atributos sensoriales, se logró clasificar variedades de melocotón y albaricoque en grupos según las características analizadas. Estim y col., (1997) determinaron las relaciones entre algunas características químicas analizadas en melocotón y nectarina, y sus correspondientes medidas o atributos sensoriales. Así, determinaron que el contenido en ácido málico, ácido cítrico y el pH se correlaciona bien con la percepción sensorial de la acidez. También se sugirió que las mediciones de acidez titulable y sólidos solubles no podían ser sustituidas por la evaluación sensorial de dulzor y acidez.

Es importante destacar la importancia que tiene el estado de madurez como uno de los factores más determinantes en la calidad final percibida por el consumidor. A su vez, el estado de madurez de melocotones y nectarinas en el momento de la recolección tiene una influencia concluyente en su posterior conservación frigorífica y en la calidad sensorial final. Esto es debido, al hecho que el sabor final del fruto, el cual es combinación de gustos y aroma, varía a lo largo de la maduración (Taylor y col., 2004). Por ello, se hace fundamental el control adecuado de la evolución de estos atributos o parámetros sensoriales que configuran la percepción general del sabor. La integración

de esta información sensorial en el cerebro deriva en un deseo o por el contrario genera una aversión en el consumidor, el cual decide si continuar o no con la masticación del fruto y por consiguiente marca su posterior comportamiento de compra. El dulzor es uno de los atributos sensoriales más decisivos en frutos de melocotón y nectarina y su percepción está correlacionada con la relación CSS/AT, así como también con algunos compuestos volátiles (Ortiz y col., 2009). La relación entreestos factores es exclusiva y específica de cada variedad, así que no hayun umbral únicofiable que garantice la satisfacción del consumidordetodas las variedades.

Las pruebas de aceptación realizadas con consumidores nos proporcionan la información necesaria para identificar cuáles son sus preferencias, y nos permiten establecer los índices mínimos de calidad (Crisosto y col., 2003). Una de las posibles causas del bajo consumo de melocotón y nectarina es la baja calidad de sus frutos especialmente debida a una ausencia de sabor y a una alta dureza de la pulpa, ambos asociados con recolecciones demasiado tempranas cuando el fruto es todavía inmaduro (Crisosto y Crisosto, 2005). Crisosto y Labavitch (2002) compararon dos variedades de melocotón ácidas y dos no ácidas e indicaron que el grado de aceptación por parte de los consumidores aumentó de manera constante con la maduración del fruto a la vez que aumentaba el contenido en sólidos solubles. Como la evolución del contenido en sólidos solubles es dependiente de la variedad, podemos decir que el índice mínimo de calidad también será específico de la variedad, y no estará únicamente basado en un parámetro. La utilización de paneles entrenados, que nos describan los perfiles sensoriales de la fruta, nos permitirá ofrecer frutos con mayor calidad al consumidor. El uso adecuado de las técnicas de análisis sensorial puede proporcionarherramientas para una mejorcomprensión de la influenciade los atributos sensoriales en la aceptación y

preferencias del consumidor, así mismo, el conocimiento de los atributos sensoriales nos proporciona una información completa y nos permite identificar características peculiaresde cada variedad, pudiendo así orientar cada una de estas a un tipo determinado de consumidor (Infante y col., 2008).

Para conocer el grado de satisfacción de un consumidor se utilizan pruebas hedónicas. La aplicación de estas pruebas puede parecer rutinaria, sin embargo, si queremos obtener datos significativos debemos realizar un planteamiento complejo y riguroso (Sancho y col., 1999). Desglosando el fundamento de la escala hedónica podríamos decir que detodas las escalas ymétodos de cata utilizando consumidores, la escalahedónicade nueve puntosocupaun lugar únicoen términos de suaplicabilidad general en cuanto a la medición de la aceptación y preferencia de un alimento. Esta escala fue desarrollada y descrita en detalle por Jones y col.(1955) y Peryam y Piligrim (1957) como partede un esfuerzo para evaluarla aceptabilidad de los alimentos militares, estos investigadores ensayaron un número diferente de escalas de longitud yvariadonúmero de categorías, así como la selección delas palabras má sadecuadas para ser utilizadas como referencias a lo largo de la categoría. Esta investigación arrojó una escala de nueve puntos o categoría y los estados para cada uno de ellos.Estas investigaciones demostraronla fiabilidad y la validez de la escala en un grado que ha sido especialmente satisfactorio. De especial valor ha sido la estabilidad de las respuestas y la medida enque dichos datos podrán ser utilizados como punto de referencia sensorial para cualquier categoría de producto alimenticio en particular.

Si bien es cierto que los consumidores pueden expresar una opinión y finalmente inclinarse por lo que más preferencia les merece, no necesariamente han de entender el

por qué prefieren una variedad frente a otra. El análisis descriptivo sensorial mediante paneles entrenados utiliza palabras específicas y escalas definidas para expresar las diferencias entre diferentes productos a evaluar. Tanto el panel de consumidores como el panel entrenado son dos herramientas muy importantes que nos ayudan a dilucidar las preferencias del consumidor y a conocer el porqué de esas preferencias. Por todo lo expuesto, el análisis sensorial ha sido utilizado para evaluar la calidad de melocotones y nectarinas para mejorar la calidad de melocotones y nectarinas destinadas tanto para consumo interno, como para la exportación (Infante y col., 2007). Shewfelt (1999) identificó la necesidad de profundizar en la investigación dela calidad poscosecha de los frutos, para poder determinar claramente las preferencias del consumidor en relación con la calidad externa e interna del fruto.

Parasatisfacer las expectativasde los consumidores, los frutos debenproporcionanunas buenas característicasorganolépticas, además de cumplir con los requerimientos de seguridady aportar un alto valor nutricional (Stefani y col., 2006).La demanda defruta de alta calidad, asegura que se proporcionen alimentos saludables, de alto valor nutricional y de buen sabor, esto pone de relieve la portancia de la utilización del análisis sensorial a lo largo de toda la cadena de comercialización desde la cosecha hasta el consumidor.

1.3 Tecnología de la conservación

La presencia de nuevas tipologíasde fruto ha obligado aponer a prueba el potencial de conservación poscosecha de diferentes variedades de melocotón y nectarina con el objetivo de proporcionar fruta de calidad que incremente la satisfacción del

consumidor. Es fundamental conocer su tolerancia a la poscosecha y a los requerimientos de la industria frutícola. Siendo así, aquellas especies o variedades con mayor potencial de conservación o más tolerantes a la conservación frigorífica serán de gran utilidad. En general, las variedades de nectarina son menos susceptibles a sufrir daños por frío que las variedades de melocotón (Retamales y col., 1992; Lurie y Crisosto2005; Crisosto, 2006). Entrelas variedades de melocotón, las variedades de pulpa fundente "melting"son más susceptibles adaños por frío que las variedades de pulpa más firme "non-melting" (Brovelli y col.,1999; Crisostoy col, 1999a). Las variedades de cosecha tardía presentan un mayor deterioro de la calidad debido a que están más expuestas a enfermedades fúngicas. Cuando los frutos se destinan a mercados distantes, deben ser cosechados con mayores valores de firmeza, para soportar la manipulacióndurante el embalajey el transporte. En muchos casos eso conduce a una recolección de los frutos demasiado temprana, cuando los frutos todavía no han desarrollado totalmente su sabor (Vendrell yCarrasquer, 1994). Pensando en esto, para mantener la calidad de la fruta una buena opción sería retrasarla cosecha hasta la maduración fisiológica completaen el árbol (Bonghi y col., 1999). Es decir, la cosechadebe ser realizada justoantes de que las frutasalcancen su climaterio ya que de esta manera los cambios metabólicos de la maduración se producirán durante la poscosecha (Pretel y col., 1993). Debido a las necesidades anteriormente mencionadas la tecnología de conservación juega un papel fundamental. Así para controlar el potencial poscosecha de distintas variedades de melocotón y nectarina deberemos conocer y controlar la temperatura, la atmósfera gaseosa y el periodo de conservación frigorífica. Respecto a la temperatura de conservación, el almacenamiento en frío representa una primera alternativa para prolongar la vida comercial de melocotones y nectarinas. Otra técnica de conservación frigorífica que nos permite alargar la

conservación de melocotones y nectarinas, minimizando el deterioro de su calidad, es el almacenamiento en atmósferas controladas (AC), la cual combina distintas concentraciones de O_2 y CO_2 y actualmente se utiliza a nivel mundial en una amplia variedad de frutos frescos y verduras. Otra estrategia seguida para intentar mejorar la calidad poscosecha de melocotones y nectarinas es la pre-maduración o pre-acondicionado a 20 ºC durante un periodo determinado previo o posterior a la conservación. Con su aplicación se intenta que continúe el proceso de maduración del fruto y evita, en gran medida, el desarrollo de algunas fisiopatías clasificadas como daños por frío, especialmente en aquellas variedades más susceptibles.

En España, el incremento de superficie plantada con nuevas variedades de melocotón y nectarina en los últimos años ha hecho necesario destinar una gran parte de su producción al almacenamiento durante periodos más largos, para así poder regular mejor su comercialización. Todo esto nos obliga a realizar estudios más detallados de conservación frigorífica de melocotones y nectarinas, para proporcionar al sector productivo y comercial de herramientas necesarias para alargar el periodo de comercialización sin que ello implique una pérdida de calidad del fruto.

1.3.1 Almacenamiento frigorífico en atmósfera normal

Para reducir la velocidad de maduración de los frutos es muy eficaz el almacenamiento a bajas temperaturas. La organización internacional para la estandarización (ISO), define como temperatura óptima de almacenamiento para melocotones y nectarinas el rango que varía entre -1 y +2 ºC, durante un almacenamiento de entre 2-4 semanas para la mayoría de variedades.

Estudios previos, Robertson y col. (1990a, b), Malakou y Nanos (2005) y Raffo y col., (2008), han establecido que el CSS en frutos almacenados en frío no presenta marcadas variaciones, los ligeros cambios detectados a lo largo del almacenamiento se asocian a la variabilidad biológica de los diferentes frutos. Sin embargo, la AT muestra un descenso en su concentración durante el almacenamiento. Existe poca información del efecto que tiene el almacenamiento en atmósfera de frío normal sobre el perfil de compuestos volátiles en melocotón y nectarinas (Robertson y col., 1990 a, b; Raffo y col., 2008). Raffo y col., (2008), en un estudio realizado en melocotones de pulpa blanca y amarilla sometidos a temperatura de 1 ºC y conservados durante 1 y 2 semanas más un día a temperatura ambiente, determinaron que los melocotones almacenados durante 2 semanas mostraron concentraciones totales de lactonas muy similares a las detectadas en cosecha. El efecto del almacenamiento en frío de aldehídos de seis átomos de carbono (C_6 aldehídos) fue variable. Un incremento en el tiempo de almacenamiento en frío tiende a reducir la capacidad de los frutos a producir algunos compuestos volátiles después de ser expuestos de nuevo a temperatura ambiente. Estos efectos son causantes de cambios en el aroma global de las variedades y por tanto pueden provocar una modificación cualitativa del sabor.

Como se ha mencionado previamente, el almacenamiento a bajas temperaturas es la forma más práctica para retardar el metabolismo y prolongar la vida comercial de las frutas. Las bajas temperaturas disminuyen la actividad enzimática y microbiana, reducen el ritmo respiratorio (conservando las reservas que son consumidas en este proceso), retardan la maduración y disminuyen el déficit de presión de vapor entre el producto y el ambiente reduciendo la transpiración (Martínez-Jávega, 1995). La respiración y la síntesis de etileno se reducen cuando los frutos están expuestos a bajas

temperaturas. También se ve reducida la actividad de las enzimas hidrolasas de la pared celular, lo que retrasa el ablandamiento del fruto. Sin embargo, uno de los principales problemas durante el almacenamiento refrigerado de melocotones y nectarinas es la aparición de una serie de desórdenes fisiológicos conocidos genéricamente con el nombre de daños por frío. Según Lill y col., (1989) y Lurie y Crisosto (2005) los daños por frío en melocotones y nectarinas, se caracterizan por provocar dos tipos de desórdenes. Los primeros son desórdenes texturales; entre estos se destacan síntomas conocidos como lanosidad ("woollyness") o harinosidad ("mealiness") (Von Mollendorf, 1987). La harinosidad se desarrolla en la fruta almacenada entre 2 y 8 °C. A este rango de temperatura de conservación también se puede desarrollar pulpa coriácea, también conocido como cuerosidad ("leatheriness"), que provoca una pérdida de la capacidad de ablandar normalmente cuando la fruta regresa a temperaturas normales (Luza y col., 1992). Los segundos son los desórdenes en la coloración de la pulpa, se destacan el pardeamiento de la pulpa o de la cavidad del hueso y la propagación de pigmentos antocianinas a través de la carne (enrojecimiento o sangrado) (Lurie y Crisosto, 2005). Debe tenerse en cuenta que cuando se prolonga el almacenamiento en frío, mantener la capacidad de la fruta para producir etileno puede ser crucial para prevenir los daños por frío y desórdenes fisiológicos (Dong y col., 2001; Zhou y col., 2001). Ben Arie y Sonego (1980) encontraron que el metabolismo de las pectinas fue anormal en melocotones almacenados en frío, dando lugar a la formación de un gel cuando las pectinas solubles se mezclan con agua. La viscosidad de la pectina soluble en melocotones conservados en frío fue superior a la de los melocotones sin conservar. La intervención del agua en la formación de geles de pectina puede explicar la reducción del jugo y consecuentemente la textura harinosa de la fruta. La incidencia de harinosidad depende de factores genéticos y del estado de madurez. Fernández-

Trujillo y col., (1998) encontraron que los frutos menos maduros son más susceptibles a la harinosidad. En general, la susceptibilidad a la harinosidad es menor para variedades tempranas respecto a variedades tardías. De acuerdo con este patrón aquellas variedades de maduración lenta serán más susceptibles a la harinosidad (Brecht y col., 1984; Kader y Chordas, 1984).

Con el objetivo de mejorar o solucionar estos daños provocados por la conservación de los frutos de melocotón y nectarina en un rango de temperatura de 2-8 ºC, se han llevado a cabo numerosos estudios, con resultados no siempre coincidentes, tratando de encontrar las bases de estos desórdenes (Ben Arie y Lavee, 1971; Buescher y Furmanski, 1978; Ben Arie y Sonego, 1980; Von Mollendorff y de Villiers, 1988; Von Mollendorff y col., 1989; Dawson y col., 1992; Von Mollendorff y col., 1993; Lurie y col., 1994; Artés y col., 1996; Obenland y Carroll, 2000; Zhou y col., 2000a,b; Jarvis y col., 2003; Lurie y col., 2003; Vincken y col., 2003).

Entre las alternativas que se han ido desarrollando para reducir la incidencia de daños por frío en melocotones cabe resaltar, el uso de variedades menos sensibles al desorden (Crisosto y col., 1999a; Lurie y Crisosto, 2005; Murray y col., 1994), la utilización de un pre-acondicionado a temperatura de 20 ºC previo al almacenamiento frigorífico (Guelfat-Reich y Ben Arie, 1966; Scott y col., 1969; Zhou y col., 2000b), el calentamiento intermitente (Ben Arie y col., 1970; Lill, 1985; Fernández-Trujillo y Artés, 1997), la conservación en atmósferas controladas y modificadas (Retamales y col., 1992; Streif y col., 1992) y finalmente el uso de pre-tratamientos de estrés térmico (Budde y col., 2002; Murray y col., 2007).

1.3.2 Almacenamiento frigorífico en atmósfera controlada

El almacenamiento refrigerado es una de las principales herramientas utilizadas para retrasar el deterioro posterior a la cosecha de melocotones y nectarinas, este procedimiento sumado al uso de atmósferas controladas (AC), especialmente con bajas concentraciones de O_2 y altas concentraciones de CO_2, ha resultado ser particularmente efectiva para limitar la incidencia de daños generados por el almacenamiento en frío y para alargar el periodo de vida comercial (Murray y col., 2007; Roig y col., 2003; Streif y col., 1992).

Las ventajas del uso de las atmósferas controladas en las cámaras de conservación han sido ampliamente demostradas en una amplia variedad de frutas y hortalizas, pero las implicaciones económicas de su uso a menudo han limitado su aplicación comercial. Sin embargo, los avances tecnológicos, equipos de control más precisos y la reducción de costos, ha permitido que el almacenamiento en AC se utilice comercialmente para una gama creciente de cultivos.

La tecnología AC consiste en una modificación de la atmósfera presente en las cámaras de almacenamiento, disminuyendo la concentración de O_2 y aumentando la concentración de CO_2 en comparación con la atmósfera normal. Esto conjuntamente con las bajas temperaturas busca alargar el periodo de almacenamiento y mantener la calidad de melocotones y nectarinas. El almacenamiento en AC ha sido objeto de una gran cantidad de estudios bioquímicos, fisiológicos y tecnológicos en fruta de pepita, pero existen pocos estudios que analicen la influencia de su aplicación en melocotón y nectarina.

El efecto de la conservación de melocotones y nectarinas en AC sobre la calidad varía dependiendo de la especie y variedad, la concentración gaseosa de la atmósfera, la temperatura de conservación, el estado de madurez del fruto en cosecha, la presencia de etileno en el almacenamiento y de tratamientos de pre-almacenamiento. En relación con la distinta combinación gaseosa podemos decir que existe un efecto interactivo de los dos gases en la extensión de la vida de almacenamiento de un fruto. Thompson (1996) revisó los efectos de O_2 en las respuestas de poscosecha de frutas, verduras y flores, y encontró que una concentración baja de O_2en la atmósfera de conservaciónprovoca una reducción de la tasa de respiración y del sustrato para la oxidación, un retraso de la maduración de las frutas climatéricas, prolonga la vida de almacenamiento, retrasa la degradación de la clorofila, reduce la tasa de producción de etileno, modifica la síntesis de ácidos grasos, reduce de la degradación de la tasa de pectinas solubles, potencia la formación de sabores y olores indeseables, altera la textura y finalmente desencadena desórdenes fisiológicos. Del mismo modo, Thompson (2003), determinó algunos de los efectos del aumento de los niveles de CO_2 en las frutas y almacenadas observando que un aumento de la concentración de CO_2 provoca una disminución de las reacciones de síntesis en frutos climatéricos, retrasa la iniciación de la maduración, inhibe algunas reacciones enzimáticas, decrece la producción de algunos compuestos volátiles, modifica el metabolismo de algunos ácidos orgánicos, reduce el promedio de pectinas, inhibe el decaimiento de la clorofila, produce un aumento de olores indeseables, reduce los desórdenes fisiológicos, retarda el crecimiento fúngico, inhibe el efecto del etileno y retiene los niveles de decoloración.

Una reducción en la concentración de oxígeno y un aumento en la concentración de dióxido de carbono pueden retardar la maduración de los melocotones y, en algunos

casos, retrasar o prevenir la aparición de daños por frío (Lill y col., 1989). Con la menor disponibilidad de oxígeno molecular se produce una disminución en el metabolismo general de las células. Sin embargo, los grandes cambios no se producen hasta que el oxígeno está por debajo del 5%. El factor crítico es la concentración real de oxígeno en las células. La concentración de oxígeno interno es controlada por la resistencia de la pulpa a la difusión de oxígeno y el ritmo de la respiración. Los cambios en estos parámetros se deben a variaciones en la concentración de oxígeno externo óptimo requerido para generar los diferentes compuestos químicos. Debido a su sensibilidad a los daños por frío de algunas variedades de melocotones y nectarinas, estas deben ser almacenadas a temperaturas más altas que otras, lo que aumenta su tasa de utilización de oxígeno. Cuando la concentración de oxígeno es baja (1-5% de O_2) y/o mejoran las concentraciones de dióxido de carbono que se aplican a los melocotones, se puede retardar el ablandamiento, el desarrollo del color, la tasa de respiración y la reducción de producción de etileno (Smilanick y Fouse, 1989). Niveles de Oxígeno de 0,25% reducen la respiración en un 45%, la tasa de producción de etileno en más del 90% (Ke y col., 1991) y retrasan el aumento de la actividad del enzima poligalacturonasa (Lurie y Pesis, 1992). Las concentraciones de dióxido de carbono son importantes durante el almacenamiento a baja temperatura. Una atmósfera que contiene 5% de CO_2 puede retrasar la aparición de trastornos fisiológicos por la baja temperatura (Lill y col., 1989). Wade (1981) determinó que una concentración de CO_2 del 20% (sin reducción de O_2) efectivamente disminuyó la incidencia de desórdenes fisiológicos en la variedad de melocotón `J.H Hale´ conservada durante 6 semanas a 0 °C. Investigaciones posteriores han demostrado que sólo unas pocas variedades responden a altos niveles de dióxido de carbono (Uthairatanakij, 2004).

La conservación en AC altera la formación de compuestos volátiles. Así, en otras variedades se ha observado que la producción total de compuestos volátiles generalmente decrece a lo largo del almacenamiento en AC (Anderson y Penney 1975; Anderson., 1979; Ortiz y col., 2009). Sin embargo, es necesario recalcar que la mejor o peor efectividad de la aplicación de AC en la conservación respecto a la producción de compuestos volátiles depende de la composición de la atmósfera que se aplique, la duración del periodo, la temperatura de almacenamiento, la variedad y el estado de madurez del fruto en el momento de la recolección. Ortiz y col., (2009) determinaron que la conservación frigorífica de la variedad 'Rich Lady' bajo condiciones de AC (3 % O_2 + 10 % CO_2 a 2 ºC) y posterior almacenamiento a 20 ºC mejora la jugosidad de los frutos, incrementa la percepción de dulzor, aumenta la emisión de algunos compuestos volátiles, favorece la percepción del sabor y la aceptación sensorial en comparación con los frutos almacenados en atmósfera de frío normal.

La influencia del almacenamiento en atmósferas controladas sobre los compuestos volátiles se manifiesta de manera diferente según la procedencia de dichos compuestos. En general las atmósferas producen una disminución en la producción de acetatos de cadena lineal, que proceden del metabolismo de los ácidos grasos, las rutas de formación de estos compuestos son dependientes de oxígeno y, por tanto se verán afectadas por los niveles bajos de este gas en la atmósfera. En cambio los ésteres de cadena ramificada que proceden del metabolismo de los aminoácidos no resultan afectados negativamente por las atmósferas controladas. Los precursores de estos son producidos en las células por el ciclo de los ácidos tricarboxílicos, que a su vez, son inhibidos por altas concentraciones de dióxido de carbono (Frenkel y Patterson, 1973).

El almacenamiento de melocotones en atmósfera controlada, especialmente rica en dióxido de carbono, durante períodos prolongados puede causar el desarrollo de sabores desagradables y la acumulación excesiva de acetaldehído y etanol (Kader, 1986; Smilanick y Fouse, 1989). Tratamientos a corto plazo con bajos niveles de oxígeno, además de reducir la tasa de ablandamiento, inducen a una acumulación rápida de acetaldehído y etanol. Sin embargo, su concentración en el tejido de la fruta disminuye gradualmente cuando la fruta se transfiere a atmósfera normal. Almacenamientos a 4 °C producen mucho menos acetaldehído y etanol, estos compuestos se acumulan en almacenamientos a más de 20 °C. Fruta almacenada a una temperatura más baja es aparentemente menos sensible a las condiciones anaeróbicas en comparación con una temperatura más alta. Lurie y Pesis (1992) demostraron que cortos periodos de exposición a condiciones anaeróbicas (24 h) retardan el ablandamiento de melocotones. La aplicación de choques gaseosos con niveles ultra-bajos de oxígeno y CO_2 del 30% en un periodo máximo de 24 a 48 horas a 20 °C ha demostrado que mantiene la firmeza de la pulpa de melocotones (Bonghi y col., 1999). Este efecto se acompaña de una fuerte inhibición del etileno, especialmente en los frutos cosechados en las primeras etapas de maduración, cuando la producción de etileno endógeno es baja. Los niveles de O_2 por debajo del 1% o los niveles de CO_2 del 20% inducen la acumulación de acetaldehído y etanol en melocotones. Resultados de anaerobiosis prolongada derivan en excesiva acumulación de acetaldehído y etanol en el mesocarpio del melocotón (Tonutti y col., 1998).

1.3.3 Pre-acondicionado previo al almacenamiento frigorífico

La temperatura ideal de almacenamiento en frío de melocotones y nectarinas se sitúa entre de 0 °C a 1,7 °C, ya que mantener la fruta a esta temperatura reduce el ablandamiento, la desecación, la incidencia de los daños internos y la posible harinosidad. Sin embargo, durante el transporte y comercialización de los frutos muchas veces estos son sometidos a temperaturas entre 2 y 8 ºC, rango en el cual los frutos, especialmente aquellas variedades más sensibles, desarrollan una serie de síntomas previamente mencionados denominados daños por frío. Para evitar estos síntomas Crisosto y col. (1999b) desarrollaron una técnica conocida como pre-acondicionado.

En un sentido amplio, el tratamiento de pre-acondicionado es un tratamiento en el que se mantiene la fruta a temperaturas específicas (normalmente 20 ºC) antes de su almacenamiento en frío (Nanos y Mitchel, 1991). La mayoría de los investigadores que utilizan este término, o el de enfriamiento retardado o almacenamiento retrasado, se refiere a los tratamientos previos a la conservación frigorífica de entre 20 y 30 °C (Zhou y col., 2000a y Crisosto y col., 2004). El objetivo del pre-acondicionado es permitir que la fruta continúe con su proceso de maduración, a una temperatura compatible con la que tenía antes de la cosecha.

Esta técnica, que se define como "un nuevo enfoque a la gestión de la temperatura", se utiliza actualmente para retrasar los síntomas del decaimiento interno y sirve para pre-madurar melocotones y nectarinas, se ha introducido con éxito en las industrias frutícolas de California y Chile. Esta técnica, consiste en retrasar

aproximadamente 48 h la conservación en frío de melocotones y nectarinas, por lo que también es llamada enfriamiento controlado (Crisosto y col., 2004). Crisosto y col., 2004 desarrollaron un protocolo de aplicación de este pre-acondicionado que pretende que las variedades de melocotón y nectarina pre-acondicionadas lleguen a los centros de distribución con una firmeza media de entre 23 y 36 N (medida en el punto más débil del fruto, zonas ecuatoriales). Aplicando esta técnica se intenta proporcionar frutos con mejor textura y sabor. La gestión de la temperatura exacta en el proceso de pre-acondicionado implica un control más estricto de la firmeza del fruto en el momento de la cosecha y finalmente del tiempo aproximado que se deberá exponer la fruta a temperatura de 20 ºC antes de su conservación frigorífica, para así ofrecer un buen producto final a los consumidores. La medida de la firmeza en la zona ecuatorial es la herramienta ideal para determinar la etapa de maduración en que se encuentran los frutos, mientras que la firmeza medida en la posición más débil del fruto (hombro o sutura) está bien relacionada con el impacto potencial, el transporte, daños y perjuicios. La firmeza final de la fruta precisamente no certifica la ejecución correcta del proceso de pre-acondicionado.

El pre-acondicionado de la fruta de hueso se realiza con frecuencia a una temperatura de 20 ºC durante 1 ó 2 días después de la cosecha y antes de ser conservada a 0 ºC. Este tratamiento busca ampliar la vida comercial de melocotones y nectarinas (Anderson y Penney, 1975; Crisosto y Crisosto, 2005). Scott y col. (1969) indicaron que frutos almacenados a 20 ° C durante 2 días antes de su conservación durante 49 días a -0,5 °C reduce considerablemente la presencia de daños por frío. Zhou y col., (2000a), en un estudio realizado con la variedad de nectarina ‘Flavor Top’, también observaron una reducción de la presencia de daños por frío en aquellos frutos que habían permanecido

durante 2 días a 20 ºC antes de su conservación en frío a 0 °C durante 42 días. Crisosto y col. (2004) determinaron que la exposición de variedades de melocotón y nectarina, sensibles a daños por frío, a una temperatura de 20 ºC durante 48 horas fue el tratamiento más efectivo para aumentar la vida comercial de sus frutos sin causar deterioro alguno en la pulpa. Este tratamiento de pre-acondicionado permitió ofrecer frutos con una buena calidad de consumo hasta de 14 días en las variedades analizadas. Dado que esta técnica de pre-acondicionado supone una pre-maduración del fruto y por tanto, produce una ligera pérdida de peso y un ablandamiento de la pulpa (Girardi y col., 2005), es necesario controlar los cambios en la calidad del fruto que se puedan producir durante esta fase de pre-acondicionado. También es muy importante que el fruto que ha sido pre-acondicionado, antes de ser conservado en frío, sea enfriado muy rápidamente, ya que este enfriamiento rápido evitará problemas tales como ablandamiento de la pulpa, senescencia y pérdida de peso (Crisosto y Crisosto, 2005). La técnica de pre-acondicionado también puede ser usada para pre-madurar variedades, que aunque no sean sensibles a la presencia de daños por frío, hayan sido cosechadas en estados inmaduros. Con esta pre-maduración se podrán ofrecer al consumidor frutos con mejor sabor y una textura más adecuada (Crisosto y col., 2004). Los cambios físicos y químicos que se producen en los melocotones pre-acondicionados permiten mejorar la calidad de la fruta y consecuentemente incrementar el grado de aceptación del consumidor, ya que se evidencia como más jugosa, aromática y sabrosa (Crisosto y col., 2004).

1.4 Bibliografía

Aharoni, A., Keizer, L.C.P., Bouwmeester, . J., Sun, Z., Alvarez-Huerta, M., Verhoeven, H.A., Blasa, J., Van Houwelingen, A.M.M., De Vos, R.C.H., Van der Voet, H., Jansen, R.C., Guis, M., Mol, J., Davis, R.W., Schena, M., van Tunen, A.J., O´Connell, A.P. 2000. Identification of the SAAT gene involved in strawberry flavor biogenesis by use of DNA microarrays. *The Plant Cell* 12, 647–661.

Anderson, R.E., Penney, R.W. 1975. Intermittent warming of peaches and nectarines stored in a controlled atmosphere or air. *Journal of American Society of Horticultural Science* 100, 151–153.

Anderson, R.E. 1979. The influence of storage temperature and warming during storage on peach and nectarine quality. *Journal of the American Society for Horticultural Science* 104, 459–461.

Arthur, C.L., Pawliszyn, J. 1990. Solid phase micro extraction with thermal desorption using fused silica optical fevers. *Analytical Chemistry* 62, 2145–2148.

Artés, F., Cano, A., Fernández Trujillo, J.P. 1996. Pectolytic enzyme activity during intermittent warming storage of peaches. *Journal of Food Science* 61, 311–313.

Aubert, C., Gunata, Z., Ambid, C., Baumes, R. 2003. Changes in physicochemical characteristics and volatile constituents of yellow-and white-fleshed nectarines during maturation and artificial ripening. *Journal of Agricultural and Food Chemistry* 51, 3083–3091.

Bassi, D., Selli, R. 1990. Evaluation of fruit quality in peach and apricot. *Advances Horticultural Science* 4, 107–112.

Bayonove, C.1973. Recherches sur l'arôme de la pêche. I. Evolution des constituants volatils au cours de la maturation de la variete `Cardinal´. *Annales Technologies Agricoles* 22, 35–44.

Bayonove, C.1974. Evolution des compose´s volatils de la peˆche pendant la maturation après récolte. *Colloques Internationales*. C. N. R. S.238, 237–333.

Ben Arie, R., Lavee, S., Guelfat-Reich, S. 1970. Control of woolly breakdown of Elberta peaches in cold storage by intermittent exposure to room temperature. *Journal of American Society and Horticultural Science* 95, 801–802.

Ben Arie, R., Lavee, S. 1971. Pectic changes occurring in `Elberta´ peaches suffering from woolly breakdown. *Phytochemistry* 10, 531–538.

Ben Arie., R, Sonego., L. 1980. Pectolytic enzyme activity involved in woolly breakdown of stored peaches. *Phytochemistry* 19, 2553–2555.

Bonghi, C., Ramina, A., Ruperti, B., Vidrih, R., Tonutti, P. 1999. Peach fruit ripening and quality in relation to picking time, and hypoxic and high CO2 short-term postharvest treatments. *Postharvest Biology and Technology* 16, 213–222.

Brecht, J.K., Kader, A.A., Ramming, D.W. 1984. Description and postharvest physiology of some slow ripening nectarine genotypes. *Journal of the American Society for Horticultural Science* 109, 596–600.

Brovelli, E.A., Brecht, J.K., Sherman, W.B., Sims, C.A. 1999. Anatomical and physiological responses of melting- and non melting flesh peaches to postharvest chilling *Journal of the American Society for Horticultural Science*123, 668–674.

Brükner, B. 2008. Consumer acceptance of fruit and vegetables: the role of flavour and other quality attributes. In fruit and vegetable flavour. Recent advances and future prospects; Brükner, B., Wyllie S.G., Eds.; CRC Press: Washington, DC; 11–18.

Budde, C.O., Lucangeli, C.D., Polenta, G.V., Murray. R.E. 2002. Golpe de altas temperaturas aplicado en poscosecha afecta la calidad de melocotón. *ITEA* 98 (2), 95–107.

Buescher, R.W., Furmanski, R.J. 1978. Role of pectinesterase and polygalacturonase in the formation of woolliness in peaches *Journal of Food Science* 43, 264–266.

Burtlett, P.N., Elliott, J.M., Gardner, J.D. 1997. Electronic noses and their application in the food industry. *Food Technology* 51, 44–48.

Buttery, R.G. 1993. Quantitative and sensory aspects of flavor of tomato and other vegetables and fruits. Flavour science. *American Chemical Society*. Washington, DC. 259-278.

Cascales, A.I., Costell, E., Romojaro, F. 2005. Effects of the degree of maturity on the chemical composition physical characteristics and sensory attributes of peach (Prunus persica) cv. Caterin. *Food Science and Technology International* 11, 345–352.

Clareton, M., 2000. Peach and nectarine production in France: Trends, consumption and perspectives, p. 83-91. Summaries Prunus breeders meeting, 2000. EMBRAPA, clima temperado Pelotas (RS). Brazil. Nov. 29 to Dec., 2000.

Colaric, M., Veberic, R., Stampar, R., Hudina, M. 2005 Evaluation of peach and nectarine fruit and correlations between sensory and chemical attributes. *Journal of Science and food Agriculture* 85, 2611–2616.

Crisosto, C.H., Johnson, R.S., Day, K.R., Cid, L., Slaughter, D., Schaap, J., Crisosto, G.M., Garner, D. 1996. Determination of maximum maturity for stone fruit. Report to the California Tree Fruit Commission, 26–39.

Crisosto, C.H., Mitchell, F.G., Ju, Z. 1999a. Susceptibility to chilling injury of peach, nectarine, and plum cultivars grown in California. *Horticultural Science* 34, 1116–1118.

Crisosto, C.H., Garner, D., Cid, L., Day, K.R. 1999b. Peach size affects storage, market life. *California Agriculture*53, 33–36.

Crisosto, C.H., Day, K.R., Johnson, R.S., Garner, D. 2000. Influence of in-season foliar calcium sprays on fruit quality and surface discoloration incidence of peaches and nectarines. *Journal of American Pomology Society* 54, 118–122.

Crisosto, C.H., Crisosto, G.M. 2001. Understanding consumer acceptance of early harvested 'Hayward' kiwifruit. Postharvest *Biology and Technology* 22, 205–213.

Crisosto, C.H., Slaughter, D., Garner, D., Boyd, J. 2001. Stone fruit critical bruising thresholds. *Journal of American Pomology Society* 55, 76–81.

Crisosto, C.H. 2002. How do we increase peach consumption?. *Acta Horticulturae* 592, 601–605.

Crisosto, C.H., Crisosto, G.M. 2002. Understanding American and Chinese consumer acceptance of `RedGlobe´ table grapes. *Postharvest Biology and Technology* 24, 155–162.

Crisosto, C.H., Labavitch, J.M. 2002. Developing a quantitative method to evaluate peach (Prunus persica) flesh mealiness. *Postharvest Biology and Technology* 25, 151–158.

Crisosto, C.H., Crisosto, G., Bowerman, E. 2003. Understanding consumer acceptance of peach, nectarine and plums cultivars. *Acta Horticulturae* 604, 115–119.

Crisosto, C.H., Garner, D., Andris, H.L., Day, K.R. 2004. Controlled delayed cooling extends peach market life, *HortTechnology*14, 99–104.

Crisosto, C.H., Crisosto, G.M. 2005. Relationship between ripe soluble solids concentration (RSSC) and consumer acceptance of high and low acid melting flesh peach and nectarine (Prunus persica (L.) Batsch) cultivars. *Postharvest Biology and Technology* 38, 239–246.

Crisosto, C. 2006. Peach quality and postharvest technology. *Acta Horticulturae*713, 479–487.

Crisosto, C.H., Crisosto, G.M., Echeverria, G., Puy, J. 2006. Segregation of peach and nectarine (Prunus persica (L.) Batsch) cultivars according to their organoleptic characteristics. *Postharvest Biology and Technology* 39, 10–18.

Croteau, R., Karp, F. 1991. Origin of natural odorants. In perfumes. Art, Science and Technology (Muller, P.M. and Lamparsky, D., eds). London: *Elsevier Applied Science* 101–126.

Chapman, G. W. Jr., Horvat, R. J., Forbus, W. R. Jr.1991. Physical and chemical changes during the maturation of peaches (cv. Majestic). *Journal of Agricultural and Food Chemistry*39, 867–870.

Dangl, J.F., Dietrich, R.A., Thomas, H. 2000. Senescence and programmed cell death, in: Buchanan, B., Gruissem, W., Jones R (Eds.) Biochemistry and molecular biology of plants. *American Society of Plant Physiologist Press* Rockville, 1057–1059.

Dawson, D.M., Melton, L.D., Watkins, C.B. 1992. Cell wall changes in nectarines (*Prunus persica*). Solubilization and depolymerization of pectic and neutral polymers during ripening and in mealy fruit. *Plant Physiology* 100, 1203–1210.

De Jong, T.M., Johnson, R.S., Doyle, J.F., Ramming, D. 2005. Research yields size-controlling rootstocks for peach production. *California Agriculture* 59, 80–83.

Derail, C., Hofmann, T., Schieberle, P.1999. Difference in key odorants of handmade juice of yellow-flesh peaches (*Prunus persica*L.) induced by the workup procedure. *Journal of Agricultural and Food Chemistry*47, 4742–4745.

De Santis D., Mencarelli F. 2001. Influenza del propylene e del 1-metilciclopropene sull'aroma delle pesche – *Frutticoltura*, Anno LXIII – n.6, 79–80.

Dong, L., Zhou, H.W., Sonego, L., Lers, A. and Lurie, S. 2001. Ethylene involvement in the cold storage disorder of `Flavortop´ nectarine. *Postharvest Biology and Technology* 23, 105–115.

Eduardo I., Chietera G., Bassi D., Rossini L., Vecchietti A. 2010. Identification of key odor volatile compounds in the essential oil of nine peach accessions. *Journal of the Science of Food and Agriculture* 90, 1146–1154.

Engel, K.H., Flath, R.A., Buttery, R.G., Mon. T.R., Ramming, D.W., Teranishi, R. 1988a. Investigation of volatile constituents in nectarines. I. Analytical and sensory characterization of aroma components in some nectarine cultivars. *Journal of Agricultural and Food Chemistry* 36, 549–553.

Engel. K.H., Ramming, D.W., Flath, R.A., Teranishi, R. 1988b. Investigation of volatile constituents in nectarines. 2. Changes in aroma composition during nectarine maturation. *Journal of Agricultural and Food Chemistry* 36, 1003–1006.

Estim, Messia M.C., Sinesio F., Nicotra A, Contre L.A., La Notte, E., Palleschi, G. 1997. Quality evaluation of peaches and nectarines by electrochemical and multivariante analyses: relationships between analytical measurements and sensory attributes. *Food Chemistry* 60, 659–666.

Europeach´10. 2010. http://www.agronline.es/galeria-multimedia-10/4761.html Consultado: 10 de Febrero 2012.

Fernández-Trujillo, J.P., Artés, F. 1997. Quality improvement of peaches by intermittent warming and modified-atmosphere packaging. *Zeitschrift für Lebensmittel-Untersuchung und -Forschung A* 205, 59–63.

Fernandez-Trujillo, J.P., Cano, A., Artes, F. 1998. Physiological changes in peaches related to chilling injury and ripening. *Postharvest Biology and Technology* 13, 109–119.

Fillon, L., Kilcast, D. 2002. Consumer perception of crispness and crunchiness in fruits and vegetables. *Fruit Quality and preference* 13, 23–29.

Frenkel, C., Patterson, M.E. 1973. Effect of carbon dioxide on the activity of succinic deshydrogenase in `Barlett´ pears during cold storage. *HortScience* 35, 1022–1025.

Friedman, E., Pichersky, E. 2005. Metabolomics, genomics, proteomics, and the identification of enzymes and their substrates and products. *Current opinion in plan biology* 8, 242–248.

Génard, M., Souty, M., Holmes, S., Reich, M., Breuils L. 1994. Correlations among quality parameters of peach fruit, *Journal of Science and Food Agricultural* 66, 241–245.

Génard, M., Reich, M., Lobit, P., Basset, J. 1999. Correlations between sugar and acid content and peach growth. *Journal of Horticultural Science and Biotechnology* 74, 772–776.

Girardi, C.L., Corrent, A.R., Lucchetta, L. 2005. Effect of ethylene, intermittent warming and controlled atmosphere on postharvest quality and the occurrence of woolliness in peach (*Prunus persica* cv. `Chiripa´) during cold storage. *Postharvest Biology and Technology* 38, 25–33.

Guelfat–**Reich, S., Ben Arie, R.** 1966. Effect of delayed storage and the stage of maturity at harvest on the keeping quality of peaches in Israel. *Israel Journal of Agricultural Research* 18, 163–170.

Hilaire, C., Giauque, P. 1994. Pêche: les variétés & leur conduite. Ctifl, Paris.

Hilaire, C., Mathieu, V., Scandella, D. 2000. La qualité organoleptique des pêches et nectarines. *Infos-Centre Technique Interprofessionnel des Fruits et Légumes*, Juin 2000, 26–29.

Hilaire, C., Mathieu, V. 2004. Test hédoniques Sur varieties de peche. D'abord, satidfaire le consommateur. *Infos-Centre Technique Interprofessionnel des Fruits et Légumes*, Mai 2004, 32–35.

Horvat, R.J., Chapman, G.W.1990. Comparison of volatile compounds from peach fruit and leaves (Cv. Monroe) during maturation. *Journal of Agriculture and FoodChemistry*38, 1442–1444.

Horvat, R.J., Chapman, G.W. Jr., Robertson, J.A., Meredith, FL, Scorza, R., Callahan, A.M., Morgens, P. 1990. Comparison of the volatile compounds from several commercial peach cultivars. *Journal of Agriculture and Food Chemistry* 38, 234–237.

Hudina, M., Stampar, F. 2000. Sugars and organic acids contents of European (*Pyrus communis* L.) and Asian Pyrus serotina Rehd.) pear cultivars. *Acta Alimentaria* 29, 217–230.

Iglesias, I., Echeverria, G. 2009. Differential effect of cultivar and harvest date on nectarine color, quality and consumer acceptance. *Scientia Horticulturae* 120, 41–50.

Infante, R., Meneses, C., Byrne, D. 2006. Present situation of peach breeding programs: Post harvest and fruit quality assessment. *Acta Horticulturae* 713, 121–124.

Infante, R., Meneses, C., Pedrieri, S. 2007. Sensory quality performance of two nectarine flash typologies exposed to distant market conditions. *Journal of Food Quality* 31 (4), 526–534.

Infante, R., Martinez-Gomez, P., Predieri, S. 2008.Quality oriented fruit breeding: Peach [*Prunus persica* (L.) Batsh]. *Journal of Food Agriculture and Environment* 6(2), 342–356.

ISO. International Organization for Standardization (1980) International Standard, Peaches–Guide to cold storage, ISO 873–1980 (E).

Jarvis, M.C., Briggs, S.P.H., Knox, J.P. 2003. Intercellular adhesion and cell separation in plants. *Plant Cell Environment*. 26, 977–989.

Jennings, W. G., Sevenant, M. R. 1964. Voatile components of peach. *Journal of food Science* vol. 29 nº 6, p 796.

Jones, L.V., Peryam, D.R., Thurstone, L.L. 1955. Development of a scale for measuring soldier´s food preferences. *Food Research* 20, 512–520.

Kader, A.A. 1986. Biochemical and physiological basis for effects of controlled and modified atmosphere in fruits and vegetables. *Journal of Experimental Botany* 40, 99–100.

Kader, A.A., Chordas, K.R. 1984. Evaluating the browning potential of peaches. California Agriculture 38, 14–15Kays, S.J. 1999. Preharvest factors affecting appearance. *Postharvest Biology and Technology*. 15, 233–247.

Ke, D., Rodriguez, L., Kader, A.A. 1991. Physiological responses and quality attributes of peaches kept in low-oxygen atmospheres. *Scientia Horticulturae* 47, 295–303.

Kramer, A., Twigg, V.B.A. 1966. Fundamentals of Quality Control for the Food Industry, 2nd ed. Aci publishing, Westport, Ct.

Lavilla, T., Recasens, I., Lopez, M. L. 2001. Production of volatile aromatic compounds in Big Top nectarines and Royal Glory peaches during maturity. In Proceedings of the 4th International Conference on PostharVest. *Acta Horticulturae*. 553; Ben-Arie, R., Philisoph-Hada, S., Eds. Jerusalem, Israel; 233–234.

Lavilla, T., Recasens, I., López, M.L., Puy, J. 2002. Multivariate analysis of maturity stages, including quality and aroma, in 'Royal Glory' peaches and 'Big Top' nectarines. *Journal of the Science of Food and Agriculture* 82 (15), 1842–1849.

Lawels, H. T., Horne, J., Giasi, P. 1996. Astringency of organic acids is related to pH. *Chemistry Senses* 21, 397–403.

Lill, R.E. 1985. Alleviation of internal breakdown of nectarines during cold storage by intermittent warming. *Science Horticultural* 25, 241–246.

Lill, R.E., O'Donaghue, E.M., King, G.A. 1989. Postharvest physiology of peaches and nectarines. *Horticultural Reviews* 11, 413–452.

Lurie, S., Pesis, E. 1992 Effect of acetaldehyde and anaerobiosis as postharvest treatments on the quality of peaches and nectarines. *Postharvest Biology and Technology* 1, 317–326.

Lurie, S., Levin, A., Greve, L.C., Labavitch, J.M. 1994. Pectic polymer changes in nectarines during normal and abnormal ripening. *Phytochemistry* 36, 11–17.

Lurie, S., Zhou, H.W., Lers, A., Sonego, L., Alexandrov, S., Shomer, I. 2003. Study of pectin esterase and changes in pectin methylation during normal and abnormal peach ripening. *Physiology Plantarum*119, 287–294.

Lurie, S., Crisosto, C. 2005. Chilling injury in peach and nectarine. *Postharvest Biology and Technology* 37:195–208.

Luza, J.G., Van Gorsel, R., Polito, V.S., Kader, A.A. 1992. Chilling injury in peaches: a cytochemical and ultrastructural cell wall study. *Journal of American Socienty of Horticultural Science* 117: 114–118.

Maga, J. A. 1976. Lactones in Foods, *Critical Reviews in food Science and Nutrition* 1–56.

Malakou, A., Nanos, G.D. 2005. A combination of hot water treatment and modified atmosphere packaging maintains quality of advanced maturity 'Caldesi 2000' nectarines and 'Royal Glory' peaches. *Postharvest Biology and Technology* 38, 106–114.

MARM (www.mapya.es). 2011. http://www.magrama.es/es/estadistica/temas/avances-de-superficies-y-producciones-de-cultivos/Avances_Cultivos_2011-05_tcm7-168113.pdfConsultado: 10 de Febrero 2012.

Martínez Jávega, J.M. 1995. Tendencias actuales en la conservación refrigerada de frutas como marcadores de la calidad higiénicas de los frutos. *Microbiología SEN* 11: 111–114.

Meredith, F.I., Robertson, J.A., Horvat, R.J.1989. Changes in physical and chemical parameters associated with quality and postharvest ripening of Harvester peaches. *Journal of Agricultural and Food Chemistry*37, 1210–1214.

Mitchell, F.G., Mayer, G., Biasi, W., Gulli, D., Faubian, D. 1990. Selecting and handling high quality stone fruit. In: 1989 research reports for California peaches and nectarines. California Tree Fruit Agreement, Sacramento, CA, 15.

Molto, E., Selfa, E., Ferriz, E., Gutierrez, A. 1999. An aroma sensor for assessing peach quality. *Journal of Agricultural Engineer Research* 72, 311–316.

Monet, R.1979. Genetic transmisión of the `fruit sweerness´character-incidence on selection for quality (in French). In. Eucarpia Symp. Fruit Sec. Tree Fruit Breeeding, Angers, 273–276.

Murray, R., Valentini, G., Yommi, A., Arroyo, L., Ángel, N., Ros, P., Velasco, G. 1994. Internal breakdown susceptibility of peach cultivars grown in the NE of Buenos

Aires (República Argentina). Reunión Internacional de Expertos en Postcosecha de Frutales de Carozo. Instituto Internacional del Frío. Mendoza, Argentina.

Murray, R., Lucangely, C., Polenta, G., Budde, C. 2007. Combined pre-storage heat treatment and controlled atmosphere storage reduced internal breakdown of `Flavorcrest´ peach. *Postharvest Biology and Technology* 44 (2), 116–121.

Nanos, G.D., Mitchell, F.G. 1991. High–temperature conditioning to delay internal breakdown development in peaches and nectarines. *HortScience* 26 (7), 882–885.

Nunes, M.C.N., Emond, J.P. 2002. Quality Curves for Two Different Peach Cultivars as a Function of the Storage Temperature. Scientific report presented to Envirotainer, Sweden by the Air Cargo Transportation Research Group, University Laval, Quebec, Canada.

Obenland, D., Carroll, T. 2000. Mealiness and pectolytic activity in peaches and nectarines in response to heat treatment and cold storage. *Journal of American Society Horticultural Science* 125, 723–728.

Ortiz, A., Echeverría, G., López, M.L., Graell, J., Lara, I. 2009. Overall quality of `Rich Lady´ peach fruit after air or CA-storage. The importance of volatile emission. *LWT Food Science and Technology* 42 (9), 1520-1529.

Ortiz, A., Graell, J., López, M.L., Echeverría, G., Lara, I. 2010. Volatile ester-synthesising capacity in 'Tardibelle' peach fruit in response to controlled atmosphere and 1-MCP treatment. *Food Chemistry*, 123, 698–704.

Oude, O., Van Trijp, H. 1996. Perceived quality: A market driven and consumer oriented approach. *Food Quality and Preference*.6, 177-183.

Ozawa, T., Llley, T.H., Haslam, E. 1987. Polyphenol interactions: astringency and loss of astringency in ripening fruit. *Phytochemistry* 26, 2937–2942.

Parker, D., Ziberman, D., Moulton, K. 1991. How quality relates to price in California fresh peaches. *California Agriculture* 45(2), 14–16.

Pecore, S., Kellen, L. 2002. A consumer-Focused QC/sensory program in the food industry. *Food Quality and Preference* 13, 369-374.

Pedrieri, S., Ragazzini, P., Rondelli, R. 2006. Sensory evaluation and peach fruit quality. *Acta Horticulturae* 713, 429–434.

Pérez, A.G., Sanz, C., Olías, J.M. 1993. Partial purification and some properties of alcohol acyltransferase from strawberry fruits. *Journal of Agricultural and Food Chemistry* 41, 1462–1466.

Peryam, D.R., Piligrim, F.J. 1957. Hedonic Scale method of measuring food preferences. *Food Technol*ogy 11 (9), 9–14.

Pretel, M.T., Serrano, M., Martínez, G., Riquelme, F., Romojaro, F. 1993. Influence of films of different permeability on ethylene synthesis and ripening of MA-packaged apricots. *Lebensmittel-Wissenschaft und -Technologie*26, 8–13.

Raffo, A., Nardo, N., Tabilio, M.R., Paoletti, F. 2008. Effects of cold storage on aroma compounds on white- and yellow-fleshed peaches. *Europe Food Research Technology* 226, 1503–1512.

Retamales, J., Cooper, T., Streif, J., Kama, J.C. 1992. Preventing cold storage disorders in nectarines. *Journal of Horticultural Science* 67, 619–626.

Riu-Aumatell, M., Castellari, M., Lopez–Tamames, E., Galassi, S., Buxaderas, S. 2004. Characterization of volatile compounds of fruit juices and nectars by HS/SPME and GC/MS. *Food Chemistry* 87, 4, 627–637.

Riu-Aumatell, M., Lopez–Tamames, E., Buxaderas, S. 2005. Assessment of the volatile composition of juices of apricot, peach, and pear according to two pectolitic treatments. *Journal of Agricultural and Food Chemistry* 53, 20, 7837–7843.

Rizzolo, A., Lombardi, P., Vanoli, M., Polesello, S. 1995. Use of Capillary Gas Chromatography/Sensory Analysis as an additional tool for sampling technique comparison in peach aroma analysis. *Journal of High Resolution Chromatography* 18, 309–314.

Robertson, J.A., Meredith, F.I., Scorza, R. 1989. Physical, chemical and sensory evaluation of high and low quality peaches. *Acta Horticulturae* 254, 155–160.

Robertson, J.A., Meredith, F.I., Horvat, R.J., Senter, S.D. 1990a. Effect of cold storage and maturity on the physical and chemical characteristics and volatile constituents of peaches (Cv. Cresthaven). *Journal of Agricultural and Food Chemistry* 38, 620–624.

Robertson, J.A., Horvat, R.J., Lyon, B.G., Meredith, FL, Senter, S.D., Okie, W.R., 1990b. Comparison of quality characteristics of selected yellow- and white-fleshed peach cultivars. *Journal of Food Science* 55, 1308–1311.

Roig, I., Vendrell, M., Lara, I. 2003. Use of CA, MA, shoks of CO_2 and heat treatments to improve storage of two peach cultivars grown in Lleida, Spain. *Acta Horticulturae* 600, 289–295.

Sancho, J., Bota, E., De Castro, J.J. 1999. Introducción al análisis sensorial de los alimentos. Edicions de la Universitat de Barcelona. Estudi General, 4.

Sanz, C., Olias, J.M., Pérez, A.G. 1997. Aroma biochemistry of fruits and vegetables. In: Tomás-Barberán, F.A., Robins, R. (Eds). Phytochemistry of fruit and vegetables. New York, Oxford University Press Inc. 125–155.

Scott, K.J., Wills, R.B.H., Roberts, E.A. 1969. Low temperatureinjury of peaches in relation to weight loss during cool storage. *Australian Journal of Experiment Agriculture Animal Husbandry* 9, 364–366.

Sevenants, M.R., Jennings, W.G. 1971. Occurrence of 6-pentyl-alpha-pyrone in peach essence. *Journal of Food Science* 36, 536.

Shaller, E., Bosset, J.O., Escher, F. 1998. Electronic nose and their application to food *Lebensmittel-Wissenschaft und -Technologie*31, 305–316.

Schawab,W., Schreier, P. 2002. Enzymic formation of flavor volatiles from lipids. In Lipid Biotechnology (Kuo,T.M.,Gardner,H.W.,eds).New York: Marcel Dekker. 293–318.

Schawab W., Davidovich-Rikanati, R., Lewinsohn, E. 2008. Biosynthesis of plant-derived flavor compounds. *The Plant Journal* 54, 712–732.

Shepard, R., Colwill, J.S., Daget, N., Thomson, D.M.H., McEwan, J.A., Lyon, D.H., Stone, H., Sidel, J.L, Red linger, P.A., Bouene, M.C. 1993. Encyclopedia of Food Science, Food Technology and Nutrition, ed. By Macrae R, Robinson RK and Sadler MJ. Academic Press, London, 4023–4075.

Shewfelt, R.L., Myers, S.C., Resurreccion, A.V.A. 1987. Effect ofphysiological maturity at harvest on peach quality during low temperaturestorage. *Journal of Food Quality* 10: 9–20.

Shewfelt, R. L. 1999. What is quality?. *Postharvest Biology and Technology* 15, 197-200.

Smilanick, J.L., Fouse, D.C. 1989. Quality of nectarines in insecticidal low O2 atmospheres at 5°C. *Journal of the American Society for Horticultural Science*, 114, 431–436.

Spencer, M.D., Pangborn, R.M., Jennings, W.G. 1978. Gas Chromatographic and sensory analysis of volatiles from cling peaches. *Journal of Agricultural and Food Chemistry* 26, 725–732.

Stefani, G., Romano, D., Cavicchi, A. 2006. Consumer expectations, liking and willingness to pay for specialty foods: do sensory characteristics tell the whole story?. *Food Quality and Preference* 17, 53–62.

Streif, J., Retamales, J., Cooper, T., Kania, J.C. 1992. Storage of nectarines in CA and high CO_2 concentrations to reduce physiological dosorders. *Gartenbauwissenschaft*, 57, 166–172.

Sturm, K., Koron, D., Stampar, F. 2003. The composition of fruit of different strawberry verieties depending on maturity stage. *Food Chemistry* 83, 417–422.

Sumitani, H., Suekane, S., Nakatani, A., Tatsuka, K. 1994. Changes in composition of volatile compounds in high pressure treated peach. *Journal of Agricultural and Food Chemistry* 42, 785–790.

Taylor, A., Hort, J., Roberts, D. 2004. In flavour Perception. Eds. Blackwell, Oxford, UK.1–38.

Takeoka, G.R., Flath, R.A., Gunter, M., Jennings, W. 1988. Nectarine volatiles: vacuum steam distillation vs. headspace sampling. *Journal of Agricultural and Food Chemistry* 36, 553–560.

Tholl, D., Boland, W., Hansel, A., Loreto, F., Röse U.S.R., Schnitzler, J.P. 2006. Practical approaches to plant volatile analysis. *The plant Journal* 45, 540–560.

Thomas, C.J., Lawless, H. T. 1995. Astringent sub qualities in acids. *Chemistry Senses* 37, 593-600.

Thompson, A.K. 1996. Postharvest Technology of fruit and Vegetables. Blackwell Publishing, Oxford, UK.

Thompson, A.K. 2003. Fruit and Vegetables. Blackwell Publishing, Oxford, UK.

Tonini, G., Caccioni, D. 1990. Biologia e Tecniche Post-Raccolta dell' Asparago, Carciofo e Sedano. MACFRUT. Prodotti Ortivi allo Stato Fresco: Biologia e Tecniche Post-Raccolta. Cesena, Italia, 28 April, 45.

Tonutti, P., Bonghi, C., Ramina, A., Vidrih, R. 1998. Molecular and biochemical effects of anoxia, hypoxia and CO_2–enriched atmosphere on `Springcrest´ peaches. *Acta Horticulturae* 465, 439–446.

Uthairatanakij, A. 2004. Responses of nectarines to atmospheres containing high carbon dioxide concentrations. PhD thesis, The University of Western Sydney, New South Wales, Australia.

Vendrell, M., Carrasquer, A.M. 1994. Fisiología poscosecha en frutos de hueso. In Seminario Calidad Post-cosecha y Productos Derivados en Frutos de Hueso, (M. Vendrell and J.M. Audergon, eds.). 37–54, Universidad de Lleida, Lleida, Spain.

Vincken, J.P., Schols, H.A., Omen, R.J.F.J., McCall, M.C., Ulvskov, P., Voragen, A.G.J., Visser, R.G.F. 2003. If homogalacturonan were a side chain of rhamnogalacturonan. I. Implications for cell wall architecture. *Plant Physiology* 132, 1781–1789.

Visai, C., Vanoli, M. 1997. Volatile compound production during growth and ripening of peaches and nectarines. *Scientia Horticulturae* 70, nª1, 15–24.

Von Mollendorff, L.J. 1987. Woolliness in peaches and nectarines: A review. 1. Maturity and external factors. *Horticultural Science* 5, 1–3.

Von Mollendorff, L.J., de Villiers, O. 1988. Role of pectolytic enzymes in the development of wooliness in peaches. *Journal of Horticultural Science* 63, 53–58.

Von Mollendorff, L.J., de Villiers, O., Jacobs, G. 1989. Effect of time of examination and ripening temperature on the degree of woolliness in nectarines. *Journal of Horticultural Science* 64, 443–447.

Von Mollendorff, L.J., de Villiers, O., Jacobs, G., Westraad, I. 1993. Molecular characteristics of pectic constituents in relation to firmness, extractable juice and woolliness in nectarines. *Journal of the American Society for Horticultural Science* 118, 77–80.

Wade, N.L. 1981. Effects of storage atmosphere and calcium on low-temperature injury of peach fruit. *Scientia Horticulturae* 15, 145–154.

Wang, Y., Yang, C., Li, S., Yang, L., Wang, Y., Zhao, J., Jiang, Q. 2009. Volatile characteristics of 50 peaches and nectarines evaluated by HP-SPME with GC-MS. *Food Chemistry* 116, 1, 356–364.

Wills, R.B.H., Mc Glasson, W.B., Graham, D., Joyce, D.C. 2007. Post harvest. An introduction to the physiology and handling of fruit, vegetables and ornamentals. University of new South Wales Press Ltd. Australia, 29–50.

Wu, B.H., Quilot, B., Kervella, J., Genard, M., Li, S.H. 2003. Analysis of genotypic variation of sugar and acids content in peaches and nectarines through the principle components Analyses. *Euphytica* 132, 375–384.

Zhang, B., Shen, J. Y., Wei, W. W., Xi, W. P., Xu, C. J., Ferguson, I., Chen, K. 2010. Expression of Genes Associated with Aroma Formation Derived from the Fatty Acid Pathway during Peach Fruit Ripening. *Journal of Agricultural and Food Chemistry* 58, 6157–6165.

Zhou, H.W., Sonego, L., Khalchitski, A., Ben Arie, R., Lers, A., Lurie, S. 2000a. Cell wall enzymes and cell wall changes in 'Flavortop' nectarines: mRNA abundance, enzyme activity, and changes in pectic and neutral polymers during ripening and in woolly fruit. *Journal of the American Society for Horticultural Science* 125, 630–637.

Zhou, H.W., Lurie, S., Lers, A., Khatchitski, A., Sonego, L., Ben Arie, R. 2000b. Delayed storage and controlled atmosphere storage of nectarines: Two strategies to prevent woolliness. *Postharvest Biology and Technology* 18, 133–141.

Zhou, H.W., Dong, L., Ben Arie, R., Lurie, S. 2001. The role of ethylene in the prevention of chilling injury in nectarines. *Journal of Plant Physiology* 158, 55–61.

Zozulya, S., Echeverri, F., Nguyen, T. 2001. The human olfactory receptor repertoire. *Genome Biology* 2, 008.1–0018.12.

2. Objetivos

El objetivo principal de esta Tesis Doctoral fue establecer las mejores condiciones de conservación de diferentes variedades de melocotón y nectarina durante su post-cosecha para aumentar su calidad y por consiguiente la aceptación por parte del consumidor. Para conseguir tal propósito, se planificaron los siguientes objetivos específicos:

1. Definir las características físico-químicas y organolépticas de las variedades de melocotón 'Early Rich®', 'Royal Glory®', 'Elegant Lady®' y 'Sweet Dream^{cov}' y las variedades de nectarina 'Big Top®', 'Honey Blaze^{cov}', 'Honey Royale^{cov}', 'Venus®', 'August Red®', 'Nectagala^{cov}' y 'Nectalady^{cov}'.

2. Establecer el potencial de conservación frigorífica de las variedades de melocotón y nectarina mencionadas en el objetivo 1 en función de sus parámetros físico-químicos y aceptación sensorial.

3. Determinar el efecto de diferentes atmósferas controladas, periodos de conservación y periodos de vida comercial a 20 ºC sobre los atributos sensoriales y parámetros fisico-químicos de las variedades de melocotón 'Early Rich®' y 'Sweet Dream$^{cov'}$ y las variedades de nectarina 'Big Top®' y 'Venus®'.

4. Evaluar si el tratamiento de pre-acondicionado para la variedad de melocotón 'Early Rich®' y la variedad de nectarina 'Big Top®' consigue mejorar el aroma y los demás atributos sensoriales, sin detrimento de su calidad estándar comercial.

3. Diseño experimental

3.1 Plan de trabajo

El plan de trabajo de esta tesis se fundamenta en cuatro estudios principales realizados durante tres campañas frutícolas consecutivas (2009-2010-2011):

Estudio 1: Caracterización varietal de melocotón y nectarina en cosecha.

Estudio 2: Efecto del sistema de conservación frigorífica en atmósfera normal.

2.1 En melocotones.

2.2 En nectarinas.

Estudio 3: Efecto del sistema de conservación frigorífica en atmósfera controlada.

Estudio 4: Efecto del sistema de pre-acondicionado previo a la conservación frigorífica.

Del mismo modo en este apartado se explicarán el material vegetal y las determinaciones analíticas llevadas a cabo con sus respectivas cronologías para cada estudio.

Estudio 1: Caracterización varietal de melocotón y nectarina en cosecha

Material vegetal: Las variedades de melocotón'Early Rich®', 'Royal Glory®', 'Elegant Lady®' y 'Sweet Dream^cov' y las variedades de nectarina 'Big Top®', 'Honey Blaze^cov', 'Honey Royale^cov', 'Venus®', 'August Red®', 'Nectagala^cov' y 'Nectalady^cov'.

Cosecha: Una fecha de cosecha dentro del periodo comercial para cada variedad.

Maduración post-cosecha: En cámara de 20 ºC durante 3 días.

Determinaciones:

- Aceptación sensorial por parte de consumidores: Escala hedónica de 9 categorías (detallado en materiales y métodos, Capítulo I).
- Características físico-químicas: firmeza, CSS, AT, color y emisión de compuestos volátiles (detallado en materiales y métodos, Capítulo).

Periodo de evaluación de las diferentes determinaciones analíticas:

1. El día de cosecha de los frutos.
2. Tras permanecer 3 días a 20 ºC.

Estudio 2: Efecto del sistema de conservación frigorífica en atmósfera normal.

Material vegetal: Las variedades de melocotón'Early Rich®', 'Royal Glory®', 'Elegant Lady®' y 'Sweet Dream^{cov}' y las variedades de nectarina 'Big Top®', 'Honey Blaze^{cov}', 'Honey Royale^{cov}', 'Venus®', 'August Red®' y 'Nectagala^{cov}'.

Cosecha: Una fecha de cosecha dentro del periodo comercial para cada variedad.

Condiciones de almacenamiento: En cámara de atmósfera normal a -0.5 ºC, durante 10, 20 y 40 días respectivamente.

Maduración post-almacenamiento: En cámara de 20 ºC durante unas horas hasta conseguir que los frutos se atemperen (0 días) y hasta 3 días.

Determinaciones:

- Aceptación sensorial por parte de los consumidores: Escala hedónica de 9 categorías (detallado en materiales y métodos, Capítulo II.1 y II.2).
- Características físico-químicas: Firmeza, CSS, AT, color y producción de compuestos volátiles (Detallado en materiales y métodos, Capítulo II.1 y II.2).

Periodo de evaluación de las diferentes determinaciones:

1. Tras la cosecha.
2. Después de 10 días de conservación, más 0 días de vida comercial.
3. Después de 10 días de conservación, más 3 días de vida comercial.
4. Después de 20 días de conservación, más 0 días de vida comercial.
5. Después de 20 días de conservación, más 3 días de vida comercial.
6. Después de 40 días de conservación, más 0 días de vida comercial.
7. Después de 40 días de conservación, más 3 días de vida comercial.

Estudio 3: Efecto del sistema de conservación frigorífica en atmósfera controlada

Material vegetal: 2 variedades de melocotón (‘Early Rich®’ y ‘Sweet Dream^cov’).

2 variedades de nectarina (‘Big Top®’ y ‘Venus ®’).

Cosecha: Una fecha de cosecha dentro del periodo comercial para cada variedad.

Condiciones de almacenamiento: Una vez recolectados los frutos de cada variedad, se hicierondistintos lotes que fueron almacenados a una temperatura de -0,5 ºC en una cámara de atmósfera normal utilizada como testigo o control (21 % O_2 / 0,03 % CO_2) y en 3 cámaras con diferentes condiciones gaseosas de atmósfera (Tabla 2). Las evaluaciones se realizaron en 2 periodos distintos (20 y 40 días), seguido por dos periodos de vida comercial (0 y 3 días a 20 ºC).

Determinaciones:

- Descripción de los perfiles sensoriales por un panel entrenado (Detallado en materiales y métodos, Capítulo III).
- Características físico-químicas: firmeza, CSS, AT, color y emisión de compuestos volátiles (detallado en materiales y métodos, Capítulo III).

Periodo de evaluación de las diferentes determinaciones:

1. Tras la cosecha.
2. Después de 20 días, más 0 días de vida comercial.
3. Después de 20 días, más 3 días de vida comercial.
4. Después de 40 días, más 0 días de vida comercial.
5. Después de 40 días, más 3 días de vida comercial.

Tabla 1. Periodos de análisis después de la aplicación de cada atmósfera controlada.

ATMOSFERAS	ALMACENAMIENTO	VIDA COMERCIAL
2 %O_2 / 5 %CO_2	20 días a -0,5 ºC 40 días a -0,5 ºC	0 días a 20 ºC 3 días a 20 ºC
3 %O_2 / 10%CO_2	20 días a -0,5 ºC 40 días a -0,5 ºC	0 días a 20 ºC 3 días a 20 ºC
6 %O_2 / 17%CO_2	20 días a -0,5 ºC 40 días a -0,5 ºC	0 días a 20 ºC 3 días a 20 ºC

Estudio 4: Efecto del sistema de pre-acondicionado previo a la conservación frigorífica

Material vegetal: 1 variedad de melocotón (‘Early Rich®’).

1 variedad de nectarina (‘Big Top®’).

Cosecha: Una fecha de cosecha dentro del periodo comercial para cada variedad.

Condiciones de almacenamiento: Los frutos de las variedades objeto de estudio se mantuvieron a temperatura de 20 ºC para su pre-acondicionado, durante 4 periodos distintos (0, 10, 24 y 36 horas) antes de su transferencia definitiva a cámara frigorífica a -0,5 ºC para su conservación durante 10, 20 y 40 días, seguido por dos periodos de vida comercial (0 y 3 días a 20 ºC).

Determinaciones:

- Características físico-químicas: firmeza, CSS, AT, color y producción de compuestos volátiles (detallado en materiales y métodos, Capítulo IV).
- Descripción de los perfiles sensoriales por un panel entrenado (Detallado en materiales y métodos, Capítulo IV).

Periodo de evaluación de las diferentes determinaciones:

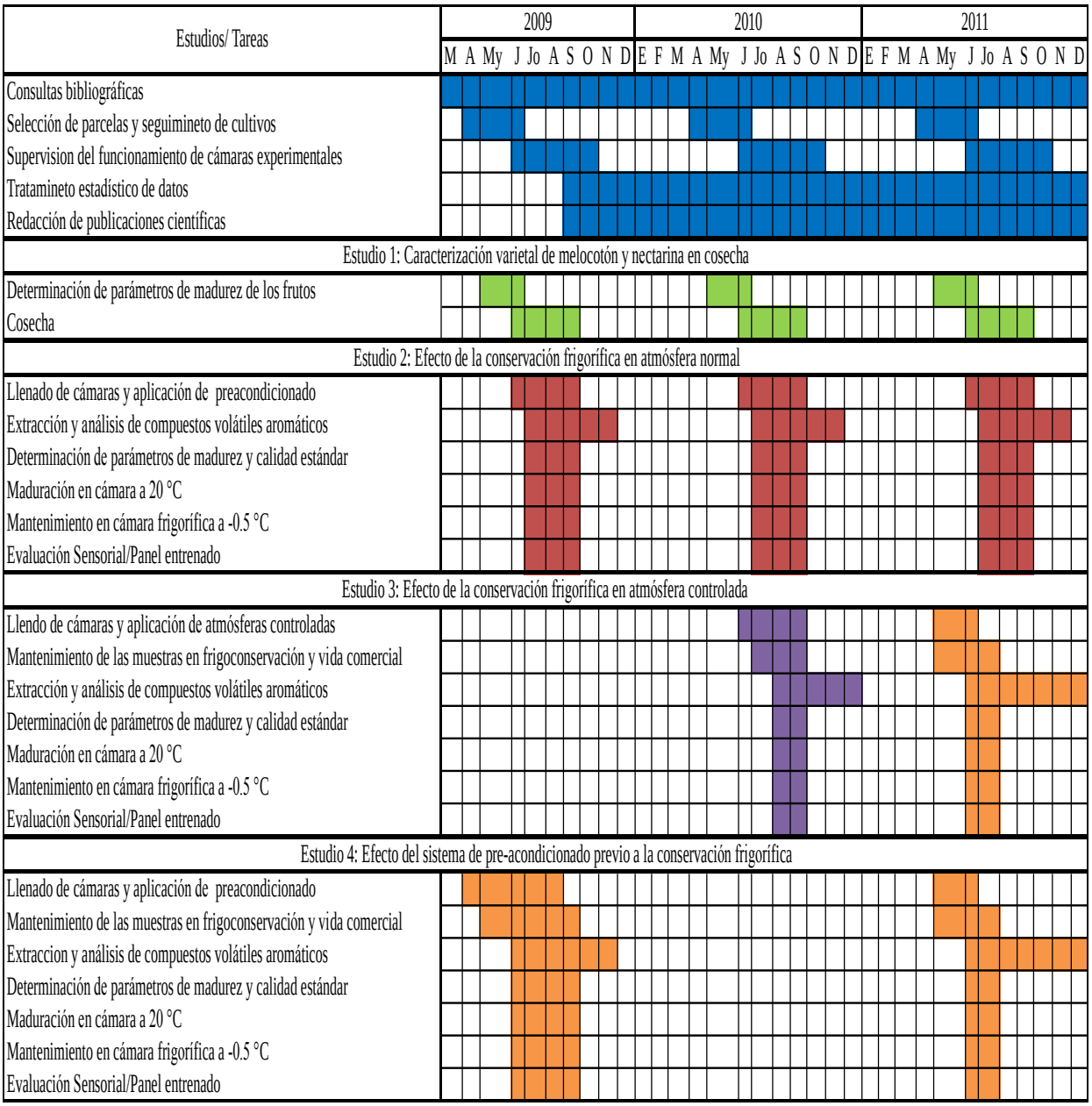
1. Después de 10 días de conservación, más 0 días de vida comercial.
2. Después de 10 días de conservación, más 3 días de vida comercial.
3. Después de 20 días de conservación, más 0 días de vida comercial.
4. Después de 20 días de conservación, más 3 días de vida comercial.
5. Después de 40 días de conservación, más 0 días de vida comercial.
6. Después de 40 días de conservación, más 3 días de vida comercial.

Tabla 2. Periodos de análisis después de aplicar cada tratamiento de pre-acondicionado.

PRE-ACONDICIONADO	ALMACENAMIENTO	VIDA COMERCIAL
0 h a 20 ºC	10 días a -0,5 ºC 20 días a -0,5 ºC 40 días a -0,5 ºC	0 días a 20 ºC 3 días a 20 ºC
10 h a 20 ºC	10 días a -0,5 ºC 20 días a -0,5 ºC 40 días a -0,5 ºC	0 días a 20 ºC 3 días a 20 ºC
24 h a 20 ºC	10 días a -0,5 ºC 20 días a -0,5 ºC 40 días a -0,5 ºC	0 días a 20 ºC 3 días a 20 ºC
36 h a 20 ºC	10 días a -0,5 ºC 20 días a -0,5 ºC 40 días a -0,5 ºC	0 días a 20 ºC 3 días a 20 ºC

Las actividades expuestas en el plan de trabajo se encuentran especificadas a continuación.

Tabla 3. Cronograma de las actividades realizadas a lo largo de la presente tesis.



A lo largo de los años de realización de la presente tesis, se han elaborado y presentado algunos resultados parciales de investigación en los siguientes congresos:

- **VII International Peach Symposium/2009**
  Lleida-España

  The influence of peach and nectarine cultivar on fruit colour, fruit quality parameters and consumer acceptance.

- **28th International Horticultural Congress/2010**
  Lisboa-Portugal

  Changes in chemical composition during cold-storage of several peach cultivars (Prunus Persica).

  Influence of volatile compounds emission and standard quality on peach and nectarine consummer´s acceptance.

  Effects of pre-storage treatment at 20ºC on the standard, sensory and aromatic quality of `Big top®´ nectarines.

- **IV Postharvest Unlimited/2011**
  Leavenworth. Washington D.C/USA

  Variability of sugar and acid profiles of 11 peach and nectarine cultivars during cold-storage under air conditions. Influence on consumer liking degree.

  Effect of the storage period and the controlled atmosphere composition during cold storage on the volatile compounds emission, standard quality and sensory properties of peaches and nectarines.

3.2 Material vegetal

Para la elaboración de esta tesis, se trabajo con 11 variedades diferentes (5 de melocotones y 6 nectarinas). Estas variedades fueron seleccionadas por ser variedades de referencia y de interés por parte del sector. En la selección se busco abarcar variedades representativas de tres diferentes periodos de recolección. Así clasificamos como variedades tempranas aquellas que se cosechan entre 90 y 120 días después de plena floración (ddpf), medias entre 121 y 150 ddpf y tardías más de 150 ddpf. Además se ha establecido una segunda clasificación en función a la concentración de acido málico (g/L), se consideran variedades subácidas/ muy dulces aquellas con < 3,3 g/L de acido málico, dulces/ semidulces con un contenido entre 3,3 – 6, equilibradas entre 6-8, acidas entre 8-10 y muy acidas >10 (Iglesias y Echeverría, 2009).

De acuerdo con estos baremos la tabla 4 muestra las once variedades, objeto de esta tesis. Todas las variedades fueron cosechadas en fincas comerciales de la provincia de Lleida.

Tabla 4. Variedades clasificadas según periodos de recolección.

Variedades	**Recolección (ddpf)**	**Acidez titulable (g. ac. mál./l)**
Big Top®	Tempranas	Dulce
Early Rich®	Tempranas	Acida
Honey Blaze^{cov}	Tempranas	Dulce
Royal Glory®	Tempranas	Acida
Venus®	Medias	Acida
Sweet Dream^{cov}	Medias	Dulce
Elegant Lady®	Medias	Acida
Honey Royale^{cov}	Medias	Dulce
Augustred®	Tardías	Dulce
Nectagala^{cov}	Tardías	Dulce
Nectalady^{cov}	Tardías	Dulce

3.3 Datos climatológicos

Las figuras 5 y 6 detallan los datos obtenidos en cuanto a la pluviometría y radiación global a través del periodo estival 2009 y 2010 en el área de Alcarràs.

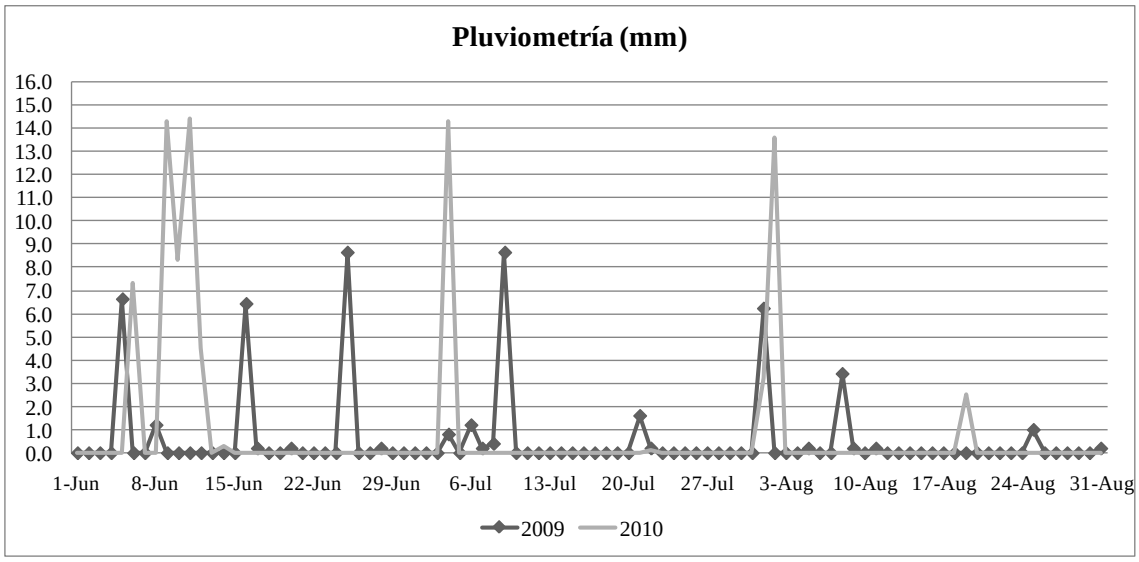


Figura 5. Variación de la pluviometría a través de los meses de junio, julio y agosto en los años 2009 y 2010.

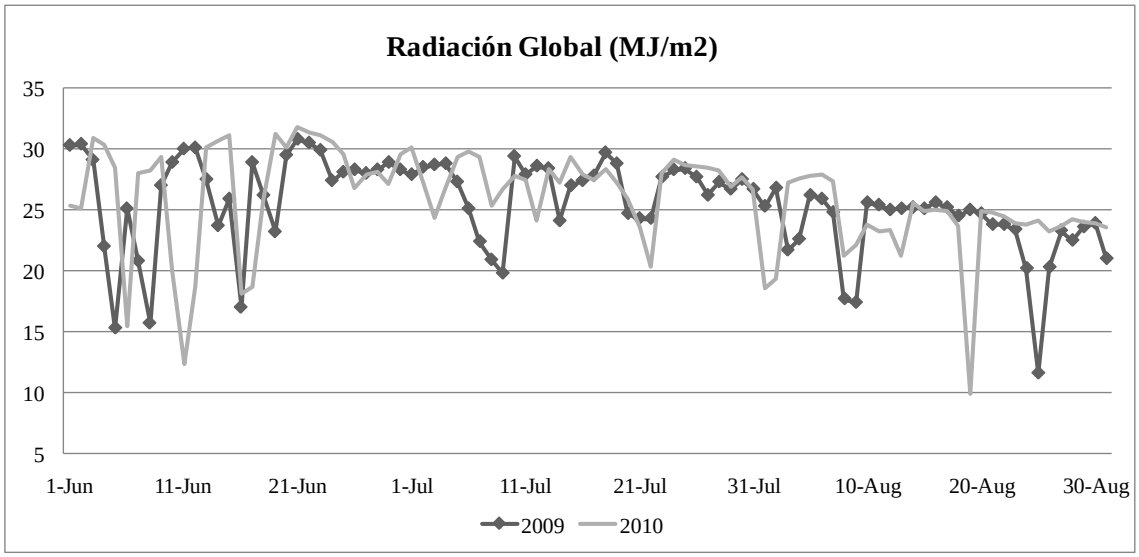


Figura 6. Variación de la radiación global a través de los meses de junio, julio y agosto en los años 2009 y 2010.

4. Resultados

Estudio 1

Caracterización varietal de melocotón y nectarina en cosecha.

CAPITULO I

Influence of volatile compound emissions and standard quality on consumer acceptance of peaches and nectarines.

Gemma Echeverría, Jaime Cano-Salazar, Luisa López y GeorginaAlins
Publicado en: *Acta Horticulturae* (en prensa)

ABSTRACT

In order to increase the satisfaction of fruit consumers, it is important to define the eating quality of fresh peaches and nectarines on the basis of consumer requirements and acceptance. With regard to eating quality, stone fruit flavour depends on a delicate balance of sugars, acids and aroma volatile compounds; a number of additional factors, such as pulp texture, also influence perceived quality. This research focuses on the evaluation of standard quality parameters and volatile compound emissions of eleven peach and nectarine cultivars and their influence on consumer acceptance. Fruits of the'Early Rich', 'Honey Blaze^{cov}', 'Elegant Lady', 'August Red', 'Royal Glory', 'Honey Royal', 'Venus', 'Big Top', 'Nectagala', 'Honey Blaze' and 'Nectalady' cultivars were picked at commercial harvest and analysed after 2 days at 20 ºC . A partial least square regression model (PLS1) was run in an attempt to correlate volatile compound emission and standard quality parameters, as X-variables, to consumer acceptance, studied as the Y-variable, and to thereby find the variables with the most weight for discriminating between cultivars. Higher acceptance scores, expressed as higher degrees of liking, were mainly associated with greater soluble solids contents and with higher emissions of delta-decalactone, gamma-dodecalactone, 1-pentanol, butyl octanoate, pentyl acetate, 2-methylpropyl hexanoate and ethyl octanoate.

Keywords: Consumer acceptance, Nectarine, Peach, Standard quality parameters, Volatile compounds.

INTRODUCTION

Quality parameters and aroma volatile compounds of peach and nectarine (*Prunus persica* L.) fruits play an important role in consumer satisfaction and influence further consumption. Taste, aroma, texture and appearance are generally considered to be the most important quality attributes of peach and nectarine fruits. Taste is related to water-soluble compounds. Aroma is elicited by compounds which exhibit some volatility.

In recent years, in order to offer the consumer a wider range of sensory perceptions, the increase in the production of stone fruit has included new cultivars with different flesh colours, flavours, soluble solids concentrations (SSC), and titratable acidities (TA). In spite of this, peach and nectarine consumption in the European Union has remained steady or even decreased (Liverani et al., 2002; Hilaire and Mathieu, 2004; Perez and Pollack, 2009). It is therefore very important to know the fruit characteristics that most influence consumer acceptance. Some relationships among the different quality attributes of peach fruits have already been studied. Bassi and Selli (1990) investigated the use of chemical (total sugars, acids and phenolics) and sensory evaluation (taste and astringency) in the assessment of fruit quality in different peach and apricot cultivars. Harker et al. (2002) compared instrumental and sensory measurements of apple taste and flavour.

The present research focuses on the evaluation of the standard quality parameters and volatile compound emissions of eleven peach and nectarine cultivars and their influence on consumer acceptance.

MATERIALS AND METHODS

Plant Material

Eleven peaches and nectarine commercial varieties (*Prunus persica* L. Batsch) were harvest from June to August in two different seasons in 2009 and 2010. Early season varieties were: 'Big Top®' (BT), 'Early Rich®' (ER), 'Honey Blaze^{cov}' (HB) and 'Royal Glory®' (RG), these varieties were harvested on 30th June 2009. Mid season harvesting varieties were: 'Sweet Dream^{cov}' (SD), 'Elegant Lady®' (EL), 'Venus®' (V) and 'Honey Royale^{cov}' (HR), and were harvested on 31th July 2009. Late season harvesting varieties were: 'August Red®' (AR), 'Nectagala^{cov}' (NG) and 'Nectalady^{cov}' (NL), these varieties were harvested on 31th August 2009. Dates of harvest in 2010 were similar to above exposed for 2009 season. Fruits were harvested when the firmness were between 38 to 50 N, considered as the optimal interval of firmness at harvest to store and preconditioning peaches and nectarines. At this stage of maturity fruit skin background color was yellow, in medium red cultivars or orange in more intense red cultivars. The eleven varieties were grown in commercial orchards at Alcarràs, Lleida, Catalonia (Spain). Trees were trained in an open vase spaced 5 x 3 m using the hybrid peach x almond INRA® GF-677 as a rootstock. Immediately after harvest, two lots of fruits of each cultivar were selected on the basis of uniformity and absence of defects. One of the lots was analyzed at the same day of harvest (H). The second lot was held at 20 ºC to simulate commercial ripening. Finally the analyses were carried out plus three days (H+2).

Analysis of volatile compounds

Six kilograms of fruit (2 kg per replicate × 3 replicates) per cultivar were selected for analysis of volatile compounds at harvest plus two days at 20 ºC. Intact

fruits were placed in an 8 L Pyrex container through which an air stream (150 mL min^{-1}) was passed for 60 min. The resulting effluent was passed through an adsorption tube filled with 350 mg of Tenax TA/Carbograph 1TD. The volatile compounds were desorbed into an Agilent 7890A gas chromatograph (Agilent Technologies, Inc., Barcelona, Spain) at 275 °C for 15 min, using an automated UNITY Markes thermal desorption system (Markes International Ltd., Llantrisant, U.K.). The identification and quantification of volatile compounds were performed on an Agilent 7890A gas chromatograph (Hewlett-Packard Co., Barcelona, Spain) equipped with a flame ionization detector (GC-FID), using a capillary column with cross-linked free fatty acid as the stationary phase (FFAP; 50 m × 0.2 mm × 0.33 μm). Helium was used as the carrier gas, at a flow rate of 42 cm s^{-1}, with a split ratio of 60:1. Both the injector and detector were kept at 240 °C. The analysis was conducted according to the following program: 40 °C (1 min); 40−115 °C (2.5 °C min^{-1}); 115−225 °C (8 °C min^{-1}); 225 °C (10 min). A second capillary column (SGE, Milton Keynes, U.K.) with 5% phenyl polysilphenylene-siloxane as the stationary phase (BPX5; 30 m × 0.25 mm i.d. × 0.25 μm) was also used for compound identification under the same operating conditions as described above.

Compounds were identified by comparing their respective retention indices with those of accepted standards and by enriching peach extract with authentic samples. Quantification was carried out using butyl benzene (assay >99.5%, Fluka) as an internal standard. Concentrations of volatile compounds were expressed as nanograms per kilogram. Compound confirmation was performed in an Agilent 6890N gas chromatograph−mass spectrometer (Agilent Technologies, Inc.), using the same capillary column as in the GC analyses. Mass spectra were obtained by electron impact ionization at 70 eV. Helium was used as the carrier gas (42 cm s^{-1}), following the same

temperature gradient program described previously. Spectrometric data were recorded (Hewlett-Packard 3398 GC Chemstation) and compared with those from the original NIST HP59943C library mass spectra. All standards for the volatile compounds were of analytical grade and were of the highest quality available. Ethyl acetate, propyl acetate, butyl acetate, hexyl acetate, ethyl 2-methylbutanoate, hexyl 2-methylbutanoate, 1-hexanol, 2-methyl-1-butanol, and 2-ethyl-1-hexanol were obtained from Fluka (Buchs, Switzerland). 2-Methylpropyl acetate was obtained from Avocado Research Chemicals Ltd. (Madrid, Spain) and decanoic acid was obtained from SAFC Supply Solutions (St. Louis, USA). The rest of the compounds were supplied by Sigma-Aldrich (Steinheim, Germany).

Physicochemical parameters

For each variety, fifteen fruits at harvest plus 48 hours at 20 ºC were individually assessed for flesh firmness, soluble solids content (SSC), titratable acidity (TA), and skin color. Flesh firmness was measured on opposite sides of each fruit with a digital penetrometer (model 53205; TR, Forli, Italy) equipped with an 8 mm diameter plunger tip; the results were expressed in newtons. SSC and TA were measured in juice pressed from whole fruits. SSC was determined with a Palette-10 hand refractometer (Atago PR-32, Tokyo, Japan), and the results were expressed as percent sucrose in an equivalent solution. TA was determined by titrating 10 mL of juice with 0.1 M NaOH to pH 8.1, and the results were given as grams of malic acid per liter.

Sensory analysis

Fruit samples from each variety in two different seasons (2009-2010) at harvest plus 48 hours at 20 ºC were subjected to consumer evaluation tests. Fifteen peaches from each treatment were used for sensory analysis. Prior to consumer evaluation, color

and flesh firmness were measured on both sides of each fruit. Then, two longitudinal wedges were taken to measure standard quality parameters as explained in the previous section. The rest of the fruits were used for the consumer evaluation. Two pieces of peach (one per cultivar from each harvest season) were placed on white plates and immediately presented to a tasting panel of 111 consumers. The consumers were all volunteers from the members of the staff at the UdL-IRTA research institute and students at the University of Lleida. All test participants were habitual (daily) peach consumers. Each piece was identified with a random three-digit code. The order of presentation of the two pieces of fruit on the white plate was randomized for each consumer. Mineral water was used as a palate cleanser between samples. All evaluations were conducted in individual booths under white-light illumination and at room temperature. To score the degree of consumer preference, each consumer tasted all samples and was asked to indicate his/her degree of like/dislike using a 9-point hedonic scale (from 1 = dislike extremely to 9 = like extremely).

Statistical Analysis

Results were treated by analysis of variance (GLM-ANOVA), followed by the least significant difference (LSD) test at $P< 0.05$. ANOVA was performed according to SAS/STAT 9.1 procedures (SAS Institute Inc., 2004). Unscrambler vers. 9.1.2. software (CAMO ASA, 2004) was used for the development of a Partial Least Square Regression model (PLS). This PLS was run in an attempt to correlate volatile compound emissions and standard quality parameters, as X-variables, to consumer acceptance, studied as the Y-variable, in order to find the variables that had most weight for discriminating

between cultivars. The samples were coded as explained in the Plant Material section.

RESULTS AND DISCUSSION

Standard Quality Parameters

No significant differences in SSC, TA or colour were detected in any of the varieties tested(Table 1). However, significant differences in firmness were observed. An important loss of firmness was detected between the harvest date plus 48 hours at 20 ºC for the varieties 'August Red', 'Elegant Lady', 'Honey Royal', 'Nectagala', 'Nectalady' and 'Venus'. For the rest of the varieties tested, no significant differences in firmness were detected.

Consumer Acceptance

Table 2 shows consumer acceptance scores for the 11 varieties analysed. It was observed that consumer acceptance scores were highest for fruits of the 'Nectalady' nectarine. The overall degree of liking remained acceptable (higher than 5 in a 9-point hedonic scale) for all the varieties except 'Big Top', 'Elegant Lady' and 'Royal Glory'. This low consumer acceptance of the latter varieties could have been due to a lack of ripeness at harvest.

Volatile compound emissions

A total of 43 volatile compounds were identified by GC-MS in the 11 varieties. The average number of volatiles per variety was 30, with a range of 23 to 37. The volatiles were widely distributed among the varieties, but only a small number of volatiles (5 to 9) contributed to more than 60 % of the total content. Many volatile compounds have already been reported in other peach varieties (Aubert and Milhet, 2007). All the samples had 16 volatiles in common: benzaldehyde, benzoic acid, naphthalene, acetophenone, acetic acid, hexenal, 2,3-butanodione, linalool, 2-ethyl-1-

hexanol, hexyl acetate, 2-methylbutyl 2-methylpropanoate, 2-ethyl-1-hexenal, 2-methylbutyl acetate, butyl acetate, 2-methylpropyl acetate and propyl acetate. The volatiles were classified into 6 chemical classes: terpenes, aldehydes, esters, alcohols, acids and ketones (data not shown).

Influence of standard quality parameters and volatile compounds on consumer acceptance

Figure 1 (A) shows a partial least square regression model (PLS) which was run in an attempt to correlate consumer acceptance, as the Y variable, to standard quality parameters and volatile compound emissions, as the X variables. Standard quality parameters and volatile compound emissions accounted for up to 89 % of the total variability in consumer acceptance. It was observed that the variables that most influenced consumer acceptance were soluble solids content (SSC), as a standard quality parameter, and delta-decalactone, gamma-dodecalactone, 1-pentanol, butyl octanoate, pentyl acetate and 2-methylpropyl hexanoate, as volatile compounds. The important influence of some volatile compounds and SSC on consumer acceptance has also been reported by other authors(Iglesias and Echeverria, 2009; Ortiz et al., 2009), who have respectively suggested that sugar content and some volatile compounds could be determining factors for consumer acceptance.

Figure 1 (B) shows the predicted versus measured consumer acceptance. This model revealed two groups exhibiting higher or lower levels of acceptance: the most accepted varieties (labelled as A in the Figure) and the least accepted varieties (labelled as B). The correlation coefficient (with the first 2 PCs) between the predicted and measured consumer acceptance was 0.95, and the RMSECV was 0.26 units of measure; these values supported the goodness of the model.

ACKNOWLEDGEMENTS

J. Cano is the recipient of a grant from the Agència de Gestió d'Ajuts Universitats i Recerca (AGAUR), Generalitat de Catalonia (Spain). This work was supported through project RTA 2008-00055-00-00 and funded by Spain's Instituto Nacional de Investigación Agraria (INIA). The authors are indebted to Mr. F. Florensa for technical assistance.

Literature Cited

Aubert, C., Milhet, C. 2007. Distribution of the volatile compounds in the different parts of a white-fleshed peach (Prunus persica L. Batsch). Food Chem. 102 (1): 375-381.

Bassi, D. and Selli, R. 1990. Evaluation of fruit quality in peach and apricot. Adv. Hort. Sci. 4:107–112.

CAMO ASA. 2004. Unscrambler Users Guide, ver. 9.1.2. Programme Package for Multivariate Calibration. Trondheim, Norway.

Echeverría, G., Graell, J., Lara, I. and López, M.L. 2008. Physicochemical measurements in 'Mondial Gala®' apples stored at different atmospheres: Influence on consumer acceptability. Postharvest Biol. Technol. 50: 135-144.

Harker, F.R., Marsh, K., Young, H., Murray, S.H., Gunson, F.A., Walker, S.B. 2002. Sensory interpretation of instrumental measurements: sweet and acid taste of apple fruit. Postharvest Biol. Technol. 24: 241-250.

Iglesias, I., Echeverria, G. 2009. Differential effect of cultivar and harvest date on nectarine colour, quality and consumer acceptance. Scientia Hort. 120: 41–50.

Lavilla, M.T., Recasens,I., López, M.L. and Puy, J. 2002. Multivariate analysis of maturity stages, including quality and aroma, in 'Royal Glory' peaches and 'Big Top' nectarines. J. Sci. Food Agric. 82:1842-1849.

Liverani, A., Giovannini, D., Brandi, F. 2002. Increasing fruit quality of peaches and nectarines: The main goals-of ISF-FO (Italy). Proceedings of the 5th International Peach Symposium, 592: 507-514.

Ortiz, A., Echeverría, G., López, M.L., Graell, J., Lara, I. 2009. Overall quality of 'Rich Lady' peach fruit after air- or CA storage. The importance of volatile emission. LWT - Food Sci. Technol. 42:1520-1529.

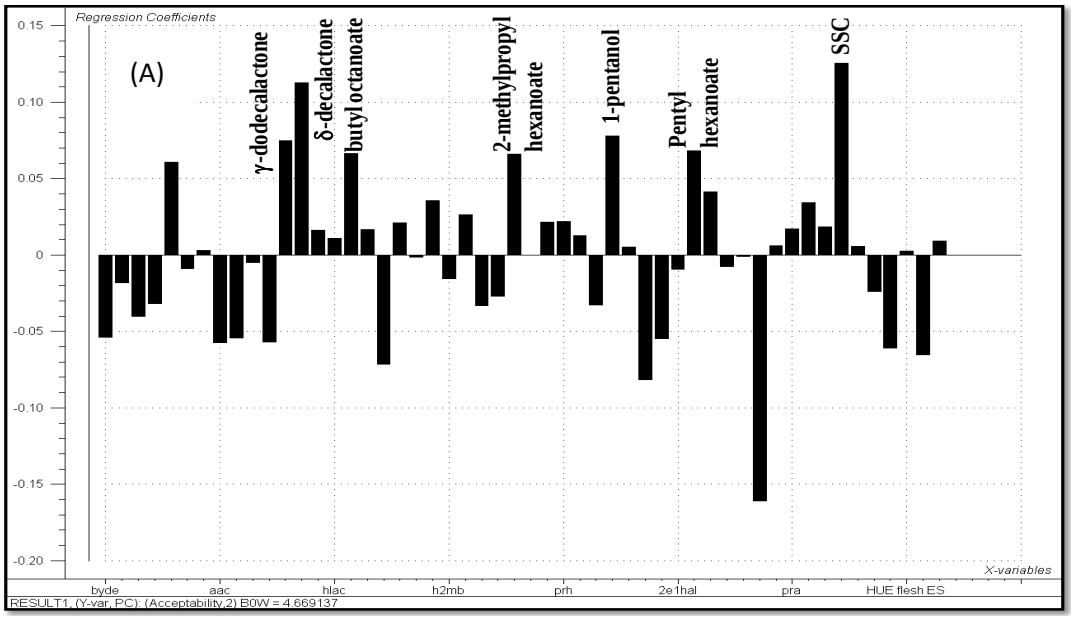
SAS Institute, Inc. 2004. SAS/STAT© 9.1 User's Guide. Cary, NC: SAS Institute Inc.

Table 1. Standard quality parameters of the 11 varieties analysed at harvest time and after 48 h of storage at 20 ºC. Data are means ± standard deviation for n=30. ES: exposed side and SS: shaded side.

AUGUST RED	SSC (ºBrix)	g malic acid/L	Firmness (N)	HUE skin ES	HUE flesh ES	HUE skin SS	HUE flesh SS
harv	12.5±0.7	11.2±1	47±6.6	28.3±9.9	87.6±5.8	79.4±11.1	90.6±2
harv+48h	12.8±0.9	12±0.9	29.3±7.2	36.3±14.9	90±2.2	87±7.4	90.4±1.2
BIG TOP							
harv	11.3±1.3	6.9±0.6	41.7±5.2	24.5±8.1	18.6±3.9	70.5±16	43.2±10.2
harv+48h	10.9±1.6	7.1±0.8	47.1±4.2	25.5±7.7	20.4±5.6	76.4±12	51.9±10
EARLY RICH							
harv	10.4±0.8	9.8±1.4	40.8±5.9	87.9±4	80.9±6.6	90.2±3.4	89.1±5.3
harv+48h	10.8±0.6	9.7±1.3	42.4±18.2	91.1±5.5	80.8±14	92.5±3.4	93.5±3.6
ELEGANT LADY							
harv	10.7±0.7	9.1±1.1	37.4±8.8	31.2±11.3	87.5±4.4	57.6±9.7	88.6±2.8
harv+48h	11.4±0.8	6.8±1	14.7±9.7	28±8.1	86.1±1.9	54.3±11.8	87.7±2
HONEY BLAZE							
harv	11.2±1.2	5.6±1.1	38.1±6	17.3±2.9	28.6±4.5	40.2±9.5	51.6±17.5
harv+48h	11±1.1	5.9±0.8	43.2±7.2	19.2±4.7	31.5±5.5	54.3±15.4	68.9±18.2
HONEY ROYAL							
harv	13.2±1.1	5.5±0.8	39.6±7.1	19.4±4.7	77.5±10	44.8±14.6	79.6±7.8
harv+48h	13.1±1.1	3.5±0.7	18.1±10.8	17±4.6	74.7±12.7	44.6±16.6	78.8±15.1
NECTA GALA							
harv	11.5±1	4.3±0.4	40.4±8.3	23.1±2.8	87.5±1.7	70.9±14.2	86.8±2.1
harv+48h	11.3±0.9	4.8±0.5	24.1±6.9	22.4±5.6	87.2±2.1	74.4±11.2	86.5±1.9
NECTA LADY							
harv	13.3±0.8	4.4±0.7	47.1±9.6	19.3±3.7	87.9±2.2	64.8±20	88.3±1.9
harv+48h	13.9±1.3	4.5±0.5	26.3±8	17.4±2.5	84.2±4.9	53.2±13.7	86.8±2.4
ROYAL GLORY							
harv	8.9±1.1	3.9±0.5	35.6±9.8	90.4±3.2	90.8±3.3	92.3±3.5	92.3±3.5
harv+48h	9.6±1.2	4.1±0.6	34.7±12.5	90.5±4.6	88.3±9.9	93.2±2.8	91.7±10.3
M-104							
harv	10.5±1.1	3.8±0.5	33.5±7	25.3±4.7	87.3±8.4	51.8±13.5	89.1±7.1
harv+48h	10.4±1.2	3.9±0.8	36.4±12.2	28.1±5.2	86±6.7	54.8±18.9	85±8.9
VENUS							
harv	11.6±0.6	10±0.5	39.2±11.1	23.5±5.5	84.2±2.3	60.5±10.4	85.4±1.9
harv+48h	11.9±0.7	9.4±0.9	28.7±13.8	19.9±6.5	84.4±4.4	68.7±12.6	87.1±2.2

Table 2. Consumer acceptance of the 11 varieties analysed at harvest time plus 48 h at 20 ºC. Consumers scored fruit slices on a nine-point hedonic scale (1, dislike extremely; 9, like extremely). Data are means ± standard deviation for n=60.

	Consumer acceptance
AUGUST RED	5.6±1.2
BIG TOP	4.7±1.5
EARLY RICH	5.9±1.2
ELEGANT LADY	4.6±1.9
HONEY BLAZE	5±1.3
HONEY ROYAL	6.3±1.5
NECTA GALA	5.5±1.7
NECTA LADY	7±1.2
ROYAL GLORY	3.8±1.5
M-104	5±1.2
VENUS	5.8±1.5



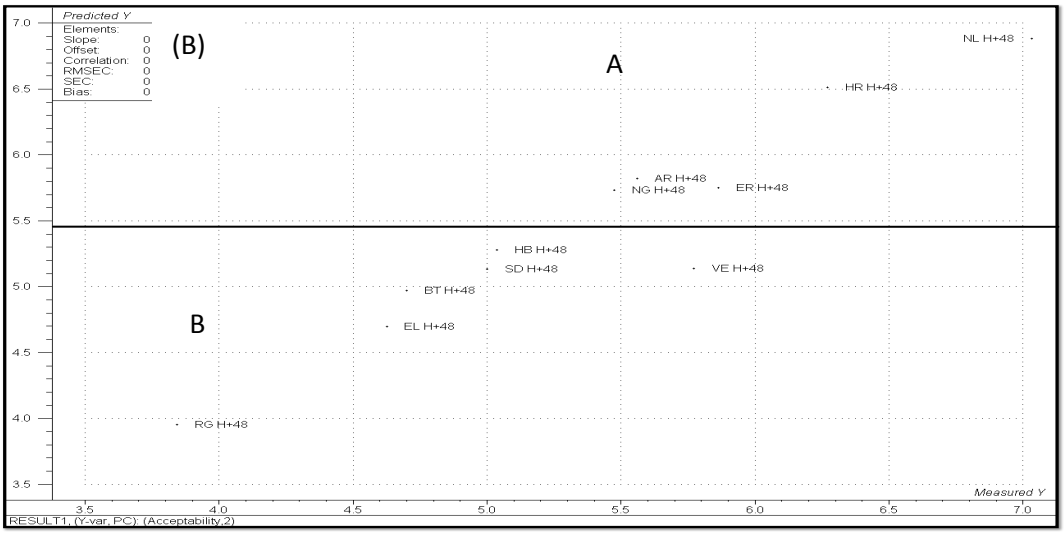


Figure 1. Partial least square regression model of all the samples. (A) Regression coefficients of PC1 vs. PC2 from a PLS model of consumer acceptance; (B) predicted vs. measured consumer acceptance using full cross-validation. Samples were labelled as described in 'Material and Methods' section.

Estudio 2

Efecto del sistema de conservación frigorífica en atmosfera normal.

2.1 En melocotón.

2.2 En nectarina.

CAPITULO II.1

Cold storage potential of four yellow-fleshed peach cultivars defined by their volatile compounds emissions, standard quality parameters, and consumer acceptance.

Jaime Cano-Salazar, Gemma Echeverría, Carlos H. Crisosto y Luisa López

Publicado en: *Journal of Agricultural and Food Chemistry* (2012) 60, 1266-1282.

ABSTRACT

'Early Rich®', 'Royal Glory®', 'Sweet Dream^{cov}', and 'Elegant Lady®' peaches were stored at -0.5 ºC for up to 40 days and then subjected to ripening at 20 ºC for up to three days. Firmness, soluble solids content (SSC), titratable acidity (TA), color, consumer acceptance, and volatile compounds were then determined. The observed physicochemical changes included a significant decrease in firmness during both storage and commercialization periods. In contrast, the SSC, TA, and color remained constant during storage. Ten days of cold storage produced the highest total volatile emissions and the greatest consumer acceptance for 'Elegant Lady®' and 'Sweet Dream^{cov}', while similar results were obtained after 40 days and 20 days for 'Royal Glory®' and 'Early Rich®', respectively. Volatile compounds that most consistently exhibited a positive correlation with consumer acceptance were depending on the cultivar.

Keywords: cold storage, consumer acceptance, peach, partial least square regression model, volatile compounds

INTRODUCTION

Peach (*Prunus persica* L. Batsch) is a climacteric stone fruit species that provides high nutrition and a pleasant flavor (*1*). Catalonia is the main peach-growing region in Spain, the second-largest producer of this fruit in the European Union. Catalonia has a total annual production of 206,816 t peaches, 23.4% of total Spanish peach production in 2008, and 83.3% of Catalan production is from Lleida province (*2*). The increasing peach production in Spain indicates that a larger percentage of total production will need to be stored for long periods to regulate commercial availability.Unfortunately, the peach fruit is characterized by high perishability due to its rapid loss of firmness during ripening. This favors spoilage and other physiological disorders and drastically restricts its storage potential and marketing possibilities (*3*). Low-temperature storage is the primary technique for delaying ripeningafter harvest. Maintaining low temperatures (-1 to +2 ºC) during storage is one of the main tools used to reducepostharvest deterioration and to maintain the overall quality and nutritional value offruits, since reducing their metabolic activity and respiration rate effectively slows downripening (*4*). However, the storage potential depends on the cultivar in question. The 'Royal Glory' peach maintains an acceptable appearance and eating quality even after six weeks of cold storage at 0 ºC plus five days of ripening at 25 ºC (*5*).

Aroma is one of the essential components of fruit quality (*6*). The relative contributions of specific volatile compounds to the flavor of peaches are cultivar-dependent (*6-9*). 'Early Rich®' is a peach with yellow flesh that produces hexyl acetate, Z-3-hexenyl acetate, γ-dodecalactone, linalool, γ-octalactone, Z-3-hexenol, δ-decalactone, and benzaldehyde, which are the key odorants in the essential oil of fruit at harvest date plus 24 h at 4 ºC (*8*). 'Royal Glory®' is an early season cultivar developed by Zaiger's, Inc. (CA, USA). It is a melting flesh variety. In this cultivar, the presence

of γ-decalactone, δ-octalactone, γ-octalactone, ethyl butyrate, hexanal, and (E)-2-hexenol is a good indicator of maturity at harvest (*9*). 'Elegant Lady®' is a mid-season, fresh, yellow-skinned, acidic cultivar which originates from Merrillin in 1979 (*10*). Most postharvest studies on this variety have been concerned with the development of rot (*11-13*), the effects of water stress on fruit quality (*14*), or the quality of fresh-cut peach (*15,16*). 'Sweet Dream' has red to dark maroon color skin and yellow with red blush flesh color. Fruit of this cultivar has relatively large size (average 255.2 g) with over 12% SSC (*17*).'Early Rich®', 'Elegant Lady®', 'Royal Glory®', and 'Sweet Dream' have higher yield than many other cultivars. Although the first comprehensive studies of peach volatile production were performed about 50 years ago (*18*), no studies on the relationships between volatile production, standard quality, and sensory evaluation in cold-stored peaches have been previously published in the literature to our knowledge.

The objectives of this study were to determine volatile compound emissions, standard quality measures, and consumer acceptance for 'Early Rich®', 'Royal Glory®', 'Elegant Lady®', and 'Sweet Dream^{cov}' peaches kept in cold storage for three different periods; to assess the relationships among sensory and instrumental qualities of cold-stored fruit using multivariate analysis; and to examine the efficacy of post-storage exposure of fruit to air at 20 ºC to stimulate volatile production after long-term storage.

MATERIAL AND METHODS

Plant Material and Storage Conditions. Peach fruits (*Prunus persica* L. Batsch) of 'Early Rich®' (ER) and 'Royal Glory®' (RG) were harvested on June 30, 2009, (115 and 125 days, respectively, after full bloom) and fruits of the 'Sweet Dream^{cov}' (SD)

and 'Elegant Lady®' (EL) were harvested on July 31,2009, (140 and 145 days, respectively, after full bloom), when most of fruit were ready to be harvested (turning from green to yellow and flesh firmness >33N). The four yellow-fleshed peach varieties were grown in commercial orchards at Alcarràs, Lleida, Catalonia (northeast Spain). Immediately after harvest, four 50-kg lots of each peach cultivar were selected on the basis of uniformity and the absence of defects. Three of these lots were stored at -0.5 ºC and 92 to 93% relative humidity in a cold air storage chamber of 22 m^3 (21 kPa O_2/0.03kPa CO_2). The other lot was analyzed at harvest (H). Samples were removed from storage after 10 (S10), 20 (S20), and 40 (S40) days and then transferred at 20 ºC to simulate commercialization period. Analyses were carried out at day 0 (SL0) and 3 (SL3) days thereafter.

Chemicals. All of the standards for the volatile compounds studied in this work were analytical grade or the highest quality available. Ethyl acetate, 2,3-butanodione, eucalyptol, butyl acetate, pentyl acetate, acetophenone, and γ-hexalactone were obtained from Fluka (Buchs, Switzerland). 2- Methylpropyl acetate was obtained from Avocado Research Chemicals, Ltd. (Madrid, Spain). 2-Ethyl-1-hexenal, Z-3-hexenyl acetate, methyl octanoate and decanoic acid were obtained from SAFC Supply Solutions (St. Louis, MO, USA). The rest of the compounds (up to 42) were supplied by Sigma-Aldrich (Steinheim, Germany).

Analysis of Volatile Compounds. Themeasurement of volatile compounds was carried out as described (*19*), with slight modifications. Six kilograms fruit (2 kg per replicate × 3) per storage period and cultivar were selected for analysis of volatile compounds, both at harvest and after removal from storage. Intact fruits were placed in an 8-L Pyrex

container through which an air stream (150 $mL \cdot min^{-1}$) was passed for 60 min. The resulting effluent was passed through an adsorption tube filled with 350 mg Tenax TA/ Carbograph 1TD. The volatile compounds were desorbed into an Agilent 7890A gas chromatograph (Agilent Technologies, Inc., Barcelona, Spain) at 275 ºC for 15 min, using an automated UNITY Markes thermal desorption system (Markes International Ltd., Llantrisant, United Kingdom). The identification and quantification of volatile compounds was performed on an Agilent 7890A gas chromatograph (Hewlett-Packard Co., Barcelona, Spain) equipped with a flame ionization detector (GC-FID), using a capillary column with cross-linked free fatty acid as the stationary phase (FFAP; 50 m × 0.2 mm × 0.33 μm). Helium was used as the carrier gas, at a flow rate of 42 $cm \cdot s^{-1}$, with a split ratio of 60:1. Both the injector and detector were kept at 240 ºC. The analysis was conducted according to the following program: 40 ºC (1 min); 40-115 ºC (2.5 $ºC \cdot min^{-1}$); 115-225 ºC (8 $ºC \cdot min^{-1}$); 225 ºC (10 min). A second capillary column (SGE, Milton Keynes, UK) with 5% phenyl polysilphenylene-siloxane as the stationary phase (BPX5; 30 m × 0.25 mm i.d. × 0.25 μm) was also used for compound identification under the same operating conditions as described above. Compounds were identified by comparing their respective retention indices with those of accepted standards and by enriching peach extract with authentic samples. Quantification was carried out using butyl benzene (assay > 99.5%, Fluka) as an internal standard while the concentrations of volatile compounds were expressed as $ng \cdot kg^{-1}$. Compound confirmation was performed in an Agilent 6890N gas chromatograph/mass spectrometer (Agilent Technologies, Inc.), using the same capillary column as in the GC analyses. Mass spectra were obtained by electron impact ionization at 70 eV. Helium was used as the carrier gas (42 $cm \cdot s^{-1}$), following the same temperature gradient program described previously.

Spectrometric data were recorded (Hewlett-Packard 3398 GC Chemstation) and compared with those from the original NIST HP59943C library mass spectra.

Analysis of Standard Quality Parameters. Fifteen fruits at harvest (harvest × commercialization period) and from each combination of factors (storage period × commercialization period) were individually assessed for flesh firmness, soluble solids content (SSC), titratable acidity (TA), and skin color. Flesh firmness was measured on opposite sides of each fruit with a digital penetrometer (Model***53205***;***TR***, Forlí, Italy) equipped with an 8-mm diameter plunger tip; the results were expressed in N. SSC and TA were measured in juice pressed from whole fruits. SSC was determined with a Palette-10 hand refractometer (Atago PR-32, Tokyo, Japan) and the results were expressed as percent sucrose in an equivalent solution. TA was determined by titrating 10 mL juice with 0.1 M NaOH to pH 8.1 and the results were given as percent malic acid. Fruit epidermis color was determined with a portable tri-stimulus colorimeter (Chroma Meter CR-400, Konica Minolta Sensing, Inc., Osaka, Japan) using CIE illuminant D_{65} with an 8-mm measuring aperture diameter. The skin color was measured at two points on the equator of each fruit which were 180º apart: one on the side exposed to sunlight (ES) and the other on the shaded side (SS). Hue angle was determined on both the exposed and the shaded sides and the resulting values were used as measurements of superficial and background color, respectively.

Sensory Analyses. For the consumer evaluation test, fruit samples from each cultivar at harvest and after the different cold storage periods were kept in a room at 20 ºC for three days. Fifteen peaches from each treatment were used for sensory analysis. Prior to consumer evaluation, color and flesh firmness were measured on both sides of each

fruit. Then, two longitudinal wedges were taken to measure standard quality parameters as explained in the previous section. The rest of the fruits were used for the consumer evaluation. Two pieces of peach (one per cultivar from each harvest season) were placed on white plates and immediately presented to a tasting panel of 111 consumers. The consumers were all volunteers from the members of the staff at the UdL-IRTA research institute and students at the University of Lleida. All test participants were habitual (daily) peach consumers. Each piece was identified with a random three-digit code. The order of presentation of the two pieces of fruit on the white plate was randomized for each consumer. Mineral water was used as palate cleansers between samples. All evaluations were conducted in individual booths under white-light illumination and at room temperature. To score the degree of consumer preference, each consumer tasted all samples and was asked to indicate his/her degree of like/dislike using a 9-point hedonic scale (1-dislike extremely to 9-like extremely).

Statistical Analyses. A multifactorial design was used to statistically analyze the results. The factors considered were cultivar, storage period, and commercialization period. All data were tested using analysis of variance (GLM-ANOVA procedure) with the SAS program package (*20*). Means were separated by the least significant difference (LSD) test at $p \leq 0.05$. Unscrambler version 9.1.2. software (*21*) was used to develop Partial Least Square Regression models (PLSR). These PLSR were run to correlate volatile compound emissions, as X-variables, to consumer acceptance, the Y-variable, to find the variables that had most weight for discriminating among storage periods for each cultivar. The samples were coded as explained above in the Plant Material and Storage Conditions section. The volatile compounds codes are in **Table 2**.

RESULTS AND DISCUSSION

Standard quality measures at harvest and after cold storage. At harvest time, no statistical differences were detected among the analyzed cultivars. Comparing firmness at harvest to that after different length of cold storage, the only cultivar that maintained firmness was 'Early Rich®'; the rest of cultivars had decreased firmness. The loss of firmness during cold storage is one of the most important changes observed in the standard quality measures (**Table 1**). The firmness of peaches from the four cultivars after cold storage plus three days at 20 ºC ranged from 7.9 to 22.6 N. These numbers are in line with those recommended by Crisosto (*22*) for peach consumption and peaches that are ready to buy, respectively. They also coincide with recommendations for the consumption of white peaches such as 'Snow King' and 'September Snow' (*23*). As expected, overall firmness decreased with days at 20 ºC for all four peach cultivars. During cold storage, the firmness of 'Elegant Lady®' and 'Sweet Dream^{cov}' declined, while increased firmness was observed for 'Early Rich®' and 'Royal Glory®'. These results could be explained as symptoms of chilling injuries (CI); these symptoms cause uneven ripening and dry textures in the fruits, which are often referred to as leatheriness (*24*). Ju and Duan (*25*) also reported that for 'Huangjin' peaches harvested at three different dates, the fruits that were picked earliest showed a greater tendency to be affected by leatheriness.

Generally speaking, days at 20 ºC did not negatively affect SSC, which remained constant; the exceptions were 'Early Rich®' and 'Elegant Lady®' fruits stored for 40 days, which showed slight decreases in SSC. In contrast, Crisosto and Crisosto (*26*) reported a slight increase in SSC during ripening after removal from cold storage; this was probably attributable to fruit shrivelling. Here, the storage period did not seem to

influence SSC (**Table 1**). These results are consistent with those previously reported by Robertson *et al*. (*3*), Malakou and Nanos (*27*), and Raffo *et al*. (*28*).

Titratable acidity (TA) generally decreased significantly during days at 20 ºC in acid cultivars ('Early Rich®' and 'Elegant Lady®'), but no significant differences were noted for sweet cultivars ('Royal Glory®' and 'Sweet Dream^{cov}'). Length of cold storage had no significant effect on TA after one day at 20 ºC except for 'Elegant Lady', in TA decreased with cold storage time. The decline in TA observed in 'Elegant Lady®' has also been reported in other peach cultivars during cold storage (*26, 27, 3*) and could be due to oxidation of organic acids (*26*).

The SSC:TA ratio was maintained through cold storage for 'Early Rich®' and 'Royal Glory®' but increased during longer cold storage times for 'Elegant Lady®' and 'Sweet Dream^{cov}', as previously reported in 'Harvester' peaches by Meredith *et al*. (*29*). Crisosto and Crisosto (*26*) reported a closer relationship between the SSC:TA ratio and eating quality than between TA or SSC considered separately.

No significant changes in skin hue were detected during storage. These results may be due to the fact that the studied cultivars are relatively new, released over the last several decades. This full red color provides more uniformity among the different cultivars and indicates that they undergo fewer changes during cold storage.

Volatile compounds emitted by peaches at harvest and after cold storage. Forty-two volatile compounds were identified and relatively quantified in both freshly harvested fruit (**Table 2**) and after cold storage (**Tables 3** and **4**). These compounds included 22 esters, four lactones, three aldehydes, two ketones, two terpenes, three acids, and six alcohols. It has been reported that more esters can be obtained by using headspace extraction rather than vacuum steam distillation (*30*). However, esters have been

identified as the main family contributing to the aroma of nine peach accessions using vacuum steam distillation as the extraction method (*8*).

The concentrations of volatile compounds emitted by 'Early Rich®', 'Royal Glory®', 'Sweet Dream^{cov}' and 'Elegant Lady®' peaches at harvest and after three days at 20 ºC are shown (**Table 2**). At harvest, the 'Early Rich®' and 'Royal Glory®' cultivars showed significantly lower total volatile compounds than 'Sweet Dream^{cov}' and 'Elegant Lady®'. However, after three days at 20 ºC, the total volatile concentration emitted by 'Early Rich®' increased three-fold, that of 'Royal Glory®' and 'Elegant Lady®' kept statistically stable, and that of 'Sweet Dream^{cov}' had declined two-fold. Infante *et al*. (*31*) on four different yellow-flesh peaches reported that the typical aroma of peach is develops after a variable period at 21 ºC. Quantitatively speaking, for all four cultivars the most important volatile compounds were hexyl acetate, 2-methylbutyl acetate, and ethyl octanoate, as esters; γ-hexalactone and γ-octalactone, as lactones; hexanal and 2-ethyl-1-hexenal, as aldehydes; 2,3-butanodione, as ketone, acetic acid, as a carboxylic acid; and 1-hexanol and 2-ethyl-1-hexanol, as alcohols. No clear preference in terpenes was detected. Differences in the emissions of volatile compounds were found both before and after cold storage as a function of early and mid season cultivars. At harvest, the total volatiles ranged from 8520 to 11256 ng·kg^{-1} for the two mid season peaches 'Sweet Dream^{cov}'and 'Elegant Lady®', respectively (**Table 2**). These values were 1.8 to 2.4 times higher than those of the early season peaches 'Early Rich®' and 'Royal Glory®'. Nevertheless, after 20 or 40 days of cold storage, the total volatile compound concentrations were 9360.3 and 7004.8 ng·kg^{-1} for the two early season peaches ('Early Rich®' and 'Royal Glory®'), respectively (**Tables 3** and **4**). These values were about double those for the mid season peaches 'Sweet Dream^{cov}'and 'Elegant Lady®' (3815 and 4392.8 ng·kg^{-1}, respectively). These results suggest that the

two early season peaches studied in this work could have more cold storage potential than the two mid season fruits.

Cold storage affected total volatile emissions in all four peach cultivars. After 40 days cold storage, total volatile emissions were 1.5 times higher than at harvest for 'Royal Glory®' and after 20 days storage; the same result was obtained for 'Early Rich®' (**Table 3**). The greatest increase in volatile compounds emitted by these early season cultivars was also obtained after 40 days for 'Royal Glory®' and 20 days for 'Early Rich®' (**Table 3**). In contrast, after 40 days at -0.5 ºC total volatile emissions were 2.5 times lower than at harvest in the 'Sweet Dream^{cov}' and 'Elegant Lady®' cultivars (**Table 4**). These results confirm those reported by Robertson *et al*. (*3*), who claimed that extending storage beyond four weeks would reduce the total volatile fraction of 'Cresthaven' peaches, although no similar reduction was observed between 20 and 40 days cold storage in 'Royal Glory®' fruits (**Table 3**).

Esters are chemical compounds responsible for fruity and floral aromas. Therefore, high ester concentrations should give the peaches a pleasant flavor (*32*). At harvest, ester compounds represented more than 68%, 36%, 34%, and 8% respectively of total volatile compounds in 'Sweet Dream^{cov}', 'Early Rich®', 'Royal Glory®' and 'Elegant Lady®' (**Table2**). Ethyl acetate (ea), hexyl hexanoate (hh), and ethyl octanoate (eo) represented 92% of the total esters in 'Sweet Dream^{cov}'. The main compound was ethyl acetate (58%), which is also the most abundant in 'Luxiang', a Chinese cultivar (*6*), and in 'Sunprice' peaches stored in a cold air atmosphere (*33*). However, the concentration of this ester was below its odor threshold of 13,500 $\mu g \cdot kg^{-1}$ (**Table 2**) and therefore would not have contributed to the aroma.

After cold storage, esters tended to predominate in the volatile profiles of acid cultivars 'Early Rich®' and 'Elegant Lady®' (**Tables 3** and **4**). The best storage period

for maximizing esters from these acid varieties was 20 days of cold storage. There were changes from the harvest ester composition during cold storage. For example, hexyl propanoate was detected for the first time after 10 days cold storage plus in 'Early Rich®' and after 20 days storage in 'Royal Glory®' (**Table 3**). Ethyl acetate was the most important ester detected in 'Royal Glory®' (20%) at harvest (**Table 2**), but it was not detected in this variety during cold storage (**Table 3**), nor was it detected after 40 days of cold storage plus 3 days of ripening at 20 ºC in any cultivar studied (**Tables 3** and **4**). In contrast, ethyl 2-methylbutanoate was initially absent at harvest (**Table 2**), but was found after cold storage (**Tables 3** and **4**). This branched-chain ester was present in the greatest quantities after 20 days at -0.5 ºC in 'Royal Glory®', regardless of the subsequent commercialization period, and after 40 days cold storage plus three days at 20 ºC in the other cultivars. Ethyl 2-methylbutanoate direct impacts peach flavor because it has a very low odor threshold (6 $ng \cdot kg^{-1}$; **Table 2**) and plays an important role in the characteristic aroma of many fruits (*34-37*).

Lactones are considered major contributors to peach aroma and the concentrations of γ-hexalactone and γ- and δ-decalactones are generally low at harvest and increase during fruit ripening (*38*). Four lactones were found in this study (**Table 2**) and these accounted for 0.5-3.5% of the total volatiles. Similar low proportions have also been reported by other researches (*6, 7*) and in our previous works on different peach cultivars (*39, 40*). Significant differences in lactones concentration were found among the four cultivars at harvest (**Table 2**), γ-hexalactone being the most important component, accounting for more than 80% of total lactones. 'Early Rich®' and 'Elegant Lady®'cultivars showed the highest concentrations of all detected lactones. Eduardo *et al.* (*8*), working with 'Early Rich®' cultivar, also obtained high emission of lactones. The latter result has remained consistent with two different methods of volatile

extraction: steam distillation (*8*) and headspace extraction (our results). Results from other authors also showed that γ- and δ-decalactones were the most important lactones of different origins (*6*).

The relative proportions of total volatile production consisting of lactones during cold storage and days at 20 ºC were similar to those achieved at harvest (**Tables 2-4**). After 40 days cold storage, total lactone concentrations were more than 2 times lower than after 10 days with the only exception being 'Sweet Dream^{cov}' when it was ripened for one day at 20 ºC (**Tables 3** and **4**). Raffo *et al.* (*28*) reported an increase in lactone fractions after seven days cold storage at 1 ºC in other yellow-fleshed cultivars, while after 14 days cold storage plus one day ripening at 22 ºC, the total lactone concentration was significantly lower than in fruits stored for seven days. Individual lactones did not contribute to these global changes in the same way. Lactones with shorter side chains, particularly γ-hexalactone, kept constant concentrations during storage in 'Royal Glory®' and 'Sweet Dream^{cov}', but declined in 'Early Rich®' and 'Elegant Lady®' peaches (**Tables 3** and **4**).

Terpenoids contribute the characteristic fruity aroma of peaches (*41*). At harvest, the two terpenes identified in the four cultivars, constituted more than 50% of the total volatile compounds emitted by 'Elegant Lady®' and conferred fruity citrus notes (**Table 2**). In contrast, these compounds represented 8.6%, 3%, and 0.8% of total volatile compounds in 'Royal Glory®', 'Sweet Dream^{cov}' and 'Early Rich®', respectively. The sum of terpenes in 'Elegant Lady®' was significantly greater than in the other cultivars at harvest (**Table 2**). The monoterpene linalool was the most abundant; its concentration was more than 20 times greater in 'Elegant Lady®' (6.1 $\mu g \cdot kg^{-1}$) than in the other cultivars (38.3-399 $ng \cdot kg^{-1}$). Linalool is one of the major compounds found in mature peaches (*3, 39*) and its predominance has also been noted in 'Early Rich®' (*8*) and

'Majestic' (by up to 30). During storage and days at 20 ºC, the relative proportion of total terpenes decreased from 29 to 0.1% ('Elegant Lady®'), 1.5 to 0.2% ('Royal Glory®'), and 0.7 to 0.2% ('Sweet Dream^{cov}'). Terpenes were not detected in samples of the 'Early Rich®' cultivar stored for 20 days at -0.5 ºC plus three days at 20 ºC (**Tables 3** and **4**). Eucalyptol was not detected in early season cultivars at harvest and was emitted after 3 days at 20 ºC (**Table 3**). Eucalyptol was identified in mid season cultivars at harvest and after cold storage in 'Elegant Lady®' (**Tables 2-4**).

The total aldehyde concentration accounted for 2 to 21% of the total volatile fraction at harvest and during cold storage (**Tables 2-4**) and depends on the genetic background (*6*). For 'Sweet Dream^{cov}' peaches, the three storage periods did not significantly influence benzaldehyde and the greatest amounts of 2-ethyl-1-hexenal were obtained after 10 days at -0.5ºC without days at 20 ºC for mid season cultivars. In previous studies carried out on another yellow-fleshed peach ('Spring Lady'), higher concentrations of hexanal and 2-ethyl-1-hexenal were obtained after 14 days cold storage at 1 ºC plus one day at 22 ºC than after 7 days (*28*). It is well-known that benzaldehyde is derived from cyanogenic glycoside, amydalin and prunasin, typical constituents of many *Prunus* species. Benzaldehyde is recognised as the almond aroma present in peach (*42*), but it was present in quantities above its odor threshold of 350 $\mu g \cdot kg^{-1}$ (**Table 2**) and would therefore not contribute to peach aroma.

Two ketones were detected in the four cultivars and account for 4 to 20% of total volatiles at harvest. During cold storage, the concentrations of 2,3-butanodione decreased in 'Early Rich®', 'Elegant Lady®', and 'Sweet Dream^{cov}' but increased in 'Royal Glory®' after 40 days of cold storage (**Tables 3** and **4**). The predominant ketone was 2,3-butanodione. This compound has a low odor threshold ($1 \mu g \cdot kg^{-1}$, **Table 1**) and would contribute buttery notes (*43*) to the aroma in 'Elegant Lady®' at harvest and after

10 days of cold storage, 'Royal Glory®' after 10 and 40 days of cold storage followed by 3 days at 20 ºC, and in 'Early Rich®' and 'Sweet Dream^{cov}' after 10 days of cold storage plus 3 days at 20 ºC (**Tables 2-4**). Nevertheless, to the best of our knowledge, no data have been reported on the effect of cold storage on its concentration in peach.

Six alcohol compounds accounted for ~ 1 to 20% of the total volatiles, depending on cultivar, cold storage period, and days at 20 ºC (**Tables 2-4**). No common trend was found for any of the detected alcohols, reflecting the different metabolic origins of these compounds. This is in accordance with previous work on 'Tardibelle' peach (*39*). During cold storage, the concentration of (Z)-3-hexen-1-ol kept constant in 'Sweet Dream^{cov}', increased in 'Royal Glory®', and declined in 'Elegant Lady®' and 'Early Rich®'. The C_6 alcohols contribute green sensory notes in ripening peach fruit (*38*). 1-Hexanol increased in 'Sweet Dream^{cov}' and 'Elegant Lady®' cultivars after 20 days of cold storage (**Table 4**). A similar trend was reported for 'Spring Lady' peaches after 14 days of cold storage plus 1 day at 22 ºC (*28*).

The relationship between consumer acceptance and volatile compounds emission. Because of the large amount of information obtained, five partial least squares regression (PLSR) models were used to correlate consumer acceptance (Y variable) to a set of potentially explanatory variables (X variables), including emission of volatile compounds. The first PLSR was run with the data obtained for the four cultivars at harvest. The rest of PLSR models were developed separately for each peach cultivar; in all models, the emission of volatile compounds and consumer acceptance were used to characterise the samples.

The first PLSR model for the harvest samples showed that 'Early Rich®' cultivar was perceived as being more appreciated by consumers, possibly due to higher

emissions of some volatile compounds such as γ-hexalactone, γ-octalactone, δ-decalactone, γ-dodecalactone, propyl acetate, 2-methylpropyl acetate, ethyl and hexyl 2-methylbutanoate, butyl hexanoate, pentyl hexanoate, hexyl hexanoate, ethyl octanoate, butyl octanoate, acetic acid, 1-hexanol and (Z)-3-hexen-1-ol (data not shown). This is in agreement with previous reports (*9*; *40*; *44*; *45*) that lactones, particularly γ- and δ-decalactone and γ- and δ-dodecalactone, are character impact compounds in peach aroma, often in association with other volatiles such as C_6 aldehydes, aliphatic alcohols, and terpenes. Odor descriptors for decalactones and dodecalactones include "peach" or "peach-like" (**Table 2**) and thus higher concentrations of these compounds are likely to influence the perception of a characteristic peach flavor by the consumer.

Because aroma perception is an important attribute for consumer acceptance of peaches, we investigated how volatile profile changes affect consumer acceptance. Special attention was focused on the emission of volatile compounds after storage, comparing the different cold storage periods among them and respect to harvest. To determine the volatile profile that most satisfied consumers for each cultivar, a PLSR model for cultivar (including harvest and cold storage samples) was carried out. The PLSR model obtained for 'Early Rich®' showed that volatile compound emissions accounted for up to 99% of the total variability in consumer preference (**Figure 1A**). 'Early Rich®' fruits maintained for 3 days at 20 ºC after harvest were situated on the right side of PC1 and were the most appreciated (**Figure 1B**). The bigger acceptability scores were related to higher emissions of propyl acetate, butyl and pentyl hexanoate, hexyl 2-methylbutanoate, ethyl and butyl octanoate, γ-octalactone, δ-dodecalactone, linalool, and (Z)-3-hexen-1-ol (**Figure 1C**).

The PLSR model obtained for 'Royal Glory®' showed that volatile compound emissions accounted for up to 99% of the total variability in consumer preference

(**Figure 2A**). 'Royal Glory®' samples after harvest were situated on the left side of the PC1 axis, which explained 83% of total variance. 'Royal Glory®' samples stored for 10, 20, and 40 days were located on the right side of PC1, away from the first group (**Figure 2A**). The **Figure 2B** shows that this later sample (stored for 40 days) was more appreciated by the participating consumers, possibly due to higher emissions of 2-methylpropyl, butyl and pentyl acetate, 2-ethyl-1-hexanal, 2,3-butanodione, eucaliptol, benzoic acid, 1-pentanol, and 1-hexanol (**Figure 2C**).

The PLSR model obtained for 'Elegant Lady®' showed that volatile compound emissions accounted for up to 95% of the total variability in consumer preference (**Figure 3A**). 'Elegant Lady®' cold stored for 10 days or just after harvest was situated on the right side of the PC1 axis, which explained 77% of total variance. In contrast, 'Elegant Lady®' samples stored for 20 and 40 days were located in the middle and the left side of PC1, respectively (**Figure 3A**). The corresponding loadings plot (**Figure 3B**) shows that 'Elegant Lady®' fruits cold stored for 10 days were more appreciated by the participating consumers, possibly due to higher emissions of ethyl and hexyl acetate, γ-hexalactone, γ-octalactone, 2-ethyl-1-hexanal, 2,3-butanodione, decanoic acid, 1-pentanol, 1-hexanol, and (Z)-3-hexen-1-ol (**Figure 3C**).

The PLSR model obtained for 'Sweet Dream^{cov}' showed that volatile compound emissions accounted for up to 100% of the total variability in consumer preference (**Figure 4A**). 'Sweet Dream^{cov}' samples cold stored for 10 days and just after harvest were situated on the right side of the PC1 axis, which explained 98% of total variance. In contrast, 'Sweet Dream^{cov}' samples stored for 20 and 40 days were located on the middle and the left side of the PC1 axis, respectively (**Figure 4A**). 'Sweet Dream^{cov}' fruits cold stored for 10 days were more appreciated by the participating consumers (**Figure 4B**), possibly due to higher emissions of ethyl and pentyl acetate, butyl

propanoate, butyl 2-methylbutanoate, 2,3-butanodione, acetophenone, acetic acid, and (Z)-3-hexen-1-ol (**Figure 4C**).

To summarise, we can note that quantitative criteria do not assure the contribution of major volatiles to consumer acceptance. In our study, the fruits most accepted by consumers were influenced for γ-hexalactone and (Z)-3-hexen-1-ol concentration in all the analyzed cultivars. However, these two volatile compounds are not major volatiles in the volatile fraction.

ACKNOWLEDGEMENTS

This work was supported through project RTA 2008-00055-00-00 and financed by Spain's *Instituto Nacional de Investigación Agraria* (INIA). J. Cano is the recipient of a PhD grant from the *Agència de Gestió d'Ajuts Universitaris i Recerca* (AGAUR), Generalitat de Catalonia (Spain). The authors are indebted to Mr. F. Florensa for technical assistance.

REFERENCES

(1) Wang, L.; Shuangjian, C.; Weifu, K.; Shaohua, L.; Douglas D. A. Salicilyc acid pretreatment alleviates chilling injury and effects the antioxidant system and heat shock proteins of peaches during cold storage. *Postharvest Biol. Technol.***2006**, *41*, 244–251.

(2) Anuario de estadística. Ministerio del Medio Ambiente y Medio Rural y Marino. http://www.marm.es/estadistica/pag/anuario/2009/ AE_2009_13_09_03.pdf.

(3)Robertson, J. A.; Meredith, F. I.; Horvat, R. J.; Senter S.D.Effect of cold storage and maturity on the physical and chemical characteristics and volatile constituents of peaches (cv. Cresthaven) *J. Agric. Food Chem.***1990,** *38*, 620–624.

(4) Lurie, S.; Crisosto,C. H. Review. Chilling injury in peach and nectarine. *Postharvest Biol. Technol.***2005**, *37*, 195–208.

(5) Manganaris, G.A.; Vasilakakis, M.; Mignani I.; ManganarisA. Cell Wall Physicochemical Properties as Indicators of Peach Quality During Fruit Ripening after Cold Storage. *Food Sci. Tech. Int.***2008**, *14*, 385–391.

(6) Wang, Y.; Yang , C.; Li S.; Yang , L.; Wang, Y.; Zhao , J.; Jiang, Q.Volatile characteristics of 50 peaches and nectarines evaluated by HP-SPME with GC-MS.*Food Chem.***2009**, *116*, 356–364.

(7) Aubert, C.; Milhet, C.Distribution of the volatile compounds in the different parts of a white-fleshed peach (Prunus persica L. Batsch).*Food Chem.***2007**, *102*, 375–384.

(8) Eduardo, I.; Chietera, G.; Bassi, D.; Rossini, L.; Vecchiettia A.Identification of key odor volatile compounds in the essential oil of nine peach accessions.*J. Sci. Food Agric.* **2010**, *90*, 1146–1154.

(9) Lavilla, T.; Recasens, I.; Lopez, M.L.; Puy, J. Multivariate analysis of maturity stages, including quality and aroma, in 'Royal Glory' peaches and 'Big Top' nectarines. *J. Sci. Food Agric.* **2002**,*82*,1842–1849.

(10) Sansavini, S.; Gamberini, A.; Bassi, D. Peach Breeding, Genetics and New Cultivar Trends. *Acta Hort.***2006,** *713*,23–48.

(11) Ju, Z.; Duan, Y.; Ju, Z.; Guo, A.Different responses of 'Snow Giant' and 'Elegant Lady' peaches to fruit maturity and storage temperature.*J. Hortic. Sci. Biotechnol.* **2001**, *76*, 575–580.

(12) Palou, L.; Crisosto, C.H.; Smilanick, J. L. Adaskaveg, J. E.; Zoffoli J. P. Effects of continuous 0.3 ppm ozone exposure on decay development and physiological responses of peaches and table grapes in cold storage. *Postharvest Biol. Technol.***2002**, *24*, 39–48.

(13) Palou, L.; Crisosto, C.H.; Garner, D.; Basinal L. M. Effect of continuous exposure to exogenous ethylene during cold storage on postharvest decay development and quality attributes of stone fruits and table grapes. *Postharvest Biol. Technol.***2003**, *27*, 243–254.

(14) Mahhou, A.; DeJong, T.M.; Shackel, K.S.; Cao, T.Water stress and crop load effects on yield and fruit quality of Elegant Lady Peach [Prunus persica (L.) Batch].*Fruits.***2006**,*61*, 407–418.

(15) Gorny, J.R.; Hess-Pierce, B.; Kader, A.A.Quality changes in fresh-cut peach and nectarine slices as affected by cultivar, storage atmosphere and chemical treatments.*J. Food Sci.* **1999**, *64*, 429–432.

(16) Alegre, I.; Abadias, M.; Anguera, M.; Usall, J.; Viñas, I. Fate of Escherichia coli O157:H7, Salmonella and Listeria innocua on minimally-processed peaches under different storage conditions. *Food Microbiology*, **2010**, *27*, 862–868

(17) Fallahi, E.; Fallahi, B.; Shafii, B.; Amin, M.E. Bloom and Harvest Dates, Fruit Quality Attributes, and Yield of Modern Peach Cultivars in the Intermountain Western United States. *HortTech.***2009**, *19*, 823–830.

(18) Guadagni, D.G.; Dimick, K.P. Apparatus and Procedure for Separation and Estimation of Volatile Components. *Fruit Flavors*. **1953**, *1*, 1169–1170.

(19) Altisent, R.; Echeverria, G.; Graell, J.; López, L.; Lara I. Lipoxygenase Activity Is Involved in the Regeneration of Volatile Ester-Synthesizing Capacity after Ultra-Low Oxygen Storage of 'Fuji' Apple.*J. Agric. Food Chem.* **2009**, *57*,4305–4312.

(20) SAS Institute, Inc. SAS *9.1. Qualification Tools User's Guide;* SAS Institute: Cary, NC. 2004.

(21)CAMO ASA. *Unscrambler Users Guide, ver. 9.1.2. Programme Package for Multivariate Calibration*. Trondheim, Norway.2004.

(22)Crisosto, C. H. How do we increase peach consumption? Proceeding of 5th International Symposium on Peach, ISHS, *Acta Hort.***2002**, *592*, 601–605.

(23) Garner, D.; Crisosto, C. H.; Otieza, E. Controled atmosphere storage and aminoethoxyvinyl-Glicine postharvest dip delay post cold storage softening of 'SnowKing' peach.*HortTech.* **2001**,*11*, 598–602

(24)Luza, J. D.; Van Gorsel, R.; Polito, V. S.; Kader, A.A. Chilling Injury in peaches: a cytochemical and ultraestructural cell wall study.*J. Am. Soc. Hort. Sci.* **1992**, *117*, 114–118.

(25) Ju, Z.; Duan, Y. Z. Leatheriness and mealiness of peaches in relation to fruit maturity and storage temperature.*J. Hort. Sci. Biotech.* **2000**, *75*, 86–91.

(26) Crisosto, C. H.; Crisosto G. M.Relationship between ripe soluble solids concentration (RSSC) and consumer acceptance of high and low acid melting

flesh peach and nectarine (*Prunus persica* (L.) Batsch) cultivars. *Postharvest Biol. Technol.***2005**, *38*, 239–246.

(27) Malakou, A.; Nanos, G. D. A combination of hot water treatment and modified atmosphere packaging maintains quality of advanced maturity 'Caldesi 2000' nectarines and 'Royal Glory' peaches. *Postharvest Biol. Technol*. **2005**, *38*, 106–114.

(28) Raffo, A.; Nardo, N.; Tabilio, M. R.; Paoletti, F.Effects of cold storage on aroma compounds of white- and yellow-fleshed peaches.*Eur. Food Res. Technol.* **2008,** *226*, 1503–1512.

(29) Meredith, F. I.; Robertson, J. A.; Hovart, R. J. Changes in Physical and chemical parameters associated with quality and postharvest ripening of harvester peaches. *J. Agric. Food Chem.***1989**, *37*, 1210–1212.

(30) Takeoka, G.R.; Flath, R.A.; Gunter, M.; Jennings, W. Nectarine volatiles: vacuum steam distillation versus headspace sampling. *J. Agric. Food Chem.*, **1988**, *36*, 553–560.

(31) Infante, R.; Farcuh, M.; Meneses, C. Monitoring the sensorial quality and aroma through an electronic nose in peaches during cold storage.*J. Sci. Food Agric.* **2008**,*88*,2073–2078.

(32) Sumitani, H.; Suekane, S.; Nakatani, A.; Tatsukat,K. Changes in Composition of Volatile Compounds in High Pressure Treated Peach.*J. Agric. Food Chem.*, **1994**, *42*, 785–790.

(33) Yang, D.S.; Balandrán-Quintana, R.R.; Ruíz, C.F.; Toledo, R.T.; Kays,S.J. Effect of hyperbaric controlled and UV treatments of peach volatiles. *Postharvest Biol. Technol*. **2009**, *51*, 334–341.

(34) Wang, Y.; Finn, C.; Qian, M. C. Impact of growing environment on Chickasaw blackberry (Rubus L) aroma evaluated by gas chromatography olfactometry dilution analysis. *J. Agric. Food Chem.* **2005**, *53*, 3563–3571.

(35) Tokitomo, Y.; Steinhaus, M.; Büttner, A.; Schieberle, P. Odor-active constituents in fresh pineapple (Ananas comosus [L.] Merr.) by quantitative and sensory evaluation.*Biosci. Biotechnol. Biochem.***2005**, *69*,1323–1330.

(36) Hinterholzer, A.; Schieberle, P.Identification of the most odour-active volatiles in fresh, hand-extracted juice of Valencia late oranges by odour dilution techniques. *Flavour Fragrance J.***1998**, *13*, 49–55.

(37) Echeverria, G., Correa, E.; Ruíz-Altisent, M.; Graell, J.; Puy, J.; López, L.Characterization of Fuji Apples from Different Harvest Dates and Storage Conditions from Measurements of Volatiles by Gas Chromatography and Electronic Nose. *J. Agric. Food Chem.* **2004**, *52*, 3069–3076.

(38) Zhang, B.; Shen, J. Y.; Wei, W. W.; Xi, W. P.; Xu, C. J.; Ferguson, I.; Chen, K. Expression of Genes Associated with Aroma Formation Derived from the Fatty Acid Pathway during Peach Fruit Ripening *J. Agric. Food Chem.* **2010**, *58*, 6157–6165.

(39) Ortiz, A.; Graell, J.; López, M.L.; Echeverría, G.; Lara, I. Volatile ester-synthesising capacity in 'Tardibelle' peach fruit in response to controlled atmosphere and 1-MCP treatment. *Food Chem*. **2010**, *123*, 698–704.

(40) Ortiz, A.; Echeverría, G.; López, M. L.; Graell, J.; Lara, I. Overall quality of 'Rich Lady' peach fruit after air- or CA storage. The importance of volatile emission. *LWT - Food Science and Technology***2009**, *42*, 1520–1529.

(41) Engel, K. H.; Flath, R. A.; Buttery, R. G.; Mon, T. R.; Ramming, D.W.; Teranishi. R. Investigation of Volatile Constituents in Nectarines. 1. Analytical

and Sensory Characterization of Aroma Components in Some Nectarine Cultivars.*J. Agric. Food Chem.***1988,** *36*, 549–553.

(42) Spencer, M.D.; Pangborn, R.M.; Jennings, W.G.Gas Chromatographic and Sensory Analysis of Volatiles from Cling Peaches.*J. Agric. Food Chem.***1978,** *26*, 725–732.

(43) Czerny,M.; Christlbauer,M.; Christlbauer,M.; Fischer,A.; Granvogl,M.; Hammer,M.; Hartl,C.; Hernandez, N.M.; Schieberle, P.Re-investigation on odour thresholds of key food aroma compounds and development of an aroma language based on odour qualities of defined aqueous odorant solutions.*Eur. Food Res. Technol*. **2008**, *228*, 265–273.

(44) Aubert, C.; Günata, Z.; Ambid, C.; Baumes, R. Changes in physicochemical characteristics and volatile constituents of yellow- and white-fleshed nectarines during maturation and artificial ripening. J. Agric. Food Chem. **2003**, *51*, 3083–3091.

(45) Rizzolo, A.; Eccher Zerbini, P.; Grassi, M.; Cambiaghi, P.; Bianchi, G.Effect of 1-Methylcyclopropene on Aroma Compounds in "Big Top" Nectarines After Shelf Life.*J. Food Qual.***2006**, *29***,** 184–202.

(46) Villatoro, C.; López, M.L.; Echeverría, G.; Lara, I.; Graell, J. Effect of controlled atmospheres and shelf life period on concentrations of volatile substances released by 'Pink Lady®' apples on consumer acceptance. *J. Sci. Food Agric.* **2009**, *89*, 1023–1034.

(47) Burdock. G.A. *Handbook of Flavor Ingredients*. 4th ed. CRC Pres. Washington. USA. 2002.

(48)Greger, V.; Schieberle, P. Characterization of key aroma compounds in apricots (*Prunus armeniaca*) by application of molecular sensory science concept.*J. Agric. Food Chem.* **2007**, *55*, 5221–5228.

(49) Buttery, R.G.; Turnbaugh, J.G.; Ling, L.C. Contribution of Volatiles to Rice Aroma. *J. Agric. Food Chem.*, **1988**, *36*, 1006–1009.

Table 1. Standard Quality Parameters of 'Early Rich®', 'Royal Glory®', 'Elegant Lady®', and 'Sweet Dream^{cov}' Peaches at Harvest and after Storage at -0.5 ºC for 10, 20 and 40 Days plus 0 and 3 Days at 20 ºC .

Cultivar	Quality parameter	At harvest		10		20		40	
		0	3	0	3	0	3	0	3
Early Rich®	SSC	10.4 b	10.8 b	11.1 b	10.9 b	11.5 ab	11.1 b	12.1 a	11.1 b
	TA	9.8 a	9.7 a	8.3 ab	6.4 e	9.2 a	7.3 cd	8.2 bc	7.0 de
	SSC/TA	1.0 b	1.1 b	1.3 b	1.7 a	1.2 b	1.5 ab	1.5 ab	1.6 a
	Firmness	40.8 a	42.7 a	23.0 bc	11.7 d	35.8 ab	19.3 cd	37.8 a	15.3 cd
	Hue Skin (ES)	87.9 a	91.1 a	17.8 b	18.4 b	22.1 b	21.6 b	37.6 b	20.3 b
	Hue Skin (SS)	90.2 a	92.5 a	46.5 b	37.8 b	45.5 b	40.1 b	20.4 b	37.8 b
Elegant Lady®	SSC	10.7 c	11.4 c	10.6 c	12.1 bc	10.9 c	11.1 c	14.2 ab	11.5 c
	TA	9.1 a	6.8 c	8.4 a	6.7 c	7.1 bc	5.2 d	6.6 c	4.3 d
	SSC/TA	1.2 d	1.7 d	1.3 d	1.8 cd	1.5 c	2.3 bc	2.1 a	2.6 b
	Firmness	37.4 a	14.7 bc	26.1 b	8.5 c	23.8 b	7.9 c	20.9 b	21.4 b
	Hue Skin (ES)	31.2 a	28.0 ab	31.9 a	26.9 bc	28.9 ab	30.0 ab	15.4 c	31.8 a
	Hue Skin (SS)	57.6 a	54.3 a	50.0 a	48.6 a	47.1 a	54.5 a	46.7 a	47.4 a
Royal Glory®	SSC	8.9 a	9.6 a	9.9 a	9.0 a	9.3 a	9.2 a	9.9 a	9.6 a
	TA	3.9 a	4.1 a	2.8 a	3.1 a	3.2 a	2.7 a	2.6 a	3.3 a
	SSC/TA	2.3 b	2.3 b	3.5 a	2.9 b	2.9 b	3.4 ab	3.8 a	2.9 b
	Firmness	35.6 ab	34.7 ab	36.1 ab	11.7 d	22.6 c	21.0 c	37.7 a	22.6 c
	Hue Skin (ES)	90.4 a	90.5 a	31.2 b	29.9 b	36.6 b	30.4 b	30.0 b	29.2 b
	Hue Skin (SS)	92.3 a	93.2 a	52.3 b	49.4 b	62.5 b	47.7 b	51.2 b	50.9 b
Sweet Dream^{cov}	SSC	10.5 ab	10.4 ab	9.7 b	11.6 a	11.2 ab	10.6 ab	11.1 ab	11.5 ab
	TA	3.8 ab	3.9 ab	3.2 b	3.1 b	2.2 b	2.9 b	2.3 b	2.7 b
	SSC/TA	2.8 c	2.7 c	3.0 bc	3.7 b	5.1 a	3.6 b	4.8 a	4.2 b
	Firmness	33.5 a	36.4 a	30.9 a	11.5 d	25.3 abc	17.2 cd	21.0 bcd	21.4 bcd
	Hue Skin (ES)	25.3 bc	28.1 bc	23.7 bc	47.8 a	30.1 bc	21.8 c	22.1 c	26.2 bc
	Hue Skin (SS)	51.8 a	54.0 a	53.1 a	45.9 ab	45.8 ab	41.1 b	51.4 ab	50.1 ab

Means followed by different small letters for each quality parameter are significantly different at $P \leq 0.05$ (LSD test). ES: exposed side; SS: shaded side.

Table 2. Volatile Compounds Emitted (ng·kg^{-1}) by Four Peach Cultivars after Harvest plus 0 and 3 Days at 20 ºC. Retention Index[a,b], Codes using for PCA Analyses, OTH[c], and Relative Proportion (%) of the Main Families of Compounds in Brackets.

				Early Rich®		Royal Glory®		Sweet Dream™		Elegant Lady®			
Compounds	**RI[a]**	**RI[b]**	**Codes**	**0**	**3**	**0**	**3**	**0**	**3**	**0**	**3**	**OTH[c]**	**CAS Number**
Ethyl acetate	911	-	ea	nd	nd	599.0 Ba	147.2 Ab	5049.2 Aa	nd	nd	nd	13500[d]	141-78-6
Propyl acetate	995	766	pra	18.9 Ab	791.7 Aa	22.1 Aa	12.2 Ba	56.1 Aa	24.9 Ba	49.6 Aa	29.2 Ba	2000[d]	109-60-4
2,3-Butanodione	999	1067	23bone	240.8 Ba	418.2 Ba	873.3 ABa	957.6 Aa	368.9 Ba	273.1 Ba	1114.2 Aa	863.6 Aa	1[f]	431-03-8
Eucalyptol	1032	1105	euOH	nd	21.4 Ba	nd	1703.4 Ba	21.4 Ab	587.0 Ba	< 10 Ab	3517.8 Aa	1[g]	470-82-6
2-Methylpropyl acetate	1052	789	2mpra	25.7 Ab	173.7 Aa	21.7 Aa	24.9 Ba	15.7 Ab	50.7 Ba	27.8 Ab	116 ABa	65[d]	110-19-0
Hexanal	1082	807	hnal	672.1 Aa	340.0 Ab	214.7 Ba	226.4 Aa	184.9 Ba	169.8 Aa	204.9 Ba	308.5 Aa	2.4[f]	66-25-1
Ethyl 2-methylbutanoate	1127	847	e2mb	< 10 Aa	< 10 Aa	nd	nd	nd	nd	nd	nd	0.006[d]	7452-79-1
Butyl acetate	1183	816	ba	51.6 Aa	57.2 Aa	68.5 Aa	32.1 Aa	40.2 Aa	33.2 Aa	67.4 Aa	87.7 Aa	66[d]	123-86-4
2-Methylbutyl acetate	1240	879	2mba	96.4 Aa	147.1 Aa	30.3 Cb	78.5 Aa	69.8 BCa	21.9 Ab	86.4 ABa	47.8 Aa	11[d]	123-92-2
Butyl propanoate	1257	912	bpr	37.1 Aa	< 10 Aa	50.1 Aa	< 10 Ab	nd	nd	nd	nd	25[d]	590-01-2
2-Ethyl-1-hexenal	1293	1033	2e1hal	240.7 Ba	179.9 ABa	109.0 Ca	94.8 Ba	256.8 Ba	148.6 Bb	839.9 Aa	263.4 Ab	nf	123-05-7
Pentyl acetate	1307	917	pa	15.9 Aa	17.0 Aa	15.1 Aa	9.8 Aa	14.7 Aa	< 10 Aa	17.4 Aa	22.2 Aa	43[d]	628-63-7
2-Methylbutyl-2-methylpropanoate	1310	1043	2mb2mpr	42.4 Ba	30.9 Aa	314.9 Aa	98.8 Ab	nd	18.0 Aa	105.0 Bb	51.1 Aa	14[g]	2445-78-5
2-Methyl-1-butanol	1329	776	2mbOH	nd	10.2 Ba	12.5 Ab	44.9 Aa	nd	nd	nd	nd	250[d]	137-32-6
Butyl 2-methylbutanoate	1348	1017	b2mb	16.4 Aa	17.4 Ba	29.4 Ab	92.4 Aa	nd	nd	21.7 Aa	nd	17[d]	15706-73-7
1-Pentanol	1375	788	pOH	27.2 Aa	23.3 Aa	13.9 Aa	11.9 Aa	nd	nd	nd	16.7 Aa	4000[j]	71-41-0
Hexyl acetate	1393	1016	ha	127.9 Aa	127.7 Aa	108.1 Aa	68.1 Aa	79.7 Aa	70.0 Aa	126.2 Aa	193.4 Aa	2[d]	142-92-7
2-Methylbuyl-2-methylbutanoate	1397	1123	2mb2mb	< 10 Aa	< 10 Aa	nd	< 10 Aa	nd	nd	14.4 Aa	< 10 Aa	nf	2445-78-5
Acetic acid	1432	-	aac	616.4 Bb	993.2 Aa	554.3 Ba	589.3 Aa	864.2 ABb	1309.9 Aa	1111.2 Aa	1325.7 Aa	99000[f]	64-19-7
Propyl hexanoate	1440	1099	prh	39.1 Ab	186.1 Aa	51.2 Ab	184.4 Aa	nd	nd	nd	nd	nf	626-77-7
Z-3-hexenyl acetate	1457	1020	z3hxea	89.1 Aa	80.1 Aa	59.3 Aa	57.8 Aa	17.7 Aa	nd	47.0 Aa	nd	13[f]	3681-71-8
1-Hexanol	1480	873	hOH	64.0 Aa	50.4 Aa	27.7 Ba	< 10 Ab	nd	19.4 Aa	18.9 Bb	41.1 Aa	500[d]	111-27-3
Methyl octanoate	1511	1128	mo	38.5 Aa	13.1 Aa	33.5 Aa	41.3 Aa	16.5 Aa	nd	34.6 Aa	33.9 Aa	200[g]	111-11-5
Z-3-hexen-1-ol	1513	857	z3henOH	nd	15.9 Ba	nd	18.6 Ba	nd	26.1 Ba	19.5 Ab	77.6 Aa	70[i]	928-96-2
Benzaldehyde	1521	971	byde	92.0 Aa	60.8 Ba	199.4 Aa	220.4 Aa	51.6 Aa	68.8 Ba	64.7 Aa	109.2 ABa	350[i]	100-52-7
Butyl hexanoate	1533	1293	bh	53.8 Aa	73.0 Aa	< 10 Ba	10.4 Ba	< 10 Ba	< 10 Ba	nd	nd	700[d]	626-82-4
Hexyl 2-methylbutanoate	1546	1239	h2mb	280.7 Aa	359.9 Aa	12.9 Bb	61.2 Ba	71.8 ABa	66.9 Ba	nd	56.4 Ba	22[g]	10032-12-0
Ethyl octanoate	1555	1003	eo	376.7 Ab	8671.2 Aa	113.8 Ba	101.7 Ba	221.9 ABa	75.8 Bb	307.3 Aa	200.5 Ba	nf	106-32-1
Benzoic acid	1560	1193	bac	246.8 Aa	132.1 Ba	286.2 Aa	294.2 Aa	311.5 Aa	295.4 Aa	245.8 Aa	365.5 Aa	85000[g]	65-85-0
2-Ethyl-1-hexanol	1619	1033	2ehOH	583.9 Aa	661.7 Aa	167.0 Ba	147.5 Aa	262 Bb	312.9 Aa	134.5 Bb	456.1 Aa	nf	104-76-4
Pentyl hexanoate	1637	1014	ph	26.6 Aa	33.4 Aa	nd	< 10 Aa	nd	nd	nd	nd	nf	540-07-8
(R)-Linalool	1679	-	liOH	38.3 Da	nd	399.0 Ba	nd	220.7 Ca	nd	6058.5 Aa	84.9 Ab	0.087[f]	126-91-0
Hexyl hexanoate	1736	1392	hh	330.3 Aa	338.2 Aa	40.6 Bb	132.2 ABa	108.7 ABa	68.0 Bb	nd	85.6 ABa	6400[g]	6378-65-0
Acetophenone	1736	1076	aone	33.2 Bb	102.3 Ba	67.1 Ba	70.3 Ba	62.5 Bb	148.4 Ba	389.1 Ab	820.8 Aa	65[j]	98-86-2
Butyl octanoate	1740	1394	bo	68.9 Aa	69.7 Aa	24.9 Ba	37.7 ABa	15.7 Ba	< 10 Ba	nd	12.8 Ba	nf	589-75-3
Benzylalcohol	1869	1046	beOH	36.5 ABa	32.8 ABa	72.4 Aa	78.5 Aa	49.3 ABa	89.9 Aa	23.6 Ba	50.7 Aa	nf	10-51-6
γ-Hexalactone	1880	-	hlac	99.0 Aa	110.7 Aa	43.2 Ba	42.5 Ba	32.7 Ba	35.4 Ba	91.3 Aa	106.4 Aa	1600[i]	695-02-7
γ-Octalactone	2111	1270	olac	42.4 Aa	69.8 Aa	14.4 Ba	27.9 ABa	10.9 Ba	12.2 Ba	nd	18.8 ABa	7[i]	104-50-7
Decanoic acid	2407	1390	deac	nd	19.0 Ba	nd	nd	< 10 Bb	24.3 Ba	25.7 Ab	108.8 Aa	2200[g]	334-48-5
δ-Decalactone	2417	1507	dlac	10.4 Ab	107.5 Aa	< 10 Ab	36.4 Ba	nd	nd	nd	nd	31[f]	211-889-1
γ-Dodecalactone	2587	1697	dolac	15.8 Ab	41.0 Aa	< 10 Ba	< 10 Ba	nd	nd	nd	nd	0.43[f]	2305-05-7
Total Esters				1749.0(36) Bb	11207.0(76.8) Aa	1596.6(34.2) Ba	1219.6(21) Ba	5816.3(68.3) Aa	449.1(11.3) Bb	904.6(8) Ba	942.7(9.9) Ba		
Total Lactones				167.6(3.5) Ab	328.9(2.3) Aa	71.4(1.5) Ba	115.0(2) Ba	43.7(0.5) Ba	47.5(1.2) Ba	91.3(0.8) Ba	125.2(1.3) Ba		
Total Aldehydes				1004.8(21) Aa	580.7(4) Ab	523.2(11.2) Ba	541.6(9.3) Aa	493.3(5.8) Ba	387.2(9.8) Aa	1109.4(10) Aa	681.1(7.2) Ab		
Total Ketones				274.1(5.7) Bb	520.6(3.7) BCa	940.4(20.2) ABa	1027.8(17.7) Ba	431.4(5.1) Ba	421.5(10.6) Ca	1503.3(13.3) Aa	1684.3(17.8) Aa		
Total Terpenes				38.3(0.8) Ba	21.4(0.15) Ba	399.0(8.6) Bb	1703.4(29.4) Ba	242.1(2.8) Bb	587.0(14.8) Bb	6067.9(53.9) Aa	3602.7(38) Ab		
Total Acids				863.3(18) ABb	1144.2(7.8) Aa	840.6(18) Ba	883.6(15.2) Aa	1181.5(14.9) ABb	1629.6(41) Aa	1382.7(12.3) Aa	1800.0(19) Aa		
Total Alcohols				711.5(15) Aa	794.3(5.3) Aa	293.4(6.3) Ba	309.3(5.4) Aa	311.3(3.6) Bb	448.3(11.3) Aa	196.4(1.7) Bb	642.2(6.8) Aa		
Total				4808.6 Bb	14597.0 Aa	4664.7 Ba	5800.2 Ba	8519.6 Aa	3970.3 Bb	11255.6 Aa	9478.3 ABa		

[a] Kovats retention index in column cross-linked FFAP. [b]Kovats retention index in a 5% phenyl polysilphenylene-siloxane BPX5. (-: eluted with the solvent; nd: not detected, nf: not found).[c]Odor threshold (μg Kg^{-1}) in water as reviewed in reference [d](*46*)and reported in references: [f] (*43*); [g] (*47*);[h] (*48*);[i] (*45*);[j] (*49*). For each day at 20 ºC, different capital letters indicate significant differences among cultivars and for each cultivar, different small letters indicate differences between days at 20 ºC ($P \leq 0.05$) by the least significant difference (LSD) test.

Table 3. Volatile Compounds Emitted (ng·kg^{-1}) by 'Early Rich®' and 'Royal Glory®' Peaches after Cold Storage, plus 0 and 3 Days at 20 ºC and Relative Proportion (%) of the Main Classes of Compounds is in Bold.

Cultivar	**Early Rich**														**Royal Glory**											
Storage period (days at -0.5 °C)	**Harvest**		**10**				**20**				**40**				**Harvest**		**10**				**20**				**40**			
Shelf life (days at 20 °C)	**0**		**0**		**3**		**0**		**3**		**0**		**3**		**0**		**0**		**3**		**0**		**3**		**0**		**3**	
Ethyl acetate	nd		47.9	b	nd		4643.9	a	nd		nd		nd		599.0	a	nd		nd		nd		nd		nd		nd	
Propyl acetate	18.9	e	1098.0	a	231.1	b	66.7	d	103.1	c	nd		nd		22.1	c	400.9	a	565.8	a	183.2	b	193.6	b	nd		nd	
2,3-Butanodione	240.8	d	754.7	b	1348.8	a	283.4	cd	461.6	c	427.2	c	944.3	b	873.3	b	442.3	b	1854.2	a	807.2	b	630.9	b	1707.0	a	1743.5	a
Eucalyptol	nd		32.9	a	25.8	b	nd		nd		nd		nd		nd		nd		nd		nd		nd		25.7	b	21.8	b
2-Methylpropyl acetate	25.7	c	87.6	c	504.7	a	47.8	c	314.0	b	nd		327.7	b	21.7	b	28.9	b	31.4	b	43.4	b	54.3	b	59.3	b	168.7	a
Hexenal	672.1	b	1255.1	a	752.4	b	367.1	b	529.9	b	363.3	b	385.1	b	214.7	b	145.8	c	153.3	c	169.9	bc	271.1	a	218.7	a	150.7	c
Ethyl 2-methylbutanoate	< 10	b	10.2	b	45.0	a	12.0	b	20.0	ab	nd		35.5	a	nd		nd		nd		11.9	a	10.3	a	nd		nd	
Butyl acetate	51.6	b	34.9	c	66.6	ab	24.2	c	56.7	b	nd		75.5	a	68.5	b	110.9	a	146.5	a	56.9	b	45.8	b	105.6	ab	109.2	a
2-Methylbutyl acetate	96.4	c	254.7	b	199.5	bc	443.5	a	178.6	bc	210.9	b	77.1	c	30.3	c	134.7	b	45.1	c	125.5	b	42.4	c	217.7	a	50.6	c
Butyl propanoate	37.1	a	20.1	b	11.2	c	24.3	b	12.5	c	nd		nd		50.1	a	nd		nd		nd		nd		nd		nd	
2-Ethyl-1-hexenal	240.7	a	332.3	a	273.0	a	194.0	ab	205.3	ab	149.5	b	171.8	ab	109.0	b	66.4	c	65.5	c	72.1	c	54.9	c	139.5	b	185.2	a
Pentyl acetate	15.9	b	19.8	b	52.1	a	11.2	c	26.1	b	9.0	c	19.1	b	15.1	b	< 10	b	< 10	b	19.2	ab	13.7	b	29.5	a	34.3	a
2-Methylbutyl-2-methylpropanoate	42.4	b	71.0	a	71.1	a	27.7	b	36.3	b	11.4	c	18.0	c	314.9	a	34.5	b	36.2	b	25.3	b	25.3	b	37.3	b	32.5	b
2-Methyl-1-butanol	nd		13.8	b	12.2	b	23.5	a	nd		25.5	a	26.5	a	12.5	c	nd		< 10	c	68.2	a	nd		41.2	b	10.3	c
Butyl 2-methylbutanoate	16.4	a	26.2	a	25.3	a	< 10	b	15.0	ab	nd		nd		29.4	c	16.1	cd	11.9	d	52.4	b	31.4	c	135.0	a	nd	
1-Pentanol	27.2	b	58.9	a	38.1	b	16.9	c	30.2	b	15.4	c	18.6	c	13.9	b	12.7	b	11.6	b	33.2	a	nd		15.9	b	19.4	b
Hexyl acetate	127.9	b	128.1	b	336.5	a	64.2	c	149.1	b	49.1	c	119.4	b	108.1	a	32.6	b	22.2	b	46.0	b	51.9	b	90.4	a	80.0	a
2-Methylbuyl-2-methylbutanoate	< 10	b	25.1	a	14.2	b	12.3	b	< 10	b	nd		nd		nd		nd		nd		nd		nd		18.3	a	nd	
Acetic acid	616.4	b	nd		111.6	c	998.5	b	1730.2	a	1026.4	b	1495.7	a	554.3	d	nd		nd		919.3	c	1071.6	c	2374.7	a	1564.9	b
Hexyl propanoate	nd		63.2	a	nd		nd		nd		nd		nd		nd		nd		nd		24.1	a	nd		nd		nd	
Propyl hexanoate	39.1	b	25.3	b	1056.5	a	17.5	b	68.0	b	nd		nd		51.2	a	< 10	b	< 10	b	nd		nd		nd		nd	
Z-3-hexenyl acetate	89.1	b	32.2	c	208.8	a	32.7	c	64.8	b	nd		nd		59.3	b	72.9	a	31.4	c	14.9	d	25.9	c	nd		nd	
1-Hexanol	64.0	ab	112.2	a	127.6	a	26.5	b	52.9	b	33.1	b	47.6	b	27.7	a	19.3	ab	21.6	ab	21.6	ab	14.5	b	34.3	a	22.9	ab
Methyl octanoate	38.5	b	27.3	b	118.0	a	50.9	b	65.2	b	nd		44.2	b	33.5	a	nd		< 10	c	nd		11.5	b	nd		15.8	b
Z-3-hexen-1-ol	nd		< 10	b	137.6	a	nd		< 10	b	nd		16.3	b	nd		< 10	b	nd		21.4	a	26.2	a	26.7	a	39.2	a
Benzaldehyde	92.0	a	73.8	a	98.1	a	71.2	a	81.8	a	106.3	a	97.5	a	199.4	a	98.4	b	nd		37.1	b	33.6	b	79.0	b	93.2	b
Pentyl hexanoate	26.6	a	32.7	a	32.4	a	23.3	a	33.7	a	nd		nd		< 10	a	nd		nd		nd		nd		nd		nd	
Hexyl 2-methylbutanoate	280.7	a	442.2	a	313.5	a	182.1	b	201.7	a	91.7	b	121.6	b	12.9	a	11.3	a	< 10	a	nd		< 10	a	17.5	a	15.9	a
Ethyl octanoate	376.7	c	172.1	d	643.3	b	230.6	c	305.6	c	60.3	d	1148.2	a	113.8	c	128.4	c	246.6	b	308.5	b	523.6	b	686.9	a	876.3	a
Benzoic acid	246.8	a	102.9	d	128.8	c	131.8	c	157.2	c	222.6	b	276.9	a	286.2	b	258.7	bc	202.6	c	150.3	d	148.1	d	383.1	a	293.3	b
2-Ethyl-1-hexanol	583.9	b	1361.6	a	769.4	b	643.8	b	583.3	b	508.7	b	532.4	b	167.0	b	130.7	b	70.0	c	118.3	b	85.9	bc	242.8	a	132.9	b
Butyl hexanoate	53.8	a	70.5	a	79.3	a	27.0	ab	27.2	ab	< 10	b	11.7	b	nd		nd		52.7	a	nd		nd		nd		nd	
(R)-Linalool	38.3	a	nd		10.2	b	< 10	b	nd		nd		nd		399.0	a	21.1	b	45.7	b	52.0	a	17.8	b	34.7	b	nd	
Hexyl hexanoate	330.3	c	605.2	a	411.5	b	241.8	d	377.7	b	164.5	e	252.9	d	40.6	a	40.9	a	23.8	b	nd		nd		nd		nd	
Acetophenone	33.2	c	149.3	b	342.8	a	152.8	b	112.7	b	140.6	b	90.6	b	67.1	b	44.8	b	159.7	a	118.2	ab	60.7	b	182.5	a	66.5	b
Butyl octanoate	68.9	a	90.7	a	70.2	a	51.4	a	64.1	a	23.5	a	30.9	a	24.9	b	19.3	b	32.5	a	nd		nd		nd		nd	
Benzylalcohol	36.5	ab	40.0	ab	53.5	a	24.3	b	43.3	a	46.9	a	39.0	ab	72.4	a	91.6	a	33.2	b	32.3	b	23.2	b	65.2	a	45.7	ab
γ-Hexalactone	99.0	b	108.4	b	155.1	a	100.7	b	95.1	b	74.9	b	73.3	b	43.2	a	44.2	a	24.5	b	29.8	b	42.5	ab	62.4	a	53.6	a
γ-Octalactone	42.4	a	26.9	b	42.6	a	47.8	a	35.1	a	nd		22.2	b	14.4	b	24.3	a	20.7	a	nd		nd		nd		nd	
Decanoic acid	nd		nd		114.2	a	nd		40.3	b	11.2	c	25.5	bc	nd		nd		46.8	a	12.3	c	27.5	b	22.1	bc	18.4	bc
δ-Decalactone	10.4	c	38.0	c	174.0	a	80.7	b	73.8	b	nd		nd		8.8	b	67.5	a	23.6	b	nd		nd		nd		nd	
γ-Dodecalactone	15.8	a	< 10	b	< 10	b	< 10	b	nd		nd		nd		< 10	c	13.1	b	11.3	b	nd		33.6	a	nd		nd	
Total Esters	1749.0	**36.4**	3385.2	**42.7**	4490.9	**48.3**	6235.1	**66.5**	2119.4	**33.1**	620.5	**16.6**	2281.8	**34.7**	1596.6	**34.2**	1031.6	**42.2**	1246.0	**31.7**	911.3	**25.0**	1029.7	**28.6**	1397.5	**19.8**	1383.3	**23.8**
Total Lactones	167.6	**3.5**	173.3	**2.3**	371.7	**4.2**	229.2	**2.5**	203.9	**3.2**	74.9	**2.0**	95.4	**1.5**	71.4	**1.5**	149.1	**6.0**	80.1	**1.7**	29.8	**0.8**	76.1	**2.2**	62.4	**0.9**	53.6	**0.9**
Total Aldehydes	1004.8	**20.9**	1661.2	**21.3**	1123.5	**12.3**	632.3	**6.4**	816.9	**12.9**	619.0	**16.4**	654.5	**10.1**	523.2	**11.2**	310.7	**10.6**	218.8	**5.5**	279.1	**7.9**	359.7	**10.2**	437.2	**6.2**	429.1	**7.4**
Total Ketones	274.1	**5.7**	904.0	**11.6**	1691.6	**18.5**	436.3	**4.7**	574.3	**9.1**	567.8	**15.1**	1034.9	**15.9**	940.4	**20.2**	487.2	**19.8**	2014.0	**50.2**	925.3	**26.3**	691.6	**19.6**	1889.5	**27.0**	1809.9	**31.3**
Total Terpenes	38.3	**0.8**	32.9	**0.4**	36.0	**0.4**	nd		nd		nd		nd		399.0	**8.6**	21.1	**0.9**	45.7	**1.1**	52.0	**1.5**	17.8	**0.5**	60.4	**0.7**	21.8	**0.2**
Total Acids	863.3	**18.0**	102.9	**1.3**	354.5	**3.9**	1130.3	**12.1**	1927.8	**30.4**	1260.2	**33.3**	1798.1	**27.6**	840.6	**18.0**	258.7	**10.5**	249.4	**6.2**	1081.9	**30.7**	1247.2	**35.4**	2779.8	**39.7**	1876.6	**32.4**
Total Alcohols	711.5	**14.8**	1586.5	**20.4**	1138.4	**12.5**	735.0	**7.9**	709.6	**11.3**	629.6	**16.7**	680.4	**10.2**	293.4	**6.3**	254.3	**10.1**	136.3	**3.6**	295.1	**7.8**	149.8	**3.5**	426.2	**5.7**	270.3	**4.0**
Total	4808.6		7845.9		9206.7		9398.1		6352.0		3772.0		6545.2		4664.7		2512.7		3990.3		3574.5		3571.9		7053.1		5844.6	

Means within each row followed by different letters indicate significant differences at P≤0.05, least significant difference (LSD) test. Volatile compounds not detected are indicated as nd.

Table 4. Volatile Compounds Emitted (ng·kg^{-1}) by 'Sweet Dream^{cov}' and 'Elegant Lady®' Peaches after Cold Storage plus 0 and 3 Days at 20 ºC. Relative Proportion (%) of the Main Classes of Compounds is in Bold.

Cultivar	**Sweet Dream^{cov}**												**Elegan Lady**											
Storage period (days at -0.5 °C)	**Harvest**		**10**				**20**				**40**				**Harvest**		**10**				**20**				**40**	
Shelf life (days at 20 °C)	**0**		**0**		**3**		**0**		**3**		**0**		**3**		**0**		**0**		**3**		**0**		**3**		**0**		**3**	
Ethyl acetate	5049.2	a	nd		1309.1	b	428.0	d	703.3	c	479.6	d	nd		nd		5790.6	a	3875.6	b	3998.3	b	nd		1887.4	c	nd	
Propyl acetate	56.1	c	< 10	d	12.6	d	225.2	a	< 10	d	10.3	d	134.9	b	49.6	b	43.4	b	31.2	b	1157.4	a	324.3	ab	72.9	b	806.7	a
2,3-Butanodione	368.9	e	2059.8	a	1793.3	b	458.4	de	591.1	de	344.2	e	795.5	cd	1114.2	b	2762.9	ab	3330.6	a	462.7	c	2135.2	b	316.4	c	723.7	c
Eucalyptol	21.4	a	nd		11.2	b	nd		nd		nd		nd		< 10	a	nd		26.8	a	18.9	a	39.4	a	18.2	a	17.2	a
2-Methylpropyl acetate	15.7	c	36.6	a	16.9	b	10.8	c	21.4	b	nd		21.8	b	27.8	c	24.3	c	124.1	b	50.4	c	280.3	a	32.1	c	133.2	b
Hexenal	184.9	c	514.4	a	304.7	b	424.1	ab	208.7	d	408.5	ab	479.3	a	204.9	b	220.9	b	273.5	ab	166.7	b	441.0	a	173.8	b	112.4	b
Ethyl 2-methylbutanoate	nd		nd		nd		nd		nd		nd		20.9	a	nd		nd		nd		nd		nd		20.5	a
Butyl acetate	40.2	b	29.0	b	29.7	bc	232.1	a	16.3	c	nd		34.6	b	67.4	cd	58.9	cd	93.8	c	1561.1	a	129.5	b	34.9	d	115.8	b
2-Methylbutyl acetate	69.8	a	15.6	b	17.1	b	15.0	b	14.6	b	15.2	b	37.3	b	86.4	b	75.5	b	51.1	b	170.4	a	57.1	b	53.4	b	103.5	ab
Butyl propanoate	nd		32.5	b	653.6	a	nd		nd		nd		nd		nd		nd		nd		17.3	a	nd		nd		nd	
2-Ethyl-1-hexenal	256.8	a	242.8	b	nd		70.7	c	25.7	d	67.5	c	76.0	c	839.9	a	734.5	a	281.7	b	36.5	b	224.9	b	26.4	b	nd	
Pentyl acetate	14.7	b	nd		136.1	a	nd		nd		nd		nd		17.4	b	15.2	b	23.7	b	12.8	b	49.1	a	nd		17.3	b
2-Methylbutyl-2-methylpropanoate	30.0	a	33.7	a	nd		nd		nd		nd		nd		105.0	a	91.9	b	54.6	c	nd		nd		nd		nd	
2-Methyl-1-butanol	nd		nd		nd		nd		nd		nd		17.5	a	nd		nd		nd		nd		nd		nd		nd	
Butyl 2-methylbutanoate	nd		nd		53.4	a	19.3	b	nd		nd		nd		21.7	a	19.0	a	nd		nd		nd		nd		nd	
1-Pentanol	nd		11.5	a	nd		nd		nd		nd		nd		nd		nd		17.9	a	nd		14.5	a	nd		nd	
Hexyl acetate	79.7	a	42.3	b	nd		< 10	c	18.2	bc	16.6	bc	33.0	b	126.2	b	110.4	b	206.8	ab	79.4	b	221.9	a	40.9	b	87.8	b
2-Methylbuyl-2-methylbutanoate	nd		nd		nd		nd		nd		nd		nd		14.4	a	12.6	a	13.1	a	nd		nd		nd		nd	
Acetic acid	864.2	a	732.0	a	1010.1	a	1043.2	a	356.8	b	447.5	b	974.3	a	1111.2	b	986.4	b	1095.4	b	1559.0	a	1211.5	ab	620.1	b	2394.9	a
Hexyl propanoate	nd		nd		nd		nd		nd		nd		nd		nd		nd		nd		nd		nd		nd		nd	
Propyl hexanoate	nd		nd		nd		nd		nd		nd		nd		nd		nd		nd		nd		nd		nd		nd	
Z-3-hexenyl acetate	17.7	a	nd		nd		nd		nd		nd		35.3	a	47.0	a	41.2	a	nd		nd		45.2	a	46.9	a	nd	
1-Hexanol	nd		24.4	a	26.6	a	nd		11.9	a	16.5	a	37.8	a	18.9	a	16.5	a	44.0	a	nd		36.9	a	44.5	a	35.8	a
Methyl octanoate	16.5	ab	nd		nd		nd		20.2	a	nd		13.6	b	34.6	b	30.3	b	36.3	b	nd		215.5	a	70.0	b	nd	
Z-3-hexen-1-ol	nd		19.7	a	19.8	a	10.2	a	16.2	a	17.0	a	17.0	a	19.5	b	17.1	b	82.9	a	21.7	b	12.9	b	nd		nd	
Benzaldehyde	51.6	a	57.5	a	44.4	a	52.8	a	47.9	a	56.8	a	63.3	a	64.7	a	39.1	a	98.6	a	48.7	a	90.0	a	101.2	a	57.6	a
Pentyl hexanoate	< 10	a	nd		nd		nd		nd		nd		nd		nd		nd		nd		nd		nd		nd		nd	
Hexyl 2-methylbutanoate	71.8	a	96.6	a	99.4	a	47.9	a	20.3	b	38.6	a	34.8	ab	nd		nd		60.3	a	< 10	b	17.2	b	nd		15.4	b
Ethyl octanoate	221.9	a	26.8	c	42.6	c	nd		35.9	c	11.4	c	183.9	b	307.3	b	268.6	b	214.3	b	99.6	c	632.4	a	59.4	c	539.9	a
Benzoic acid	311.5	a	240.1	ab	204.0	b	155.4	b	260.9	ab	244.2	ab	280.6	a	245.8	b	229.0	b	369.6	a	205.2	b	245.9	ab	228.7	b	266.3	ab
2-Ethyl-1-hexanol	262.0	b	548.3	a	358.1	ab	491.0	a	178.3	b	502.6	a	588.4	a	134.5	b	117.7	b	488.2	a	124.0	b	152.7	b	161.7	b	97.6	b
Butyl hexanoate	nd		nd		nd		nd		nd		nd		nd		nd		nd		nd		nd		nd		nd		nd	
(R)-Linalool	220.7	a	nd		16.5	b	14.1	b	10.9	b	21.8	b	19.0	b	6058.5	a	5302.5	a	3762.2	b	12.9	c	nd		nd		nd	
Hexyl hexanoate	108.7	ab	225.1	a	nd		nd		30.9	b	91.2	b	118.3	ab	nd		nd		183.4	a	nd		11.3	b	36.9	b	nd	
Acetophenone	62.5	b	108.1	ab	142.1	ab	68.7	b	68.2	b	159.8	a	127.1	ab	389.1	b	965.8	a	665.0	ab	717.3	ab	425.3	b	368.5	b	270.5	b
Butyl octanoate	15.7	ab	23.7	a	nd		28.6	a	< 10	b	10.7	b	nd		nd		nd		27.5	a	24.1	a	nd		nd		nd	
Benzylalcohol	49.3	a	38.4	ab	21.9	b	30.6	ab	29.9	ab	16.2	b	20.6	b	23.6	b	37.4	a	22.7	b	38.5	a	18.1	b	39.9	a	20.3	b
γ-Hexalactone	32.7	a	13.9	b	< 10	b	13.6	b	< 10	b	14.8	b	16.0	b	91.3	b	79.8	b	113.8	a	33.5	c	108.6	a	18.0	c	21.6	c
γ-Octalactone	10.9	a	nd		nd		nd		nd		24.6	a	nd		nd		nd		20.1	a	18.9	a	13.5	a	nd		nd	
Decanoic acid	< 10	b	< 10	b	11.3	b	10.5	b	18.3	ab	16.8	ab	20.8	a	25.7	c	17.5	c	113.5	a	26.8	c	89.9	b	16.1	c	14.3	c
δ-Decalactone	nd		nd		nd		nd		nd		nd		nd		nd		nd		nd		10.8	b	79.2	a	nd		nd	
γ-Dodecalactone	nd		nd		nd		nd		nd		nd		nd		nd		nd		nd		nd		nd		nd		nd	
Total Esters	5816.3	**68.3**	561.9	**11.0**	2370.4	**37.6**	1006.8	**25.9**	881.1	**32.3**	673.5	**21.8**	668.4	**15.3**	904.6	**8.0**	6582.0	**36.3**	4995.9	**31.1**	7170.7	**67.4**	1983.7	**27.0**	2335.0	**51.9**	1840.0	**31.4**
Total Lactones	43.7	**0.5**	13.9	**0.3**			13.6	**0.4**			39.3	**0.9**	16.0	**0.2**	91.3	**0.8**	79.8	**0.4**	133.9	**0.9**	63.2	**0.5**	201.3	**2.8**	18.0	**0.2**	21.6	**0.4**
Total Aldehydes	493.3	**5.8**	814.8	**15.8**	349.1	**5.5**	547.6	**14.4**	282.4	**10.5**	532.7	**17.9**	618.6	**15.1**	1109.4	**9.9**	994.5	**5.5**	653.7	**4.2**	252.0	**2.2**	756.0	**10.3**	301.4	**6.6**	170.0	**2.9**
Total Ketones	431.4	**5.1**	2167.9	**42.0**	1935.4	**30.8**	527.1	**13.8**	659.4	**24.6**	503.9	**16.9**	922.5	**22.5**	1503.3	**13.4**	3728.8	**20.6**	3995.6	**25.5**	1180.0	**11.1**	2560.5	**35.0**	684.9	**15.6**	994.2	**17.0**
Total Terpenes	242.1	**2.8**	nd		27.6	**0.4**	14.1	**0.4**	10.9	**0.2**	21.8	**0.7**	19.0	**0.2**	6067.9	**53.9**	5302.5	**29.3**	3789.0	**24.1**	31.8	**0.2**	39.4	**0.5**	18.2	**0.4**	17.2	**0.1**
Total Acids	1181.5	**13.9**	972.1	**18.9**	1225.4	**19.5**	1209.0	**31.6**	636.0	**23.7**	708.5	**23.8**	1275.8	**31.1**	1382.7	**12.3**	1232.9	**6.8**	1578.6	**10.1**	1791.1	**16.9**	1547.3	**21.1**	864.9	**19.7**	2675.5	**45.6**
Total Alcohols	311.3	**3.7**	642.3	**12.1**	426.5	**6.2**	531.8	**13.7**	236.4	**8.2**	552.3	**18.0**	681.2	**15.5**	196.4	**1.7**	188.7	**1.0**	655.6	**4.2**	184.2	**1.7**	235.2	**3.2**	246.2	**5.6**	153.7	**2.6**
Total	8519.6		5172.9		6334.5		3850.1		2706.0		3032.0		4201.6		11255.6		18109.1		15802.4		10672.9		7323.3		4468.5		5872.3	

Means within each row followed by different letters indicate significant differences at $P \leq 0.05$, by the least significant difference (LSD) test. Volatile compounds not detected are indicated as nd.

Figures

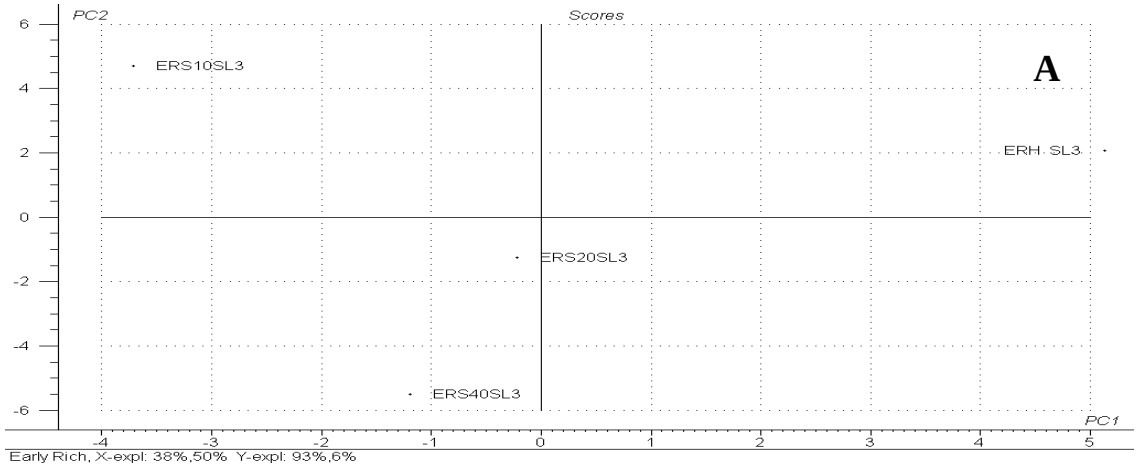
Figure 1. PLS model using the data for ‘Early Rich’ cultivar. A) Scores; B) correlation loadings; C) regression coefficients from a PLS model of variable acceptance.

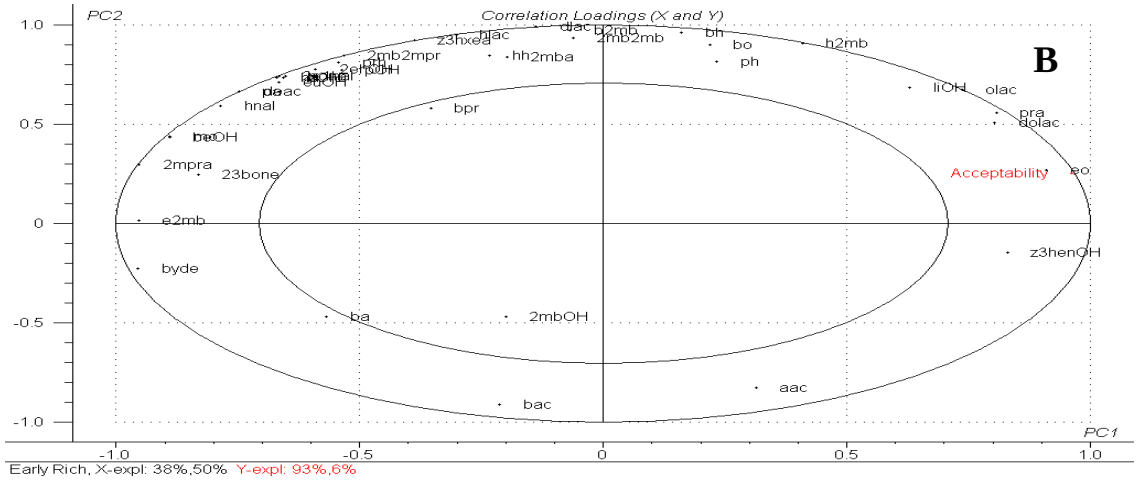
Figure 2. PLS model using the data for ‘Royal Glory’ cultivar. A) Scores; B) correlation loadings; C) regression coefficients from a PLS model of variable acceptance.

Figure 3. PLS model using the data for ‘Elegant Lady’ cultivar. A) Scores; B) correlation loadings; C) regression coefficients from a PLS model of variable acceptance.

Figure 4. PLS model using the data for ‘Sweet Dream’ cultivar. A) Scores; B) correlation loadings; C) regression coefficients from a PLS model of variable acceptance.

Figure 1.


PC2
Scores
A
ERS10SL3
ERH SL3
ERS20SL3
ERS40SL3
PC1
Early Rich, X-expl: 38%,50% Y-expl: 93%,6%


PC2
Correlation Loadings (X and Y)
B
hnal
bpr
2mpra
23bone
e2mb
byde
ba
2mbOH
bac
aac
Acceptability
z3henOH
olac
dolac
h2mb
ph
bo
bh
hh2mba
2mb2mpr
PC1
Early Rich, X-expl: 38%,50% Y-expl: 93%,6%

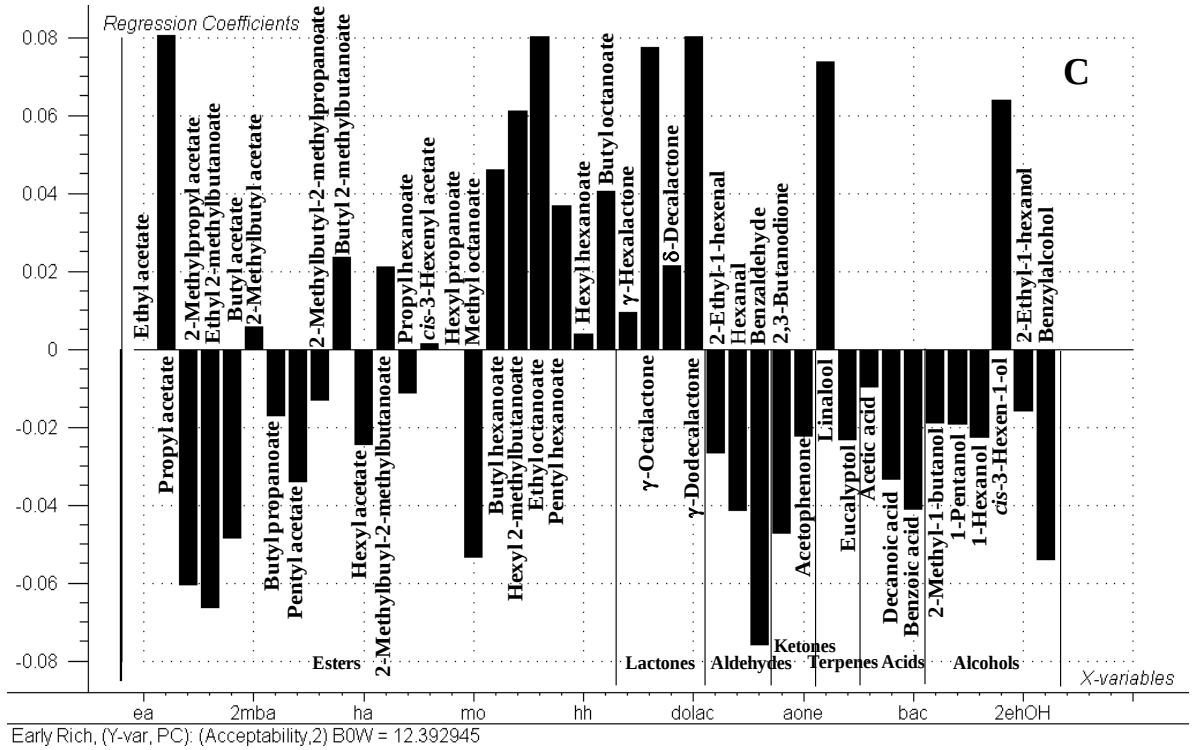
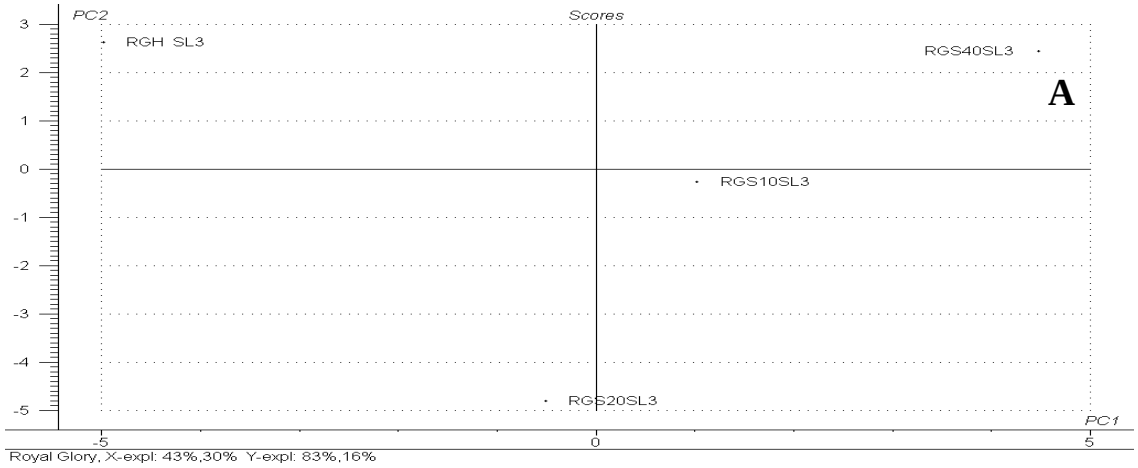
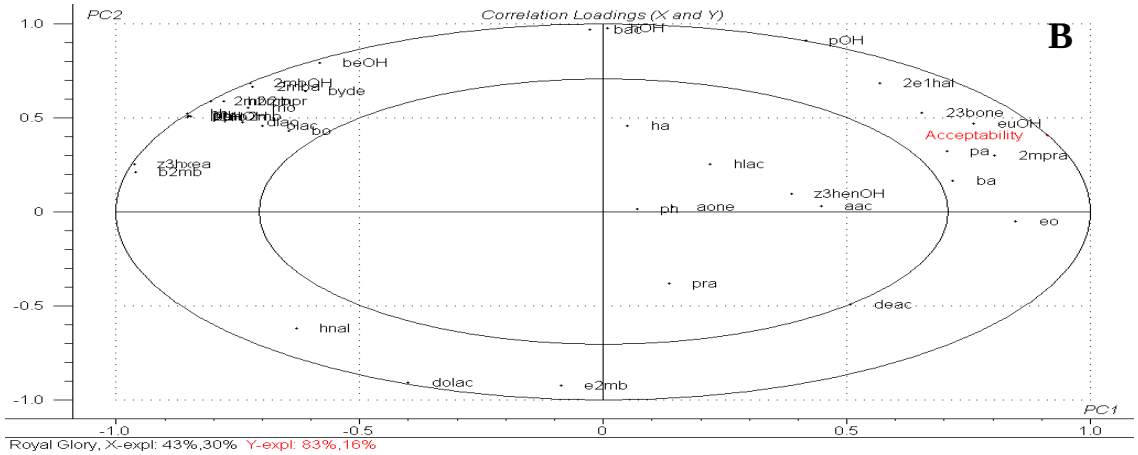

Regression Coefficients
C
Ethyl acetate
2-Methylpropyl acetate
Ethyl 2-methylbutanoate
Butyl acetate
2-Methylbutyl acetate
2-Methylbutyl-2-methylpropanoate
Butyl 2-methylbutanoate
Propyl hexanoate
cis-3-Hexenyl acetate
Hexyl propanoate
Methyl octanoate
Hexyl hexanoate
Butyl octanoate
γ-Hexalactone
δ-Decalactone
2-Ethyl-1-hexenal
Hexanal
Benzaldehyde
2,3-Butanodione
Linalool
Eucalyptol
Acetic acid
Decanoic acid
Benzoic acid
2-Methyl-1-butanol
1-Pentanol
1-Hexanol
cis-3-Hexen-1-ol
2-Ethyl-1-hexanol
Benzylalcohol
Propyl acetate
Butyl propanoate
Pentyl acetate
Hexyl acetate
2-Methylbutyl-2-methylbutanoate
Butyl hexanoate
Hexyl 2-methylbutanoate
Ethyl octanoate
Pentyl hexanoate
γ-Octalactone
γ-Dodecalactone
Acetophenone
Esters
Lactones
Aldehydes
Ketones
Terpenes
Acids
Alcohols
X-variables
ea
2mba
ha
mo
hh
dolac
aone
bac
2ehOH
Early Rich, (Y-var, PC): (Acceptability,2) B0W = 12.392945

Figure 2.


PC2
Scores
RGH SL3
RGS40SL3
A
RGS10SL3
RGS20SL3
PC1
Royal Glory, X-expl: 43%,30% Y-expl: 83%,16%


PC2
Correlation Loadings (X and Y)
baOH
pOH
beOH
2e1hal
byde
23bone
euOH
Acceptability
ha
pa
2mpra
hlac
ba
z3hxea
b2mb
z3henOH
ph
aone
aac
eo
pra
deac
hnal
dolac
e2mb
B
PC1
Royal Glory, X-expl: 43%,30% Y-expl: 83%,16%

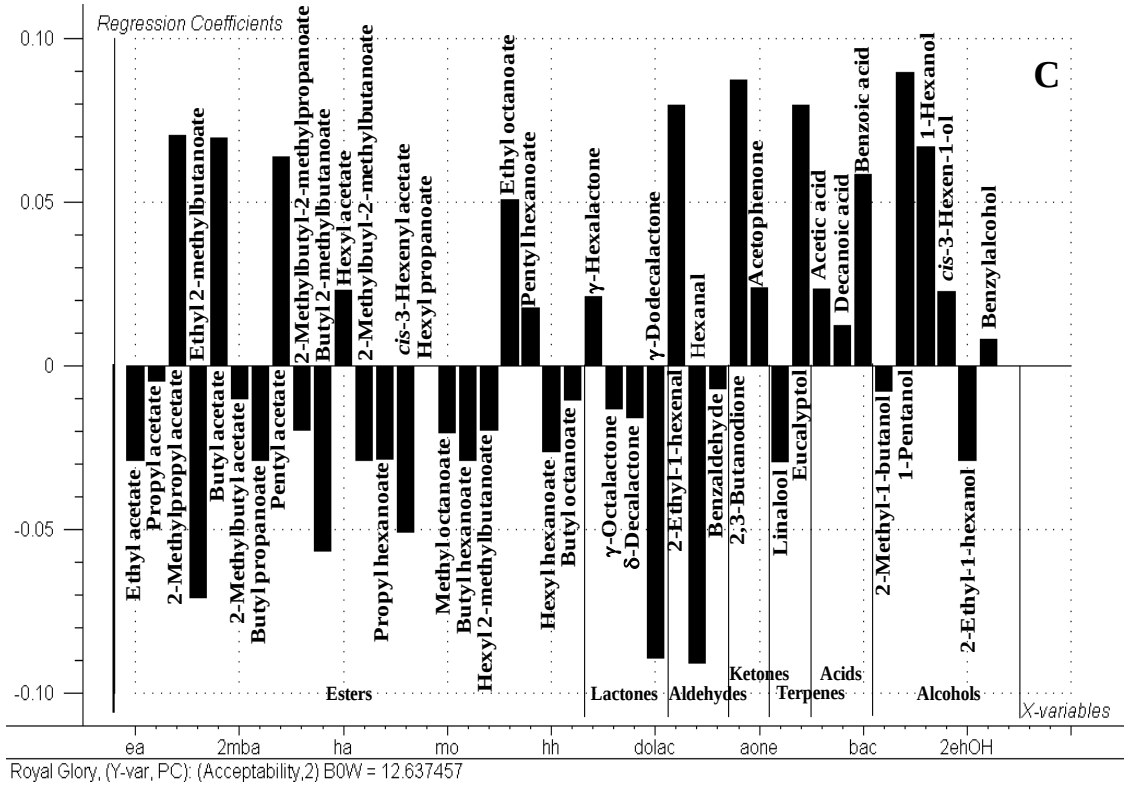
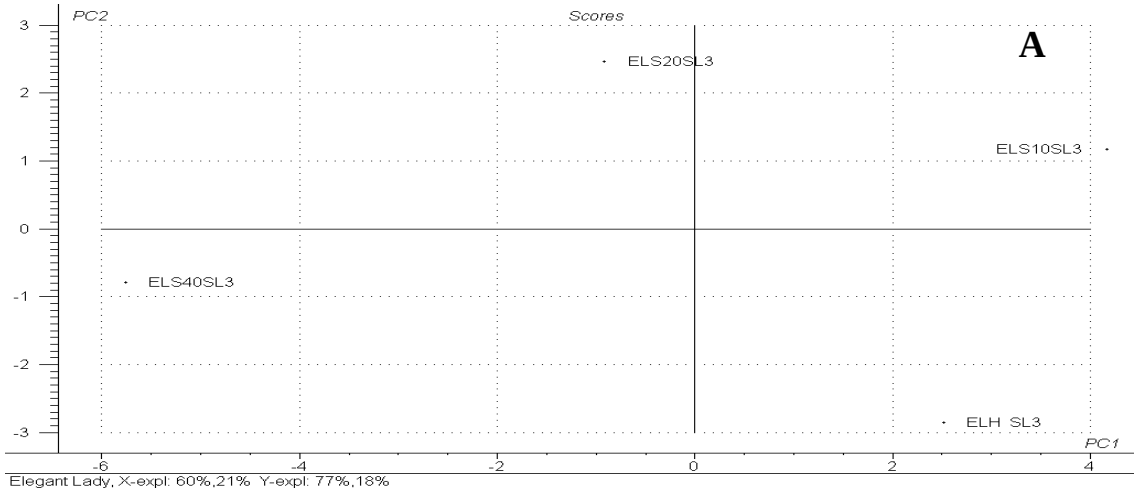
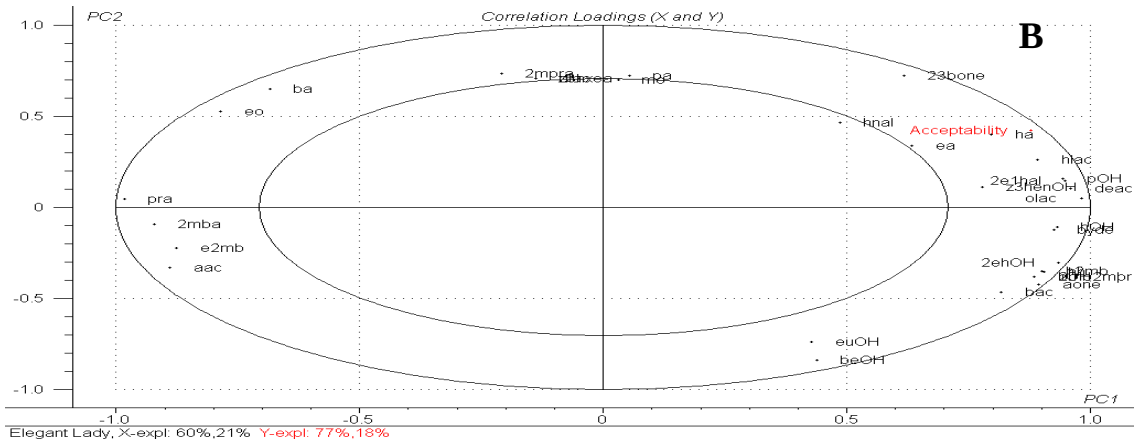

Regression Coefficients
C
Ethyl acetate
Propyl acetate
2-Methylpropyl acetate
Ethyl 2-methylbutanoate
Butyl acetate
2-Methylbutyl acetate
Butyl propanoate
Pentyl acetate
2-Methylbutyl-2-methylpropanoate
Butyl 2-methylbutanoate
Hexyl acetate
2-Methylbuyl-2-methylbutanoate
cis-3-Hexenyl acetate
Hexyl propanoate
Ethyl octanoate
Pentyl hexanoate
γ-Hexalactone
γ-Dodecalactone
Hexanal
Acetophenone
Acetic acid
Decanoic acid
Benzoic acid
1-Hexanol
cis-3-Hexen-1-ol
Benzylalcohol
Propyl hexanoate
Methyl octanoate
Butyl hexanoate
Hexyl 2-methylbutanoate
Hexyl hexanoate
Butyl octanoate
γ-Octalactone
δ-Decalactone
2-Ethyl-1-hexenal
Benzaldehyde
2,3-Butanodiione
Linalool
Eucalyptol
2-Methyl-1-butanol
1-Pentanol
2-Ethyl-1-hexanol
Esters
Lactones
Aldehydes
Ketones
Terpenes
Acids
Alcohols
X-variables
ea
2mba
ha
mo
hh
dolac
aone
bac
2ehOH
Royal Glory, (Y-var, PC): (Acceptability,2) B0W = 12.637457

Figure 3.


A
Scores
PC2
PC1
ELS20SL3
ELS10SL3
ELS40SL3
ELH SL3
Elegant Lady, X-expl: 60%,21% Y-expl: 77%,18%


B
Correlation Loadings (X and Y)
PC2
PC1
Acceptability
ba
eo
pra
2mba
e2mb
aac
23bone
hnal
ea
hac
olac
euOH
beOH
bac
Elegant Lady, X-expl: 60%,21% Y-expl: 77%,18%

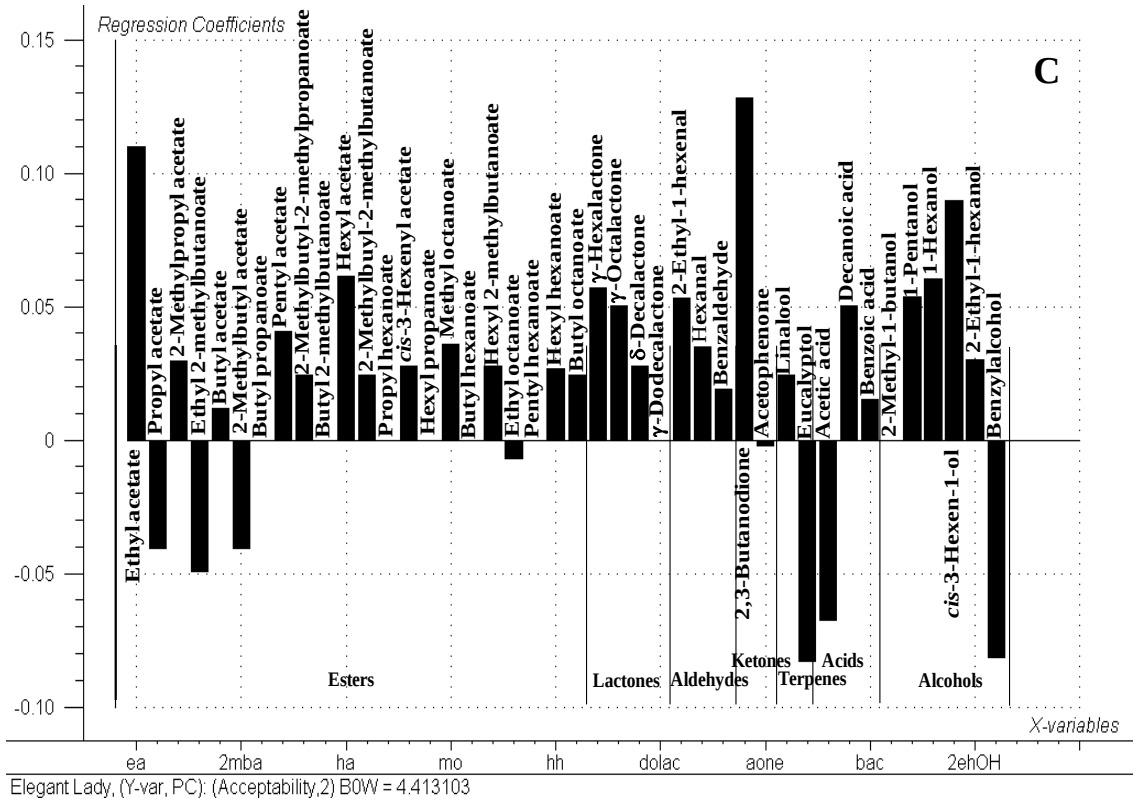
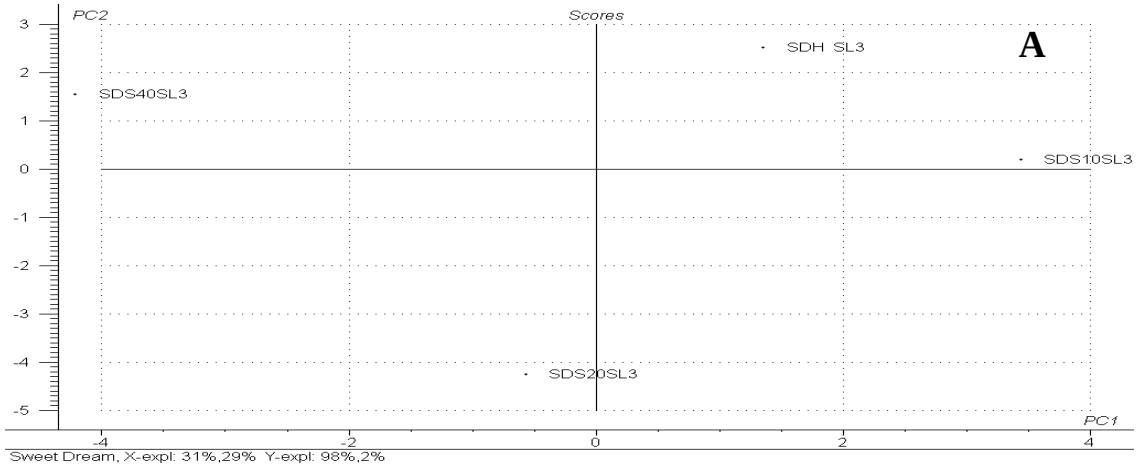
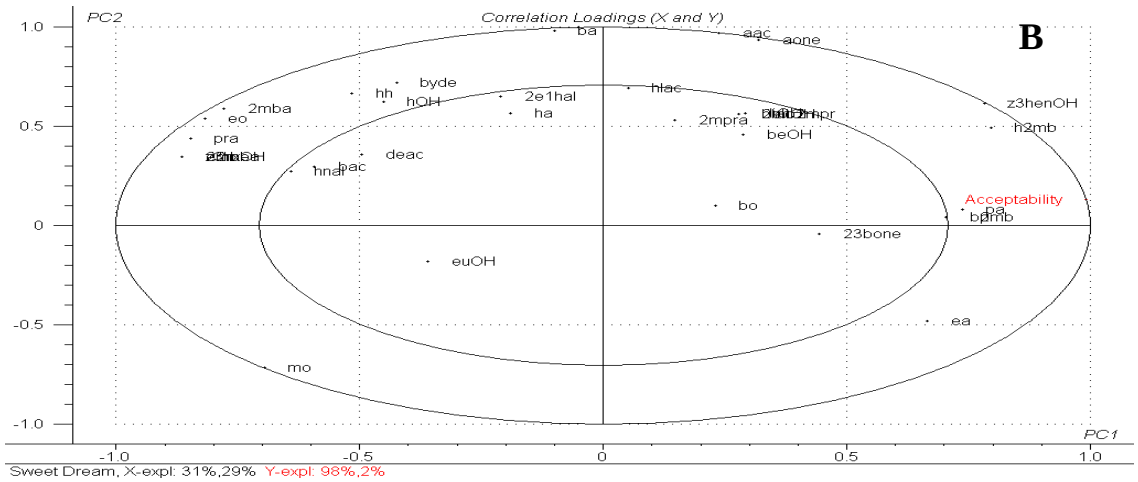
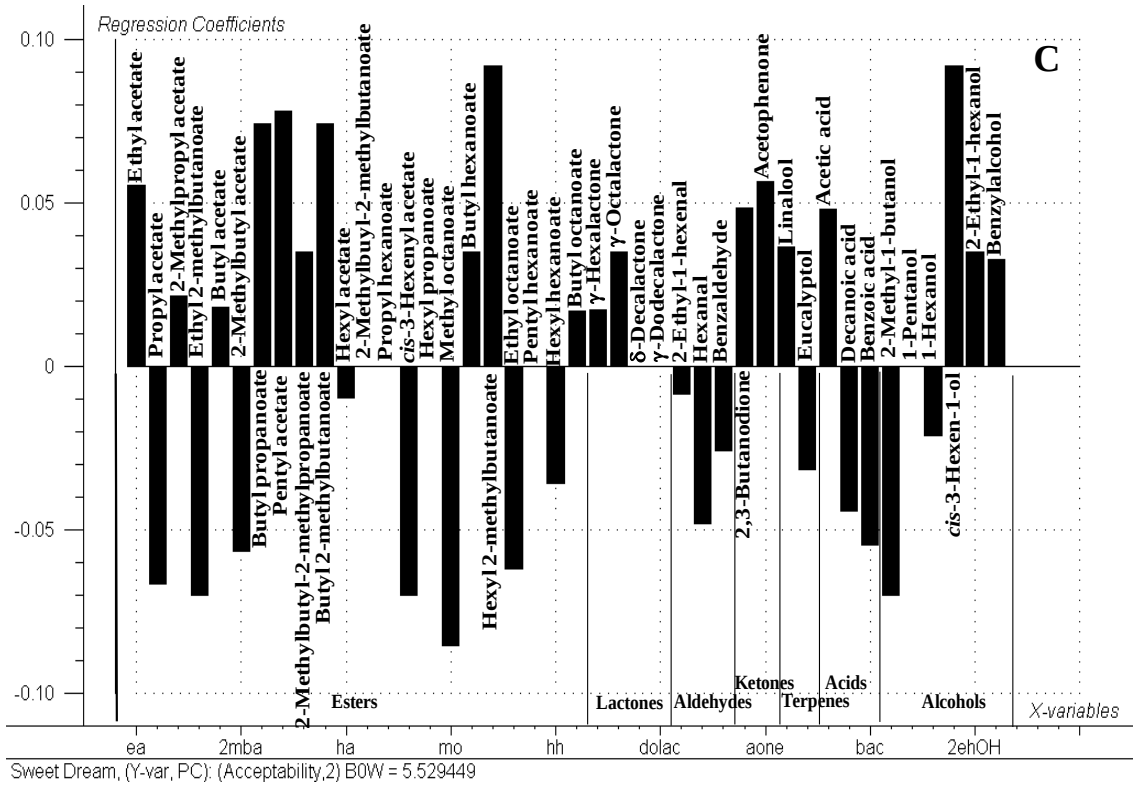

C
Regression Coefficients
X-variables
Ethyl acetate
Propyl acetate
2-Methylpropyl acetate
Ethyl 2-methylbutanoate
Butyl acetate
2-Methylbutyl acetate
Butyl propanoate
Pentyl acetate
2-Methylbutyl-2-methylpropanoate
Butyl 2-methylbutanoate
Hexyl acetate
2-Methylbuyl-2-methylbutanoate
Propyl hexanoate
cis-3-Hexenyl acetate
Hexyl propanoate
Methyl octanoate
Butyl hexanoate
Hexyl 2-methylbutanoate
Ethyl octanoate
Pentyl hexanoate
Hexyl hexanoate
Butyl octanoate
γ-Hexalactone
γ-Octalactone
δ-Decalactone
γ-Dodecalactone
2-Ethyl-1-hexenal
Hexanal
Benzaldehyde
2,3-Butanodione
Acetophenone
Linalool
Eucalyptol
Acetic acid
Decanoic acid
Benzoic acid
2-Methyl-1-butanol
1-Pentanol
1-Hexanol
cis-3-Hexen-1-ol
2-Ethyl-1-hexanol
Benzylalcohol
Esters
Lactones
Aldehydes
Ketones
Terpenes
Acids
Alcohols
ea
2mba
ha
mo
hh
dolac
aone
bac
2ehOH
Elegant Lady, (Y-var, PC): (Acceptability,2) B0W = 4.413103

Figure 4.


PC2
Scores
A
SDH SL3
SDS40SL3
SDS10SL3
SDS20SL3
PC1
Sweet Dream, X-expl: 31%,29% Y-expl: 98%,2%


PC2
Correlation Loadings (X and Y)
B
ba
aac
aone
byde
hh
hOH
2e1hal
hlac
ha
2mba
eo
2mpra
z3henOH
beOH
m2mb
pra
deac
bac
hnal
bo
Acceptability
pa
bpmb
23bone
euOH
ea
mo
PC1
Sweet Dream, X-expl: 31%,29% Y-expl: 98%,2%


Regression Coefficients
C
Ethyl acetate
Propyl acetate
2-Methylpropyl acetate
Ethyl 2-methylbutanoate
Butyl acetate
2-Methylbutyl acetate
Butyl propanoate
Pentyl acetate
2-Methylbutyl-2-methylpropanoate
Butyl 2-methylbutanoate
Hexyl acetate
2-Methylbuyl-2-methylbutanoate
Propyl hexanoate
cis-3-Hexenyl acetate
Hexyl propanoate
Methyl octanoate
Butyl hexanoate
Hexyl 2-methylbutanoate
Ethyl octanoate
Pentyl hexanoate
Hexyl hexanoate
Butyl octanoate
γ-Hexalactone
γ-Octalactone
δ-Decalactone
γ-Dodecalactone
2-Ethyl-1-hexenal
Hexanal
Benzaldehyde
2,3-Butanodione
Acetophenone
Linalool
Eucalyptol
Acetic acid
Decanoic acid
Benzoic acid
2-Methyl-1-butanol
1-Pentanol
1-Hexanol
cis-3-Hexen-1-ol
2-Ethyl-1-hexanol
Benzylalcohol
Esters
Lactones
Aldehydes
Ketones
Terpenes
Acids
Alcohols
X-variables
ea
2mba
ha
mo
hh
dolac
aone
bac
2ehOH
Sweet Dream, (Y-var, PC): (Acceptability,2) B0W = 5.529449

CAPITULO II.2

Cold storage of six nectarine cultivars: Consequences for volatile compounds emission, physicochemical parameters, and consumer acceptance.

Jaime Cano-Salazar, Luisa López, Carlos H. Crisosto y Gemma Echeverría
Enviado a: *Journal of Agricultural and Food Chemistry*

ABSTRACT

The effects of cold storage and shelf life of` 'Big Top®', 'Honey Blaze^{cov}', 'Honey Royale^{cov}', 'Venus®', 'August Red®' and 'Nectagala^{cov}' nectarines were evaluated. Volatile compounds, firmness, soluble solids content, titratable acidity, color, and degree of consumer acceptance of the fruit were determined at harvest, after storage at -0.5 ºC for 10, 20, or 40 days and following three days at 20 ºC. Ten days cold storage produced the highest total ester emission and ≥ 70% satisfied consumers for `Nectagala$^{cov}$´ and `August Red´, while similar results were obtained after 20 days and 40 days, respectively, for the 'Big Top' and 'Honey Blaze^{cov}' cultivars. Increased consumer acceptance was associated to the cultivars and storage time that resulted in firmer fruits and greater concentrations of specific volatile compounds.

Keywords: Nectarines; cold storage, quality; volatile compounds; consumer acceptance.

INTRODUCTION

Contrary to common belief, nectarines (*Prunus persica* L. Batsch) are not a cross between peaches and plums (*1*). Most aspects of nectarine trees, leaves, and flowers are indistinguishable from those of peach;even so, peach researchers have noted differences between peaches and nectarines (*2*). These differences include fruit size, shape, firmness, external color, aroma, flavor, and disease resistance (*3,4*). Nectarines have also exhibited better storage characteristics than peaches (*5*).

Nectarine is an important commercial crop in Spain, the world's fourth-largest producer of peaches and nectarines (*6*). Most nectarines sold in Spain are produced in Catalonia (northeastern Spain). The increased stone fruit production in recent years has included new cultivars with different flesh colors, flavors, soluble solids concentrations, and titratable acidities. In spite of this increase, nectarine consumption in Spain has remained steady. This has been explained as the consequence of consumer dissatisfaction (*7*).Nectarine fruit is characterized by high perishability caused by rapid softening during shelf life. This favors rot and other physiological disorders and drastically restricts storage potential and marketing possibilities. Low-temperature storage is the primary technology for delaying shelf lifeafter harvest. Maintaining low temperatures (-1 to +2 ºC) during storage is the primary tool used to reducepostharvest deterioration and maintain overall fruit quality, since reducing metabolic activity and respiration rates effectively slows ripening (*8*).However, storage potential depends on cultivar. For instance, some early-maturing, white-fleshed nectarine cultivars tended to maintain quality under controlled atmosphere storage better than later-maturing cultivars (*9*).

Nectarine flavor is the result of a complex combination of taste and odor.Aroma is an essential factor for evaluating nectarine quality (*1*).It is generally accepted that

only volatile compounds present in concentrations above their odor thresholds contribute to overall nectarine aroma (*10*).Volatile composition is also cultivar-dependent; the volatile profile of nectarine include alcohols, aldehydes, esters, ketones, terpenes, and lactones, mainly γ- and δ-decalactones (*11-16*).Since flavor is a key attribute for sensory quality and consumer acceptance in stone fruit (*17*),its absence is often associated withunsatisfactory eating quality regardless of firmness and external appearance. Improving volatile production has therefore become an important challenge for the fruit industry.

Intensive research has focused on changes in the physicochemical characteristics and volatile composition of nectarines during maturation and ripening (*1,18-22*).Ester and lactone compounds provide fruity notes and C_6 aldehyde and alcohol compounds contribute green sensory notes to the aroma of the ripening fruit, respectively (*16*). Benzaldehyde and linalool increase significantly during maturation (*18*).Although the first comprehensive studies of nectarine volatile production were performed about 40 years ago (*11*),to the best of our knowledge no previous studies on the relationships between volatile production, quality, and sensory evaluation in cold-stored fruit have appeared in the literature.

The objectives of this study were to evaluate the relationships between volatile compounds emissions, physicochemical measures, and consumer acceptance of 'Big Top', 'Honey Blaze^{cov}', 'Honey Royale^{cov}', 'Venus', 'August Red' and 'Nectagala^{cov}' nectarines after cold storage for three different periods and to examine the ability of post-storage exposure of fruit to air at 20 ºC to stimulate volatile production after cold storage. These varieties were selected in order to cover all the season-maturity period and their represent the most produced nectarine varieties in Europe.

MATERIAL AND METHODS

Plant Material and Storage Conditions. Nectarine fruits (*Prunus persica* L. Batsch) of early-season varieties 'Big Top' and 'Honey Blaze^{cov}' were harvested on June 30, 2009, at 115 and 125 days after full bloom (DAFB), respectively. Fruits of mid-season varieties 'Honey Royale^{cov}' and 'Venus' were harvested on July 31, 2009, at 140 and 145 DAFB, respectively, and fruits of late-season varieties 'August Red' and 'Nectagala^{cov}' were harvested on August 31,2009, at 178 and 184 DAFB, respectively. The six nectarine varieties were grown in commercial orchards at Alcarràs, Lleida, Catalonia (northeastern Spain). Immediately after harvest, four 50-kg lots from each cultivar were selected on the basis of uniformity and the absence of defects. Three lots were stored at -0.5 ºC and 92 to 93% relative humidity in a 22 m^3 cold air storage chamber (21 kPa O_2/0.03 kPa CO_2). The fourth lot was analyzed at harvest (H). Samples were removed from cold storage after 10 (S10), 20 (S20), or 40 (S40) days and held at 20 ºC to simulate commercial period (shelf life). Analyses were carried out after allowing the fruit to reach 20 ºC after removal from each cold storage period (SL0 or without days at 20 ºC) and following three (SL3) days at 20 ºC thereafter.

Chemicals. All of the standards for the volatile compounds studied in this work were analytical grade or the highest quality available. Ethyl acetate, 2,3-butanodione, eucalyptol, butyl acetate, pentyl acetate, acetophenone, and γ-hexalactone were obtained from Fluka (Buchs, Switzerland). 2- Methylpropyl acetate was obtained from Avocado Research Chemicals, Ltd. (Madrid, Spain). 2-Ethyl-1-hexenal, Z-3-hexenyl acetate, methyl octanoate and decanoic acid were obtained from SAFC Supply Solutions (St. Louis, MO, USA). The rest of the compounds (up to 43) were supplied by Sigma-Aldrich (Steinheim, Germany).

Analysis of Volatile Compounds. Themeasurement of volatile compounds was carried out as described (*23*).Six kilograms fruit (2 kg per replicate × 3) per storage period and cultivar were selected for analysis of volatile compounds, both at harvest and after removal from storage. Intact fruits were placed in an 8-L Pyrex container through which an air stream (150 mL min^{-1}) was passed for 60 min. The resulting effluent was passed through an adsorption tube filled with 350 mg Tenax TA/ Carbograph 1TD. The volatile compounds were desorbed into an Agilent 7890A gas chromatograph (Agilent Technologies, Inc., Barcelona, Spain) at 275 ºC for 15 min, using an automated UNITY Markes thermal desorption system (Markes International Ltd., Llantrisant, United Kingdom). The identification and quantification of volatile compounds was performed on an Agilent 7890A gas chromatograph (Hewlett-Packard Co., Barcelona, Spain) equipped with a flame ionization detector (GC-FID), using a capillary column with cross-linked free fatty acid as the stationary phase (FFAP; 50 m × 0.2 mm × 0.33 μm). Helium was used as the carrier gas, at a linear velocity of 42 cm s^{-1}, with a split ratio of 60:1. Both the injector and detector were kept at 240 ºC. The analysis was conducted according to the following program: 40 ºC (1 min); 40-115 ºC (2.5 ºC min^{-1}); 115-225 ºC (8 ºC min^{-1}); 225 ºC (10 min). A second capillary column (SGE, Milton Keynes, UK) with 5% phenyl polysilphenylene-siloxane as the stationary phase (BPX5; 30 m × 0.25 mm i.d. × 0.25 μm) was also used for compound identification under the same operating conditions as described above. Compounds were identified by comparing their respective retention indices with those of accepted standards and by enriching peach extract with authentic samples. Quantification was carried out using butyl benzene (assay > 99.5%, Fluka) as an internal standard while the concentrations of volatile compounds were expressed as ng kg^{-1}. Compound confirmation was performed in an Agilent 6890N gas chromatograph/mass spectrometer (Agilent Technologies, Inc.),

using the same capillary column as in the GC analyses. Mass spectra were obtained by electron impact ionization at 70 eV. Helium was used as the carrier gas (42 cm s^{-1}), following the same temperature gradient program described previously. Spectrometric data were recorded (Hewlett-Packard 3398 GC Chemstation) and compared with those from the original NIST HP59943C library mass spectra.

Analysis of Physicochemical Parameters. Fifteen fruits either at harvest or after each combination of factors (storage period × shelf life period) were individually assessed for flesh firmness, soluble solids content (SSC), titratable acidity (TA), and skin color. Flesh firmness was measured on opposite sides of each fruit with a digital penetrometer (Model.***53205***;***TR***, Forlí, Italy) equipped with an 8-mm diameter plunger tip; the results were expressed in N. SSC and TA were measured in juice pressed from whole fruits. SSC was determined with a Palette-10 hand refractometer (Atago PR-32, Tokyo, Japan) and the results were expressed as percent sucrose in an equivalent solution. TA was determined by titrating 10 mL juice with 0.1 M ofNaOH to pH 8.1 and the results were given as grams of malic acid per liter. Fruit epidermis color was determined with a portable tri-stimulus colorimeter (Chroma Meter CR-400, Konica Minolta Sensing, Inc. Osaka, Japan) using CIE illuminant D_{65} and with an 8-mm measuring aperture diameter. The skin color was measured at two points on the equator of each fruit that were 180º apart; one was on the side exposed to sunlight (ES) and the other was on the shaded side (SS). Hue angle was determined on both sides and the resulting values were used as measurements of superficial (ES) and background (SS) color.

Sensory Analyses. For consumer evaluation, fruit samples for each treatment (cultivar and storage period) were kept in a room at 20 ºC for 3 days. Twenty nectarines per treatment were used for sensory analysis. Prior to evaluation, the color and flesh

firmness were measured on both sides of each fruit. Two longitudinal wedges were then analyzed for physicochemical measures as explained above. The rest of the fruit was used for consumer evaluation. A piece of nectarine for each cultivar was placed on a white plate and immediately presented to a tasting panel of 111 consumers, straight after each harvest. The consumers were all volunteers and were either staff members at the UdL-IRTA research institute or students at the University of Lleida. All test participants were habitual nectarine consumers. Each piece was identified by a random three-digit code. The order of presentation of the two pieces of fruit on the white plate was randomized for each consumer. Mineral water was used as palate cleansers between samples. To score the degree of consumer preference, each consumer tasted all samples and was asked to indicate his/her degree of like/dislike using a 9-point hedonic scale (1-dislike extremely to 9-like extremely). The percentage of satisfied consumers was defined as the percentage of participating consumers who scored a particular sample with a mark of 6 or higher. Samples could be re-tasted as often as the tasters wanted to ensure that they were confident about the different scores. The same consumers participated in all the different evaluations.

Statistical Analyses.A multifactor design was used for statistical analysis of the results. The factors considered were: cultivar, storage time, and shelf life time. All data were tested using analysis of variance (GLM-ANOVA procedure) with the SAS program package (24).Means were separated by the least significant difference (LSD) test at $p \leq 0.05$. Unscrambler version 9.1.2. software (25)was used to develop Partial Least Square Regression model (PLSR). This PLSR was used as a predictive method to relate consumer acceptance (Y) to a set of explanatory variables (X) which contains the volatile compounds and physicochemical measures. As a pre-treatment, data were

centered and weighted using the inverse of the standard deviation of each variable in order to avoid the influence of the different scales used for the variables (26).Full cross-validation was run as a validation procedure.

RESULTS AND DISCUSSION

Physicochemical Measures at Harvest and after Cold Storage. At harvest, cultivars showed statistically similar average firmness except 'Big Top' and 'August Red', which were more firm than the others. Firmness measurements were between 38.14 and 47.09 N, consistent withthe recommended harvest firmness for nectarine fruits intended for cold storage (*8*).The soluble solids content (SSC) and titratable acidity exhibited the expected varietal differences; sugar and acid concentrations are cultivar-dependent (*7*).As expected, the 'Honey Royale^{cov}' variety had the highest SSC. However, in our study, 'Big Top' and 'Honey Blaze^{cov}', which are typically sweet varieties with very high SSC, exhibited low SSC instead. This could have been due to reduced sunlight during the month before harvest of the early-season cultivars(May 15 to June 17); this solar radiation was notably lower than the average for the previous 10 years. The variety with the highest TA was 'August Red',followed by 'Venus', 'Big Top', 'Honey Blaze^{cov}', 'Honey Royale^{cov}', and 'Nectagala^{cov}'. All the varieties studied here were selected because they typically exhibithigh coloration (*7*),consequently statistical differences were not detected, except for 'Honey Blaze^{cov}'.

In general, after each cold storage period, the loss of firmness during shelf life was one of the most important changes among the physicochemical measures (**Table 1**), the only variety that maintained firmness was 'Nectagala^{cov}'. Along cold storage plus 0 days at 20 ºC, all the varieties presented a quite stable firmness, except 'Honey

Royale[cov]' variety which showed a significant softening. After three days at 20 ºC after cold storage, firmness ranged from 7.0 N for 'Venus' to 32.1 N for 'Big Top'. The extreme firmness for 'Big Top', even after three days of storage at 20 ºC, agrees with previous results of its special texture (*27-30*).

Shelf life at 20 ºC did not generally affect SSC, which remained constant. The only exception was in 'Honey Royale[cov]' fruits cold-stored for 20 days, which exhibited a slight decrease in SSC. A slight increase in SSC during shelf life after removal from cold storage has been reported (*31*).In general, in this study the storage period did not influence SSC (**Table 1**). These results indicate that even though nectarines are climacteric fruits, postharvest variations in SSC should be relatively unimportant (*32*).

In general, TA decreased with cold storage and subsequent shelf life for all varieties. The decrease in TA with cold storage is attributable to the oxidation of organic acids (*31, 33*).

The SSC/TA ratio remained constant throughout cold storage and following shelf life for 'Nectagala[cov]' nectarines. For acid cultivars such as 'August Red' and 'Venus', SSC/TA increased with shelf life after each cold storage time as previously reported for 'Harvester' peaches (*34*).For the other varieties, inconsistent behavior was observed. A closer relationship was reported between the SSC/TA ratio and eating quality than between TA or SSC considered separately (*31*).However, the establishment of a minimum quality index based on SSC or SSC/TA must be evaluated for each stone fruit cultivar (*35*).

No significant differences in hue were detected during cold storage for 'August Red', 'Big Top' or 'Venus'. Over recent decades, new cultivars have been released which develop a full, intense red color at an early stage of maturity (*36-38*).As seen

here, this full red color makes these cultivars more uniform and means that they undergo fewer changes during cold storage.

Volatile Compounds Emitted by Nectarines at Harvest and after Cold Storage. Differences in volatile profiles before and after cold storage were found among the different cultivars (**Table 2**). Up to 23 out of 43 volatile compounds detected at harvest were detected for the first time after cold storage, depending on cultivar. In early-season cultivars 'Big Top' and 'Honey Blaze^{cov}', eight new compounds were identified after cold storage. In mid-season cultivars 'Venus' and 'Honey Royale^{cov}', five and nine new compounds were identified after cold storage, respectively, while ten new compounds were detected after cold storage in the two late-season cultivars 'August Red' and 'Nectagala^{cov}'. For instance, ethyl 2-methylbutanoate was not detected at harvest but appeared during cold storage in one early cultivar ('Big Top'), two mid-season varieties ('Venus' and 'Honey Royale^{cov}'), and one late-season cultivar ('Nectagala^{cov}'). In contrast, 2-methylpropyl hexanoate was only detected at harvest in 'Big Top' nectarines.

Most of these volatile compounds were esters and since esters and lactones are the most important contributors to nectarine aroma (*39*), particular attention was placed on these compounds. Emissions of eight straight-chain esters (ethyl acetate, butyl propanoate, pentyl acetate, hexyl propanoate, methyl octanoate, ethyl octanoate, pentyl hexanoate, and hexyl hexanoate), five branched-chain esters (ethyl 2-methylbutanoate, 2-methylbutyl-2-methylpropanoate, butyl 2-methylbutanoate, Z-3-hexenyl acetate, and hexyl 2-methylbutanoate), and four cyclic esters (γ-hexalactone, γ-octalactone, δ-decalactone, and γ-dodecalactone) were detected in nectarines after cold storage. As a consequence, increased fruity and floral notes (*16*)were observed in the volatile profiles

of ‘Big Top’, ‘Honey Blaze^{cov}’, ‘Venus’, ‘Honey Royale^{cov}’, ‘August Red’ and ‘Nectagala^{cov}’ nectarines after cold storage (**Table 2**).

The same aldehydes, ketones, terpenes, and acetic acid that were present at harvest were identified and quantified in the volatile fractionsemitted by these six cultivars after cold storage (**Table 2**).

The effects of cold storage on early-season varieties were mainly characterized by opposing changes in two major groups of volatile compounds, esters and acids (**Figure 1**). Esters were the main compounds isolated from ‘Big Top’ and ‘Honey Blaze^{cov}’, representing ≥ 50% of total volatile compounds in fruit kept in cold storage for 10 days without shelf life. The relative proportion of esters decreased by up to 17% in early-season varieties after 40 days cold storage. An increase in the relative proportion of acids was observed during cold storage: ≥ 39% in ‘Big Top’ and ≥ 30% in ‘Honey Blaze^{cov}’ nectarines after 40 days cold storage, depending on shelf life.

In mid-season cultivars like ‘Venus’ and ‘Honey Royale^{cov}’, the volatile profile was dominated by esters (75-15%), acids (42-8%) and ketones (40-7%). These three organic families represented more than 78% of total volatile compounds in samples kept in cold storage. During cold storage and/or shelf life at 20 ºC, the relative proportions of ester and ketone compounds decreased by up to 37% in ‘Venus’ after 40 days cold storage. With the relative proportion of esters decreasing after 40 days cold storage, the proportion of acids increased during the same period. Acids became the most abundantcompounds in ‘Venus’ (41% of total volatile compounds) and the second-most abundant compounds in ‘Honey Royale^{cov}’ (26% of total volatile compounds) after 40 days cold storage.

During cold storage and shelf life of two late-season varieties, the volatile profile was dominated by acids (65-17%), ketones (55-8.5%), and esters (52-3.5%). The

relative proportion of acids was higher than that of esters in fruits kept in cold storage for 10 or 40 days plus zero days of shelf life. There was an increase in the relative proportion of esters during shelf life in both 'August Red' and 'Nectagala^{cov}' nectarines, particularlyafter 10 days cold storage (**Figure 3**).

Differences among cultivars in volatile emissions were found both before and after cold storage (**Tables 3-5**). At harvest, the total volatiles emitted by 'Venus' were triple those emitted by 'Big Top', 'Honey Royale^{cov}', 'August Red', or 'Nectagala^{cov}', whose emissions ranged from 2,275 to 3,132 ng kg^{-1}. After 10 days cold storage plus three days at 20 ºC, the total volatiles of 'Honey Royale^{cov}' was 12,565 ng kg^{-1}; this was more than those of 'Big Top', 'Venus', or 'August Red' (5,360, 5,350, or 4,987 ng kg^{-1}, respectively) and about four times higher than 'Nectagala^{cov}' and 'Honey Blaze^{cov}' (3,569 and 2,523 ng kg^{-1}, respectively).

Cold storage and shelf life affected total volatile emissions in early- and late-season cultivars (**Tables 3 and 5**). The greatest increases in volatile compounds emitted by 'Honey Blaze^{cov}', and 'August Red' were obtained after 40 days cold storage plus three days at 20 ºC. In contrast, a significant decrease in total volatile emissions was noted in 'Big Top' and 'Honey Royale^{cov}' after 40 days cold storage plus zero days at 20 ºC (**Tables 3 and 4**).

'Big Top', 'Venus', 'Honey Royale^{cov}' and 'Nectagala^{cov}' cultivars cold stored after 20 or 40 days showed ethyl 2-methylbutanoate concentrations higher than for fruit stored for 10 days. Ethyl 2-methylbutanoate directly affected nectarine flavor because it has a very low odor threshold (6 ng kg^{-1}; **Table 2**) and plays an important role in the characteristic aroma of many fresh fruits such as apple (*40*),blackberry (*41*),orange (*42*),and pineapple (*43*).

The emission of acetate esters, and especially of 2-methylpropyl, pentyl, and hexyl acetates, increased with cold storage in 'Big Top' and 'Honey Blaze^{cov}' nectarines. In fruits kept for 40 days cold storage plus 3 days at 20 ºC, a large increase was observed (**Table 3**).

Four lactones were found, although not all were detected in all nectarines (**Tables 3-5**). Lactones accounted for 0.5 to 3.5% of total volatiles (**Figures 1-3**). These low proportions were consistent with previous observations of mature nectarines (*16*).In our study, the most abundant and stable lactone during cold storage followed by shelf life was γ-hexalactone. Lactones are prominent volatiles in nectarine aroma (*1*) and concentrations of γ-hexalactone and γ- and δ-decalactones are generally low at harvest and increase during shelf life (*44*).In early-season cultivars, γ-dodecalactone was first detectedafter 10 days cold storage. This lactone has the lowest odor threshold (430 ng kg^{-1}, **Table 2**) and could therefore influence nectarine aroma (*20*).Furthermore, γ-octalactone and δ-decalactone were identified in 'Honey Blaze^{cov}' after 10 days cold storage. In contrast, γ-dodecalactone was not detected in the two mid-season cultivars or in 'Nectagala^{cov}'. This influence of cultivar on lactone compounds has been previously noted: 10 lactones were found in the essential oil of three nectarine accessions, but none lactones were detected in 'Romagna Big' nectarines (*22*).

Significant differences in lactone concentrations were found among the six cultivars and different cold storage times. In early-season and 'Nectagala' cultivars, there was no decrease in total lactones after 40 days cold storage plus three days at 20 ºC, while there was a decrease in mid-season and 'August Red' cultivars.Individual lactones did not contribute to these global changes in the same way. In general, γ-hexalactone concentrations were present in all the studied varieties after cold storage, excepting in late-season cultivars cold stored for 40 days without shelf life.

Total aldehyde concentrations accounted for 3 to 20% of the total volatile fraction during cold storage followed by shelf life (**Figures 1-3**). This depends on the genetic background of the cultivar (*16*).The concentrations of three C_6 aldehydes emitted by 'Venus' and 'August Red' increased after 40 days cold storage plus three days at 20 ºC. Benzaldehyde is derived from cyanogenic glycoside, amydalin, and prunasin, which are typical constituents of many *Prunus* species. Benzaldehyde was recognized as the almond aroma present in peach, but was present in quantities below its odor threshold of 350 μg kg^{-1} (**Table 2**).

Two ketones were detected in the six cultivars and accounted for 6 to 55% of total volatiles after cold storage plus shelf life (**Figures 1-3**). During cold storage, total ketone concentrations decreased in 'Big Top' and the two mid-season varieties but increased in late-season cultivars (**Tables 3-5**). The predominant ketone was 2,3-butanodione. This is a compound with a low odor threshold (1μg kg^{-1}, **Table 2**)that would have contributed buttery notes to the aroma of `Big Top´, 'Venus', and 'Honey Royale^{cov}'after 10 days cold storagefollowed by three days at 20 ºCand in 'August Red' after 20 days cold storage plus three days at 20 ºC. The cold storage period seems to delay synthesis of this ketone, except in 'Honey Blaze$^{®}$' and 'Nectagala^{cov}'. Nevertheless, to the best of our knowledge no data have previously been reported on the effect of cold storage on the concentration of this ketone in nectarine fruits.

Three organic acids accounted for 2 to 65% of the total volatile fraction during cold storage followed by shelf life (**Figures 1-3**). The concentration of acetic acid emitted by all six cultivarsincreased or remained quite stable after 40 days cold storage plus three days at 20 ºC compared to the rest of storage and shelf life periods (**Tables 3-5**). Acetic acid was the most abundant acid present in all cultivars, but as its odor threshold is 99,000 μg kg^{-1} (**Table 2**), it would not have contributed to nectarine aroma.

Terpenoids contribute the characteristic fruity aroma to nectarines and two compounds accounted for about 0.4 to 6% of total volatiles depending on the cultivar, cold storage time, and shelf life time (**Figures 1-3**). The monoterpene linalool was the most abundant in early-season varieties (**Table 3**); its predominance has also been noted in other nectarine cultivars such as 'Romagna Big' (*22*), 'Fantasia', and 'Early Red' (*16*). During cold storage, linalool concentrations decreased in all cultivars except 'Honey Blaze^{cov}'. Linalool and eucalyptol were only detected in 'Venus' at harvest and after 10 days cold storage. The concentration of eucalyptol increased after 40 days cold storage in 'August Red', but always remained very low in early-season varieties.

Six alcohols accounted for 4 to 18.5% of total volatiles depending on the cultivar, cold storage time, and shelf life time (**Figures 1-3**).After 40 days cold storage, total alcohols decreased in 'Big Top' and 'Nectagala^{cov}', but increased in 'August Red' after three days at 20 ºC (**Tables 3-5**). 2-Ethyl-1-hexanol was the most abundant alcohol in all cultivars during cold storage. During cold storage, the concentration of 2-Ethyl-1-hexanol remained constant in 'Big Top', 'Honey Blaze' (early-season cultivars), and 'Honey Royale' (mid-season cultivar), increased in 'August Red' and declined in 'Nectagala' (late-season cultivars).

Consumer Acceptance. There were no statistically significant differences in consumer acceptance either among cultivars at harvest or for a given cultivar during cold storage (data not shown). Consumer acceptance was highly variable, which could have given us similar average values of acceptance.To study consumer acceptance in more detail, we analyzed the percentage of satisfied consumers for each cultivar and storage time, including at harvest (**Table 6**). At harvest, the highest percentages of satisfied consumers, ≥70%, were associated with the sweet cultivars 'Honey Royale^{cov}', 'Honey

Blaze[cov]', 'Big Top', and 'Nectagala[cov]'. In contrast, acid cultivars such as 'Venus' and 'August Red' only satisfied about 50% of consumers. These results agree with reported findings that among six nectarine cultivars, the sweet cultivars were better appreciated by consumers (*7*). The six cultivars showed different changes in consumer acceptance from harvest through different lengths of cold storage. 'Big Top' became more acceptable to consumers with longer cold storage. 'Venus' acceptability remained stable during cold storage. Consumer satisfaction with 'Honey Royale[cov]' declined after 10 days cold storage. For 'Nectagala[cov]' and 'August Red', the percentage of consumer satisfaction increased at 10 and 20 days but decreased at 40 days.

To determine the variables that most influenced consumer acceptance, a partial least square regression model (PLSR) was developed using physicochemical measures (SSC, TA, SSC/TA and firmness) and volatile compound emissions as the X variables and the degree of consumer acceptance as the Y variable. Physicochemical measures and volatile compound emissions accounted for up to 81% of the total variability in consumer acceptance (**Figure 4A**). 'Big Top' (regardless cold storage time), 'Nectagala' (10 and 20 days cold storage) and 'Honey Blaze' (40 days cold storage) nectarines were located on the right side of the PC1 axis, which explained alone 64% of total variance and, which in turn, were associated with higher consumer acceptance. In contrast, the rest of cultivars stored at different cold storage time on the left side of PC1, away from the first group (**Figure 4A and 4B**). The **figure 4C** showed the influence of instrumental variables on consumer acceptance. The volatile compounds benzyl alcohol, butyl octanoate, γ-hexalactone, hexyl hexanoate, 2-ethyl-1-hexanol, hexyl 2-methylbutanoate, hexanol, 2-methylbutyl 2-methylpropanoate, 2-ethyl-1-hexenal, and 2-methylbutyl acetate, and flesh firmness (showing positive relation to consumer acceptance) were among the variables that most influenced consumer acceptance.

Coinciding with previous reports of ‘Pink Lady’ apples cold stored, hexyl hexanoate and hexyl 2-methylbutanoate were found to have most influence on consumer acceptance (*45,46*).The importance of some volatile compounds on peach consumer acceptance has also been reported previously (*47*).

ACKNOWLEDGEMENTS

This work was supported through project RTA 2008-00055-00-00 and financed by Spain’s *Instituto Nacional de Investigación Agraria* (INIA). J. Cano is the recipient of a PhD grant from the *Agència de Gestió d’Ajuts Universitaris i Recerca* (AGAUR), Generalitat de Catalonia (Spain). The authors are indebted to Mr. F. Florensa for technical assistance.

REFERENCES

(1) Aubert, C.; Günata, Z.; Ambid, C.; Baumes, R. Changes in physicochemical characteristics and volatile constituents of yellow- and white-fleshed nectarines during maturation and artificial ripening. *J. Agric. Food Chem.* **2003a**, *51*, 3083–3091.

(2) Dagar, A.; Wekslera, A.; Friedman, H.; Ogundiwinc, E.A.; Crisosto, C.H.; Ahmadc, R.; Lurie, S. Comparing ripening and storage characteristics of ‘Oded’ peach and its nectarine mutant ‘Yuval’. *Postharvest Biol. Technol.***2011**, *60*, 1–6.

(3) Wen, I.C.; Koch, K.E.; Sherman, W.B. Comparing fruit and tree characteristics of two peaches and their nectarine mutants. *J. Am. Soc. Hortic. Sci.***1995a**, *120*, 101–106.

(4) Wen, I.C.; Sherman, W.B.; Koch, K.E. Heritable pleiotropic effects of the nectarine mutant to peach. *J. Am. Soc. Hortic. Sci.***1995b**, *120*, 721–725.

(5) Crisosto, C.H.; Mitchell, F.G.; Zhiguo, J. Susceptibility of chilling injury of peach, nectarine and plum cultivars grown in California. *HortSci*. **1999**, *34*, 1116–1118.

(6) Food and Agriculture Organization of the United Nations Statistics. Production of peaches and nectarines in the world. http://faosfat.fao.org./site/339/ default.aspx (accessed March, 2009).

(7) Iglesias, I.; Echeverria, G. Differential effect of cultivar and harvest date on nectarine color, quality and consumer acceptance. *Sci. Hortic*. **2009**, *120*, 41–50.

(8) Lurie, S.; Crisosto, C.H. Review. Chilling injury in peach and nectarine. *Postharvest Biol. Technol*. **2005**, *37*, 195–208.

(9) Drake, S.R.; Elfving, D.C. Short-term controlled atmosphere storage for storage-life extension of white-fleshed peaches and nectarines. *J. Food Qual*. **2003**, *26*, 135–147.

(10) Lavilla, T.; Recasens, I.; López, M.L.; Puy, J. Multivariate analysis of maturity stages, including quality and aroma, in 'Royal Glory' peaches and 'Big Top' nectarines. *J. Sci. Food Agric*. **2002**, *82*, 1842–1849.

(11) Lim, L.; Romani, R. Volatiles and the harvest maturity of peaches and nectarines. *J. Sci. Food*. **1964**, *29*, 246–253.

(12) Engel, K.H.; Flath, R.A.; Buttery, R.G.; Mon, T.R.; Ramming, D.W.; Teranashi, R. Investigation of volatile constituents in nectarines. 1. Analytical and sensory characterization of aroma components in some nectarine cultivars. *J. Agric. Food Chem*. **1988a**, *36*, 549–533.

(13) Takeoka, G.R.; Flath, R.A.; Gunter, M.; Jennings, W. Nectarine volatiles: vacuum steam distillation versus headspace sampling. *J. Agric. Food Chem*. **1988**, *36*, 553–560.

(14) Berger, R.G. Fruits I. In *Volatile Compounds in Foods and Beverages*; Maarse, H., Ed.; Dekker: New York, EEUU, 1991.

(15) Visai, C.; Vanoli, M. Volatile compound production during growth and ripening of peaches and nectarines. *Sci. Hortic*. **1997**, *70*, 15–24.

(16) Wang, Y.; Yang , C.; Li S.; Yang , L.; Wang, Y.; Zhao, J.; Jiang, Q. Volatile characteristics of 50 peaches and nectarines evaluated by HP-SPME with GC-MS. *Food Chem.***2009**, *116*, 356–364.

(17) Aubert, C.; Bony, P.; Chalot, G.; Hero, V. Changes in physicochemical characteristics and volatile compounds of apricot (*Prunus armeniaca L.* cv. Bergeron) during storage and post-harvest maturation. *Food Chem*. **2010**, *119*, 1386–1398.

(18) Engel, K.H.; Ramming, D.W.; Flath, R.A.; Teranashi, R. Investigation of volatile constituents in nectarines. 2. Changes in aroma composition during nectarine maturation. *J. Agric. Food Chem*. **1988b**, *36*, 1003–1006.

(19) Aubert, C.; Ambid, C.; Baumes, R.; Günata, Z. Investigation of bound Aroma constituents of yellow-fleshed nectarines (*Prunus persica L*. Cv. Springbright). Changes in bound aroma profile during maturation. *J. Agric. Food Chem*. **2003b**, *51*, 6280–6286.

(20) Rizzolo, A.; Eccher Zerbini, P.; Grassi, M.; Cambiaghi, P.; Bianchi, G. Effect of 1-methylcyclopropene on aroma compounds in “Big Top” nectarines after shelf life. *J. Food Qual*. **2006**, *29*, 184–202.

(21) Vanoli, M.; Jacob, S.; Eccher Zerbini, P.; Rizzolo, A.; Spinelli L.; Torricelli, A. Time-Resolved reflectance spectroscopy as a tool for selecting at harvest ‘Ambra’ nectarines for aroma quality. *Acta Hortic*. **2008**, *796*, 231–235.

(22) Eduardo, I.; Chietera, G.; Bassi, D.; Rossini, L.; Vecchiettia A. Identification of key odor volatile compounds in the essential oil of nine peach accessions. *J. Sci. Food Agric*. **2010**, *90*, 1146–1154.

(23) Cano-Salazar, J.; Echeverria, G.; Crisosto, C.; López, L. Cold storage potential of four yellow-fleshed peach cultivars defined by their volatile compound emissions, standard quality parameters, and consumer acceptance. *J. Agric. Food Chem*. **2011**, DOI: 10.1021/jf204126m.

(24) SAS Institute, Inc. SAS 9.1. Qualification Tools User's Guide; SAS Institute: Cary, NC, 2004.

(25) CAMO ASA. *Unscrambler Users Guide*, ver. 9.1.2; Programme Package for Multivariate Calibration. Trondheim, Norway, 2004.

(26) Martens, H.; Naes, T. Partial least squares regression. In Multivariate Calibration; Wiley J. and Sons Eds. Chichester, UK, 1989.

(27) Kader, A.A. *Postharvest Technology of Horticultural Crops*. University of California Division of Agri. and Natural Resources, 2nd ed, 1992.

(28) Crisosto, C.H.; Slaughter, D.; Garner, D.; Boyd, J. Stone fruit critical bruising thresholds. *J. Am. Pomol. Soc*. **2001**, *55*, 76–81.

(29) Metheney, P.D.; Crisosto, C.H.; Garner, D. Developing canning peach critical bruising thresholds. *J. Am. Pomol. Soc*. **2002**, *56*, 75–78.

(30) Ghiani, A.; Negrini, N.; Morgutti, S.; Baldin, F.; Nocito, F.; Spinardi, A.; Mignani, L.; Bassi, D.; Cocucci, M. Melting of `Big Top´ nectarine fruit: some physiologycal, biochemical, and molecular aspects. *J. Am. Soc. Hortic. Sci.***2011**, *136*, 61–68.

(31) Crisosto, C.H.; Crisosto G.M. Relationship between ripe soluble solids concentration (RSSC) and consumer acceptance of high and low acid melting flesh

peach and nectarine (*Prunus persica* L. Batsch) cultivars. *Postharvest Biol. Technol.***2005**, *38*, 239–246.

(32) Altube, H.; Budde, C.; Ontivero, M.; Rivata, R. Determination of the harvest indexes in peach trees cvs. Flordaking and San Pedro 16-33. *Agricultura Técnica (Chile)* **2001**, *61*, 140–150

(33) Robertson, J.A.; Meredith, F.I.; Horvat, R.J.; Senter S.D. Effect of cold storage and maturity on the physical and chemical characteristics and volatile constituents of peaches (cv. Cresthaven). *J. Agric. Food Chem*. **1990**, *38*, 620–624.

(34) Meredith, F.I.; Robertson, J.A.; Hovart, R.J. Changes in physical and chemical parameters associated with quality and postharvest ripening of Harvester peaches. *J. Agric. Food Chem*. **1989**, *37*, 1210–1212.

(35) Crisosto, C.H.; Garner, D.; Crisosto, G.M.; Bowerman, E. Increasing "Blackamber" plum (Prunus salicina Lindell) consumer acceptance. *Postharvest Biol. Technol*. **2004**, *34*, 237–244.

(36) Carbó, J.; Iglesias, *I.* Melocotonero: las variedades de más interés. Ed.; Institut de Recerca i Tecnologia Agroalimentàries, Barcelona, Spain, 2002.

(37) Scorza, R.; Sherman, W.B. Peaches. Fruit Breeding, vol.1, Janick, J, Moore, J. N. Eds. Tree and Tropical Fruits. John Wiley Sons, Inc, New York, EEUU, 1996.

(38) Bellini, E.; Nencetti, V.; Natarelli, L.; Liverani, A.; Insero, O.; Conte, L. Liste varietali dei fruttiferi 2004. Pesco. *L´ Informatore Agrario***2004**, *24*, 53–69.

(39) Sumitani, H.; Suekane, S.; Nakatani, A.; Tatsukat, K. Changes in composition of volatile compounds in high pressure treated peach. *J. Agric. Food Chem*. **1994**, *42*, 785–790.

(40) Echeverria, G.; Correa, E.; Ruíz-Altisent, M.; Graell, J.; Puy, J.; López, L. Characterization of Fuji apples from different harvest dates and storage conditions

from measurements of volatiles by gas chromatography and electronic nose. *J. Agric. Food Chem*. **2004**, *52*, 3069–3076.

(41) Wang, Y.; Finn, C.; Qian, M.C. Impact of growing environment on Chickasaw blackberry (Rubus L) aroma evaluated by gas chromatography olfactometry dilution analysis. *J. Agric. Food Chem*. **2005**, *53*, 3563–3571.

(42) Hinterholzer, A.; Schieberle, P. Identification of the most odour-active volatiles in fresh, hand-extracted juice of Valencia late oranges by odour dilution techniques. *Flavour Fragr. J*. **1998**, *13*, 49–55.

(43) Tokitomo, Y.; Steinhaus, M.; Büttner, A.; Schieberle, P. Odor-active constituents in fresh pineapple (Ananas comosus [L.] Merr.) by quantitative and sensory evaluation. *Biosci. Biotechnol. Biochem*. **2005**, *69*, 1323–1330.

(44) Zhang, B.; Shen, J.Y.; Wei, W.W.; Xi, W.P.; Xu, C.J.; Ferguson, I.; Chen, K. Expression of genes associated with aroma formation derived from the fatty acid pathway during peach fruit ripening. *J. Agric. Food Chem*. **2010**, *58*, 6157–6165.

(45) López, M.L.; Villatoro, C.; Fuentes, T.; Graell, J.; Lara, I.; Echeverría G. Volatile compounds, quality parameters and consumer acceptance of 'Pink Lady®' apples stored in different conditions. *Postharvest Biol. Technol*. **2007**, *43*, 55–66

(46) Villatoro, C.; López, M.L.; Echeverría, G.; Lara, I.; Graell, J. Effect of controlled atmospheres and shelf life period on concentrations of volatile substances released by 'Pink Lady®' apples on consumer acceptance. *J. Sci. Food Agric*. **2009**, *89*, 1023–1034.

(47) Ortiz, A.; Echeverría, G.; López, M.L.; Graell, J.; Lara, I. Overall quality of 'Rich Lady' peach fruit after air- or CA storage. The importance of volatile emission. LWT - *Food Sci. Tech. Int*. **2009**, *42*, 1520–1529.

Table 1. Standard Quality Measures of Nectarine Fruits at Harvest and after Storage at -0.5 ºC for 10, 20, or 40 Days with or without Three Days at 20 ºC.

Days at -0.5ºC		Harvest		10				20				40			
Days at 20ºC				0		3		0		3		0		3	
Big Top	SSC	11.3	a	11.6	a	11.0	a	11.4	a	12.2	a	11.5	a	10.6	a
	TA	8.1	a	5.9	b	5.9	b	5.1	b	4.9	b	5.2	b	5.8	b
	SSC/TA	14.1	c	19.7	bc	18.8	bc	22.6	ab	25.3	a	22.8	a	17.7	bc
	Firmness	47.1	a	43.6	a	32.1	b	43.0	a	29.5	bc	40.1	ab	28.8	c
	Hue skin (ES)	24.5	a	19.6	a	23.1	a	19.1	a	23.6	a	22.2	a	25.3	a
	Hue skin (SS)	70.5	a	53.9	a	58.3	a	66.4	a	54.9	a	59.3	a	55.0	a
Honey Blaze[cov]	SSC	11.2	a	11.8	a	11.9	a	11.3	a	11.1	a	10.2	b	11.0	a
	TA	5.6	a	4.7	ab	4.9	ab	3.4	c	4.5	ab	3.3	c	4.0	bc
	SSC/TA	21.0	d	25.4	bc	24.7	c	34.3	a	25.3	bc	31.6	a	27.5	b
	Firmness	38.1	a	36.8	a	29.6	ab	33.6	ab	24.4	b	35.5	a	13.6	c
	Hue skin (ES)	17.3	a	16.7	a	20.5	a	21.8	a	24.0	a	22.6	a	23.0	a
	Hue skin (SS)	40.2	b	40.7	b	48.1	ab	52.5	a	51.0	ab	55.4	a	47.1	ab
Venus	SSC	11.6	a	11.5	a	12.2	a	11.9	a	12.1	a	11.4	a	11.8	a
	TA	9.9	a	10.0	a	10.1	a	8.3	b	6.9	b	7.9	b	7.0	b
	SSC/TA	11.7	c	11.4	c	12.2	bc	14.3	b	17.5	a	14.4	b	16.8	a
	Firmness	39.2	a	25.2	b	7.0	d	20.0	b	7.3	d	18.0	bc	15.0	c
	Hue skin (ES)	23.5	a	19.7	a	18.5	a	24.3	a	21.6	a	23.6	a	18.7	a
	Hue skin (SS)	60.5	a	54.9	a	52.9	a	68.4	a	57.3	a	69.9	a	61.7	a
Honey Royale[cov]	SSC	13.2	b	13.6	b	12.9	b	14.9	a	11.1	c	11.5	c	14.0	ab
	TA	5.5	a	3.2	b	2.8	b	2.5	b	3.0	b	3.0	b	2.7	b
	SSC/TA	26.4	d	45.3	b	43.0	b	59.9	a	37.0	c	38.3	c	53.0	a
	Firmness	39.6	a	36.4	a	8.4	d	28.3	b	7.9	e	16.8	c	28.1	bc
	Hue skin (ES)	19.4	b	18.3	bc	18.3	bc	41.7	a	16.8	c	23.6	b	13.7	d
	Hue skin (SS)	44.8	b	39.8	b	37.3	b	36.0	b	44.9	b	69.9	a	39.4	b
August Red	SSC	12.5	a	12.8	a	13.0	a	12.4	a	12.5	a	12.9	a	12.5	a
	TA	11.2	a	9.6	a	8.5	a	10.5	a	9.7	a	9.4	a	8.0	a
	SSC/TA	11.2	d	13.4	bc	15.3	a	11.8	cd	13.2	bc	13.9	b	15.7	a
	Firmness	47.0	a	30.2	b	17.4	d	27.8	b	20.6	cd	22.1	bc	17.5	d
	Hue skin (ES)	28.3	a	30.2	a	29.5	a	29.2	a	27.7	a	31.1	a	31.2	a
	Hue skin (SS)	79.4	a	82.9	a	84.1	a	87.2	a	82.7	a	86.7	a	82.1	a
Nectagala[cov]	SSC	11.5	a	11.6	a	11.4	a	11.2	a	12.4	a	12.7	a	12.3	a
	TA	4.3	a	3.8	a	3.8	a	3.1	a	3.2	a	2.7	a	2.6	a
	SSC/TA	27.1	a	30.8	a	30.7	a	36.5	a	39.0	a	49.5	a	47.4	a
	Firmness	40.4	a	21.0	b	17.2	b	19.1	b	17.8	b	19.7	b	17.2	b
	Hue skin (ES)	23.1	a	23.6	a	27.9	a	20.4	a	20.6	a	20.8	a	20.4	a
	Hue skin (SS)	70.9	a	66.6	b	83.8	a	71.7	a	63.0	b	70.2	a	65.1	b

Means followed by different small letters for each quality measure are significantly different at $p \leq 0.05$ (LSD test). SSC: Soluble solids content. TA: Titratable acidity. ES: exposed side. SS: shaded side.

Table 2. Volatile Compounds Detected in Six Nectarine Cultivars (labeled as X).

Volatile compounds	Code[a]	RI[b]	RI[c]	OTH[d]	CAS Registry No	Big Top		Honey Blaze[cov]		Venus		Honey Royale[cov]		August Red		
						Harvest	Cold Storage	Harvest	Cold Storage	Harvest	Cold Storage	Harvest	Cold Storage	Harvest	Cold Storage	H
Ethyl acetate	ea	911	–	13,500	141-78-6	nd	X	nd	nd	nd	X	X	X	X	X	
Propyl acetate	pra	995	766	2,000	109-60-4	X	X	X	X	X	X	X	X	X	X	
2,3-Butanodione	23bone	999	1067	1	431-03-8	X	X	X	X	X	X	X	X	X	X	
Eucalyptol	euOH	1032	–	1	470-82-6	X	X	X	X	X	X	X	X	X	X	
2-Methylpropyl acetate	2mpra	1052	789	65	110-19-0	X	X	X	X	X	X	X	X	X	X	
Hexanal	hnal	1082	807	2.4	66-25-1	X	X	X	X	X	X	X	X	X	X	
Ethyl 2-methylbutanoate	e2mb	1127	847	0.006	7452-79-1	nd	X	nd	nd	nd	X	nd	X	nd	nd	
Butyl acetate	ba	1183	816	66	123-86-4	X	X	X	X	X	X	X	X	X	X	
2-Methylbutyl acetate	2mba	1240	879	11	123-92-2	X	X	X	X	X	X	X	X	X	X	
Butyl propanoate	bpr	1257	912	25	590-01-2	X	X	X	X	nd	X	nd	X	nd	nd	
2-Ethyl-1-hexenal	2e1hal	1293	1033	not found	123-05-7	X	X	X	X	X	X	X	X	X	X	
Pentyl acetate	pa	1307	917	43	628-63-7	X	X	X	X	X	X	nd	X	nd	X	
2-Methylbutyl 2-methylpropanoate	2mb2mpr	1310	1043	14	2445-78-5	nd	X	X	X	X	X	X	X	nd	nd	
2-Methyl-1-butanol	2mbOH	1329	776	250	137-32-6	X	X	nd	X	nd	X	X	X	X	X	
Butyl 2-methylbutanoate	b2mb	1348	1017	17	15706-73-7	X	X	X	X	nd	nd	nd	nd	nd	nd	
1-Pentanol	pOH	1375	788	4,000	71-41-0	X	X	nd	X	X	X	nd	X	nd	X	
Hexyl acetate	ha	1393	1016	2	142-92-7	X	X	X	X	X	X	X	X	X	X	
2-Methylbuyl 2-methylbutanoate	2mb2mb	1397	1123	not found	2445-78-5	X	X	nd	nd	nd	nd	nd	nd	nd	nd	
Acetic acid	aac	1432	–	99,000	64-19-7	X	X	X	X	X	X	X	X	X	X	
Hexyl propanoate	hp	1435	1110	not found	2445-76-3	nd	X	nd	nd	nd	X	nd	X	nd	nd	
Propyl hexanoate	prh	1440	1099	not found	626-77-7	X	X	X	X	nd	nd	nd	nd	nd	nd	
2-Methylpropyl hexanoate	2mprh	1444	1293	not found	105-79-3	X	nd	nd	nd	nd	nd	nd	nd	nd	nd	
Z-3-hexenyl acetate	Z3hxea	1457	1020	13	3681-71-8	X	X	X	X	X	X	nd	X	nd	nd	
1-Hexanol	hOH	1480	873	500	111-27-3	X	X	X	X	X	X	X	X	X	X	
Methyl octanoate	mo	1511	1128	200	111-11-5	X	X	X	X	X	X	X	X	nd	X	
Z-3-hexen-1-ol	Z3henOH	1513	857	70	928-96-2	nd	X	nd	X	X	X	nd	X	X	X	
Benzaldehyde	byde	1521	971	350	100-52-7	X	X	X	X	X	X	X	X	X	X	
Butyl hexanoate	bh	1533	1014	700	626-82-4	X	X	nd	nd	X	X	nd	nd	nd	nd	
Hexyl 2-methylbutanoate	h2mb	1546	1239	22	10032-12-0	X	X	X	X	X	X	X	X	nd	X	
Ethyl octanoate	eo	1555	1003	not found	106-32-1	X	X	X	X	X	X	X	X	nd	X	
Benzoic acid	bac	1560	1193	85,000	65-85-0	X	X	X	X	X	X	X	X	X	X	
2-Ethyl-1-hexanol	2ehOH	1619	1033	not found	104-76-4	X	X	X	X	X	X	X	X	X	X	
Pentyl hexanoate	ph	1637	1293	not found	540-07-8	nd	X	nd	nd	nd	nd	nd	nd	nd	nd	
(R)-Linalool	liOH	1679	1105	0.087	126-91-0	X	X	X	X	X	X	X	X	X	X	
Hexyl hexanoate	hh	1736	1392	6,400	6378-65-0	X	X	nd	X	X	X	X	X	nd	X	
Acetophenone	aone	1736	1076	65	98-86-2	X	X	X	X	X	X	X	X	X	X	
Butyl octanoate	bo	1740	1394	not found	589-75-3	X	X	X	X	X	X	X	X	nd	nd	
Benzylalcohol	beOH	1869	1046	not found	10-51-6	X	X	X	X	X	X	X	X	X	X	
γ-Hexalactone	hlac	1880	1266	1,600	695-02-7	X	X	X	X	X	X	X	X	nd	X	
γ-Octalactone	olac	2111	1270	7	104-50-7	X	X	nd	X	X	X	nd	X	nd	X	
Decanoic acid	deac	2407	1390	2,200	334-48-5	nd	X	nd	X	X	X	X	X	X	X	
δ-Decalactone	dlac	2417	1507	31	211-889-1	X	X	nd	X	X	X	nd	X	nd	X	
γ-Dodecalactone	dolac	2587	1697	0.43	2305-05-7	nd	X	nd	X	nd	nd	nd	nd	nd	X	

[a]Codes used for principal component analysis. [b]RI: retention index in a FFAP column and [C]RI: retention index in a BPX5 column. Volatile compounds not detected: nd. [d]Odor threshold (μg kg^{-1}) in water as reviewed in ref (*23*).

Table 3. Volatile Compounds Emitted (Nanograms per Kilogram) by 'Big Top' and 'Honey Blaze[cov]' Nectarines after Cold Storage at -0.5 ºC with or without Three Days at 20 ºC.

Early-season varieties	Big Top												Honey Blaze[cov]											
Days at -0.5 ºC	Harvest	10			20			40			Harvest	10			20			40					
Days at 20 ºC		0		3	0		3	0		3		0		3	0		3	0		3			
Ethyl acetate	nd	17.5	a	22.8	a	nd		21.4	a	nd		nd	nd		nd		nd		nd		nd			
Propyl acetate	<10	488.2	a	516.1	a	171.9	b	601.9	a	nd		nd	20.3	432.2	a	23.4	b	407.2	a	22.9	b	nd		nd	
2-Methylpropyl acetate	21.5	40.7	c	42.7	c	55.0	b	50.2	bc	nd		116.1	a	213.1	30.9	b	62.7	b	29.7	b	61.9	b	46.9	b	219.0	a
Ethyl 2-methylbutanoate	nd	<10		<10		18.3	b	<10		37.0	a	nd		nd	nd		nd		nd		nd		nd	
Butyl acetate	42.1	97.7	b	103.9	a	30.6	c	120.4	a	nd		36.1	c	55.1	119.1	a	21.5	b	113.3	a	20.8	a	25.8	b	88.5	a
2-Methylbutyl acetate	29.7	109.5	b	117.9	b	261.1	a	134.9	b	231.2	a	273.4	a	71.3	143.3	a	133.0	a	139.0	a	126.6	a	205.4	a	185.3	a
Butyl propanoate	113.1	17.9	a	19.3	a	28.2	a	22.0	a	nd		nd		99.3	nd		12.5	a	nd		11.7	a	nd		nd	
Pentyl acetate	10	<10		<10		<10		<10		<10		12.1	a	87.5	<10		11.2	b	<10		10.8	b	11.4	b	24.5	a
2-Methylbutyl 2-methylpropanoate	153.9	51.8	a	53.7	a	36.0	b	63.9	a	32.4	b	50.3	a	368.4	35.5	a	50.6	a	37.1	a	49.7	a	27.1	a	43.2	a
Butyl 2-methylbutanoate	24.5	41.5	a	44.8	a	nd		51.2	a	nd		nd		48.8	24.3	a	nd		20.8	a	nd		nd		nd	
Hexyl acetate	45.1	73.2	b	79.5	b	37.3	c	90.2	a	43.6	c	95.5	a	93.3	34.0	b	54.8	b	34.6	b	52.7	b	36.5	b	109.4	a
2-Methylbuyl 2-methylbutanoate	nd	25.4	a	26.7	a	nd		31.4	a	nd		nd		nd	nd		nd		nd		nd		nd		nd	
Propyl hexanoate	32	12.0	a	11.1	a	<10		14.9	a	nd		nd		36.3	66.6	b	148.4	a	57.1	b	140.6	a	nd		nd	
Z-3-hexenyl acetate	58.4	70.6	a	92.1	a	43.6	b	86.5	a	nd		nd		51.4	72.4	a	68.0	a	81.3	a	67.8	a	nd		nd	
Hexyl propanoate	nd	100.2	a	92.6	a	nd		124.0	a	16.3	b	nd		nd	nd		nd		nd		nd		nd		nd	
2-Methylpropyl hexanoate	<10	nd		nd		nd		nd		nd		nd		nd	nd		nd		nd		nd		nd		nd	
Methyl octanoate	33	<10		<10		<10		11.0	a	<10		13.2	a	35.5	24.7	a	<10		39.4	a	<10		28.4	a	13.7	b
Butyl hexanoate	<10	179.8	b	185.7	b	nd		221.9	a	nd		56.7	c	nd	nd		nd		nd		nd		nd		nd	
Hexyl 2-methylbutanoate	11.6	716.3	a	737.7	a	12.5	c	883.7	a	17.9	c	175.3	b	10.4	18.7	a	11.4	a	16.0	a	11.3	a	10.2	a	12.1	a
Ethyl octanoate	229	81.1	b	84.3	b	329.0	a	100.1	b	26.8	c	86.5	b	82.5	79.0	b	98.3	b	69.5	b	97.3	b	144.2	b	506.8	a
Pentyl hexanoate	nd	34.9	a	36.2	a	<10		43.1	a	nd		11.4	b	nd	nd		nd		nd		nd		nd		nd	
Hexyl hexanoate	22	314.5	a	331.4	a	19.3	b	387.8	a	13.4	b	146.8	b	nd	38.7	a	36.6	a	48.0	a	38.1	a	11.0	b	41.3	a
Butyl octanoate	25.4	56.2	a	59.9	a	11.4	b	69.3	a	nd		21.4	b	<10	18.9	a	15.4	a	21.8	a	16.4	a	nd		nd	
γ-Hexalactone	26.5	30.7	c	34.1	b	28.7	c	37.8	b	12.7	d	49.7	a	36.3	44.4	a	41.4	a	48.8	a	41.3	a	30.3	a	67.4	a
γ-Octalactone	<10	12.8	a	14.1	a	13.2	a	15.7	a	nd		nd		nd	24.6	a	18.4	a	26.5	a	18.3	a	nd		nd	
δ-Decalactone	<10	16.8	b	20.6	b	51.9	a	20.6	b	nd		12.8	b	nd	73.1	a	41.0	a	68.3	a	41.0	a	nd		24.5	b
γ-Dodecalactone	nd	<10		<10		nd		<10		nd		nd		nd	13.3	a	<10		14.2	a	<10		nd		nd	
2-Ethyl-1-hexenal	133.7	115.2	a	127.7	a	77.2	b	141.8	a	82.1	a	116.2	a	11.8	68.3	a	94.0	a	71.5	a	91.3	a	108.9	a	99.6	a
Hexanal	223.3	240.5	a	230.4	a	101.5	d	170.9	b	129.8	c	137.2	c	195.7	184.5	a	119.1	b	246.3	a	151.6	b	195.8	a	154.2	b
Benzaldehyde	112.0	26.2	b	18.4	b	51.3	a	63.7	a	34.4	b	71.8	a	97.5	63.3	a	85.9	a	78.1	a	63.8	a	26.4	b	64.0	a
2,3-Butanodione	419.8	364.6	c	1030.8	a	340.6	c	660.2	b	333.2	c	542.4	b	740.1	270.4	c	900.8	a	460.9	b	784.5	b	525.0	b	1221.7	a
Acetophenone	38.4	67.3	b	120.8	a	114.7	a	49.3	b	58.8	b	60.4	b	25.1	71.1	a	32.6	b	93.8	a	88.6	a	65.9	a	74.2	a
Linalool	579.4	49.3	a	54.5	a	40.5	b	60.7	a	10.2	c	22.1	c	603.5	21.7	ab	59.5	a	22.8	ab	57.2	a	<10	c	22.3	ab
Eucalyptol	21.0	23.9	a	nd		nd		nd		nd		nd		<10	nd		nd		nd		nd		nd		16.9	a
Acetic acid	46.1	nd		88.7	b	nd		159.1	b	970.6	a	1266.4	a	300.0	nd		nd		142.6	b	1406.5	a	1164.1	a	1192.1	a
Decanoic acid	nd	nd		nd		nd		17.0	a	11.6	a	18.2	a	nd	nd		21.4	a	nd		26.0	a	nd		28.0	a
Benzoic acid	198.1	117.7	b	170.4	b	138.6	b	316.1	a	261.2	a	317.8	a	194.4	115.3	b	144.3	b	165.7	b	184.2	b	239.8	a	247.1	a
2-Methyl-1-butanol	24.8	34.7	a	37.3	a	nd		42.7	a	19.2	b	16.4	b	nd	nd		nd		nd		nd		35.8	a	10.9	b
1-Pentanol	12.3	13.2	a	15.4	a	nd		16.3	a	<10		nd		nd	14.3	a	10.3	a	12.2	a	<10		12.6	a	10.4	a
1-Hexanol	37.1	29.9	a	31.9	a	11.7	b	36.9	a	16.0	b	26.1	ab	30.3	19.9	a	20.4	a	20.7	a	19.8	a	16.0	a	21.7	a
Z-3-hexen-1-ol	nd	<10		<10		nd		<10		nd		nd		nd	nd		22.0	a	nd		20.6	a	nd		nd	
2-Ethyl-1-hexanol	134.2	526.6	a	638.4	a	97.4	b	646.7	a	134.1	b	361.1	ab	169.5	150.0	a	108.5	a	170.3	a	108.2	a	170.6	a	124.6	a
Benzylalcohol	99.3	24.2	b	34.4	b	40.0	b	130.9	a	58.7	b	57.9	b	17.2	33.3	b	39.0	b	81.5	a	41.5	b	52.2	b	23.0	c
Total Esters	867.9	2550.0	a	2678.7	a	1086.4	b	3144.4	a	431.4	b	1094.9	b	1281.2	1146.7	a	756.3	ab	1122.2	a	736.2	ab	546.8	b	1243.8	a
Total Lactones	37.9	66.8	a	76.0	a	93.8	a	82.2	a	12.7	b	62.6	a	36.3	155.4	a	109.5	a	157.8	a	109.4	a	30.3	b	91.9	a
Total Aldehydes	469.0	381.9	a	376.5	a	230.0	b	376.4	a	246.2	b	325.3	a	305.0	316.0	a	299.0	a	395.9	a	306.7	a	331.2	a	317.8	a
Total Ketones	458.2	431.9	c	1151.6	a	455.3	c	709.5	b	392.0	c	602.8	b	765.2	341.5	d	933.3	b	554.7	c	873.1	b	590.9	b	1295.8	a
Total Terpenes	600.4	73.2	a	54.5	b	40.5	c	60.7	a	10.2	e	22.1	d	611.6	21.7	b	59.5	a	22.8	b	57.2	a	8.4	c	39.2	ab
Total Acids	244.2	117.7	b	259.1	b	138.6	b	492.3	b	1243.4	a	1602.4	a	494.4	115.3	b	165.7	b	308.3	b	1616.6	a	1404.0	a	1467.3	a
Total Alcohols	307.7	635.6	a	763.7	a	149.1	b	882.0	a	237.7	b	461.6	b	217.0	217.4	a	200.2	b	284.7	a	199.8	b	287.2	a	190.6	b
Total	2985.3	4257.1	b	5360.1	a	2193.6	c	5747.5	a	2573.7	c	4171.7	b	3710.7	2314.0	b	2523.4	b	2846.3	b	3899.0	b	3198.7	b	4646.4	a

Means within the variety followed by different small letters are significantly different at $p \leq 0.05$ (LSD test). Volatile compounds not detected are indicated by nd.

Table 4. Volatile Compounds Emitted (Nanograms per Kilogram) by 'Venus' and 'Honey Royale^{cov}' Nectarines after Cold Storage at -0.5 ºC with or without Three Days at 20 ºC.

Mid-season varieties	Venus												Honey Royale^{cov}											
Days at -0.5ºC	Harvest	10			20			40			Harvest	10			20			40					
Days at 20ºC		0		3	0		3	0		3		0		3	0		3	0		3			
Ethyl acetate	nd	478.1	ab	nd	910.9	a	nd	252.1	b	nd	352.7	2509.1	b	5605.5	a	3795.3	ab	nd		nd		nd		
Propyl acetate	30.4	16.1	b	20.4	b	132.6	a	39.1	b	17.0	b	75.5	ab	<10	61.9	c	49.4	c	1093.2	a	865.5	a	70.1	c	356.3	b
2-Methylpropyl acetate	24.2	22.2	b	60.3	a	23.5	b	89.6	a	23.0	b	99.2	a	<10	36.8	b	115.7	b	45.8	b	224.7	a	25.0	b	95.6	b
Ethyl 2-methylbutanoate	nd	nd		nd		114.4	a	nd		<10		<10		nd	13.3	b	nd		nd		nd		<10		85.9	a
Butyl acetate	55.1	24.0	b	15.3	b	205.9	a	34.5	b	15.0	b	46.6	b	<10	24.6	b	41.4	b	1496.1	a	193.4	b	32.2	b	114.2	b
2-Methylbutyl acetate	120.3	45.6	ab	47.0	ab	99.2	a	29.3	b	33.0	b	nd		40.5	176.6	a	39.6	c	164.6	a	86.5	bc	53.4	c	103.5	b
Butyl propanoate	nd	168.3	a	97.2	a	<10		nd		nd		nd		nd	17.2	a	<10		20.3	a	nd		nd		nd	
Pentyl acetate	26.6	nd		13.5	a	<10		nd		nd		12.6	a	nd	<10		21.8	b	10.6	b	70.2	a	<10		26.3	b
2-Methylbutyl 2-methylpropanoate	74.9	15.7	b	32.8	a	nd		nd		nd		nd		41.6	41.0	a	35.2	a	nd		17.6	b	nd		nd	
Hexyl acetate	242.7	nd		nd		32.5	a	56.7	a	30.3	a	nd		25.5	54.2	c	173.2	b	64.4	c	316.3	a	42.0	c	214.7	b
Z-3-hexenyl acetate	44.8	nd		nd		22.0	a	nd		17.4	a	nd		nd	nd		nd		nd		153.7	a	nd		nd	
Hexyl propanoate	nd	nd		nd		23.7	a	nd		nd		nd		nd	nd		27.6	a	nd		nd		nd		nd	
Methyl octanoate	20.2	41.9	b	82.8	a	13.7	c	18.2	c	17.4	c	<10		21.5	21.1	b	163.8	a	<10	b	153.2	a	nd		nd	
Butyl hexanoate	18.7	40.7	a	nd		14.9	b	nd		nd		nd		nd	nd		nd		nd		nd		nd		nd	
Hexyl 2-methylbutanoate	206.4	150.9	a	166.9	a	150.3	a	13.7	b	27.9	b	111.0	a	112.8	<10		15.8	b	nd		nd		nd		34.3	a
Ethyl octanoate	401.5	49.5	b	206.3	a	20.6	b	78.4	ab	nd		157.2	a	36.2	56.4	b	423.0	b	35.0	b	3207.5	a	252.8	b	1626.6	a
Hexyl hexanoate	347	180.1	a	74.7	b	17.5	b	nd		12.3	b	46.5	b	137.6	nd		nd		nd		nd		13.5	b	21.7	a
Butyl octanoate	37	23.7	a	nd		nd		nd		nd		nd		15.3	nd		nd		<10		nd		nd		nd	
γ-Hexalactone	101.3	20.8	a	25.7	a	15.6	a	13.0	a	14.8	a	22.1	a	12.1	16.3	bc	48.4	a	13.2	c	26.6	b	<10		14.9	bc
γ-Octalactone	<10	nd		32.2	a	nd		nd		nd		nd		nd	nd		nd		<10		nd		nd		nd	
δ-Decalactone	33.5	nd		22.7	a	nd		nd		nd		nd		nd	nd		63.8	a	<10		77.9	a	nd		15.4	b
2-Ethyl-1-hexenal	683.5	71.6	a	nd		nd		25.4	a	18.1	a	15.8	a	58.8	229.3	a	369.8	a	36.2	b	34.7	b	19.6	b	25.9	b
Hexenal	813.5	165.8	a	149.4	a	138.8	ab	83.1	b	127.4	ab	152.5	a	74.4	339.7	a	236.9	b	177.9	bc	407.6	a	130.4	c	130.1	c
Benzaldehyde	74.6	61.8	a	76.9	a	44.5	b	50.0	a	72.2	a	75.4	a	45.5	119.0	a	93.0	ab	75.4	b	123.2	a	62.2	b	79.1	b
2,3-Butanodione	873	1191.1	a	1403.7	a	239.0	b	218.8	b	160.0	b	188.7	b	167.1	2986.0	a	3003.7	a	519.8	b	2523.3	a	306.5	b	1107.7	b
Acetophenone	252.1	379.5	b	435.3	a	206.4	c	245.1	c	201.6	c	192.7	c	309.1	222.9	ab	420.6	a	79.7	b	165.0	b	87.1	b	121.1	b
Linalool	2878.5	18.7	a	30.6	a	nd		nd		nd		nd		<10	nd		117.0	a	<10		nd		nd		nd	
Eucalyptol	21	27.4	b	266.5	a	nd		nd		nd		nd		59.0	97.7	ab	22.1	b	20.4	b	237.1	a	15.2	b	22.7	b
Acetic acid	932.9	307.2	b	1221.5	a	685.5	ab	560.4	ab	594.8	ab	809.7	a	205.1	388.5	b	835.8	ab	1099.9	a	778.6	ab	447.6	b	1263.4	a
Decanoic acid	36.7	11.6	c	60.3	a	12.5	c	26.3	b	14.1	b	24.8	b	<10	32.2	b	66.2	a	<10		38.8	b	11.8	c	25.8	b
Benzoic acid	324.2	218.9	a	335.4	a	193.2	a	207.1	a	260.5	a	234.3	a	272.8	245.0	a	332.9	a	160.2	a	296.5	a	179.7	a	246.2	a
2-Methyl-1-butanol	nd	23.7	a	nd		nd		nd		nd		10.1	b	6.6	14.6	b	nd		nd		nd		nd		137.0	a
1-Pentanol	22.9	nd		141.2	a	nd		nd		nd		nd		nd	11.0	a	nd		nd		nd		nd		nd	
1-Hexanol	27.3	45.7	a	29.1	a	10.3	ab	nd		15.6	ab	nd		<10	20.0	a	16.1	a	10.7	a	26.7	a	nd		25.2	a
Z-3-hexen-1-ol	nd	nd		nd		nd		nd		nd		nd		nd	nd		28.7	a	<10		nd		nd		nd	
2-Ethyl-1-hexanol	809.9	87.6	a	246.6	a	345.5	a	57.7	a	162.2	a	254.2	a	222.7	169.0	a	152.3	a	28.3	b	173.5	a	92.1	ab	90.1	ab
Benzylalcohol	34	42.9	a	55.8	a	25.3	a	84.2	a	33.6	a	29.3	a	59.4	36.1	a	37.4	a	43.8	a	34.4	a	30.8	a	22.4	b
Total Esters	1649.8	1256.9	a	817.1	a	1797.4	a	359.5	a	454.4	a	567.8	a	804.6	3029.5	ab	6720.4	a	6736.5	a	5288.6	a	504.2	b	2679.0	ab
Total Lactones	142.7	20.8	b	80.6	a	15.6	b	13.0	b	14.8	b	22.1	b	12.1	16.3	b	112.2	a	22.5	b	104.5	a	<10	b	30.3	b
Total Aldehydes	1571.6	299.2	a	226.3	ab	183.3	ab	158.5	b	217.7	ab	243.7	a	178.7	688.0	a	699.7	a	289.5	b	565.6	a	212.2	b	235.1	b
Total Ketones	1125.1	1570.6	a	1839.0	a	445.4	b	463.8	b	361.6	b	381.5	b	476.2	3208.8	a	3424.2	a	599.5	bc	2688.3	a	393.7	c	1228.8	b
Total Terpenes	2899.5	46.1	b	297.1	a	nd		nd		nd		nd		65.8	97.7	b	139.1	b	25.6	b	237.1	a	15.2	b	22.7	b
Total Acids	1293.8	537.7	c	1617.2	a	891.3	c	793.8	c	869.5	c	1068.9	b	483.5	665.7	b	1234.9	a	1268.5	a	1114.0	ab	639.1	b	1535.5	a
Total Alcohols	894.1	199.9	ab	472.7	a	381.1	a	141.9	b	211.4	ab	293.6	a	294.0	250.8	a	234.5	a	89.9	b	234.5	a	122.9	ab	274.7	a
Total	9576.6	3931.2	a	5350.1	a	3714.1	ab	1930.4	b	2129.3	ab	2577.6	ab	2314.9	7956.9	ab	12565.1	a	9032.0	ab	10232.5	a	1895.4	c	6006.2	bc

Means within the variety followed by different small letters are significantly different at $p \leq 0.05$ (LSD test). Volatile compounds not detected are indicated by nd.

Table 5. Volatile Compounds Emitted (Nanograms per Kilogram) by 'August Red' and 'Nectagala^{cov}' Nectarines after Cold Storage at -0.5 ºC with or without Three Days at 20 ºC.

Late-season varieties	August Red												Nectagala^{cov}											
Days at -0.5 ºC	Harvest	10			20			40			Harvest	10			20			40					
Days at 20 ºC		0		3	0		3	0		3		0		3	0		3	0		3			
Ethyl acetate	641.2	214.4	b	1835.9	a	nd		nd		nd	882.0	128.6	b	1255.9	a	nd		nd		nd			
Propyl acetate	47.0	nd		28.7	c	27.0	c	60.5	b	<10	20.1	13.1	c	<10		72.9	b	77.9	b	<10		140.8	a
2-Methylpropyl acetate	62.2	21.1	c	40.5	bc	56.0	b	51.4	bc	22.8	bc	95.1	a	27.3	37.9	ab	38.9	ab	87.1	a	89.1	a	57.7	a	51.9	ab
Ethyl 2-methylbutanoate	nd	nd		nd		nd		nd		nd		nd		nd	nd		nd		21.7	a	21.0	a	nd		nd	
Butyl acetate	30.5	nd		42.9	b	10.9	c	46.1	b	<10		72.0	a	32.5	14.8	b	16.6	b	50.3	a	52.3	a	22.6	b	54.9	a
2-Methylbutyl acetate	<10	30.5	a	38.8	a	12.5	b	19.8	b	nd		nd		21.7	55.8	ab	83.1	ab	186.4	a	189.7	a	nd		50.4	ab
Pentyl acetate	nd	nd		49.6	a	nd		10.0	b	nd		11.0	b	nd	nd		32.0	a	76.0	a	86.4	a	nd		nd	
2-Methylbutyl-2-methylpropanoate	nd	nd		nd		nd		nd		nd		nd		<10			nd		nd		nd		10.6	b	15.8	a
Butyl 2-methylbutanoate	nd	nd		nd		nd		nd		nd		nd		nd	nd		nd		95.1	a	nd		nd		nd	
Hexyl acetate	67.9	nd		83.4	a	20.9	c	60.9	ab	12.6	c	73.3	a	36.5	22.7	b	39.2	b	105.9	a	101.9	a	16.0	b	41.6	b
Hexyl propanoate	nd	nd		nd		nd		nd		nd		nd		nd	59.1	ab	nd		nd		nd		nd		38.1	a
Methyl octanoate	nd	nd		42.9	b	nd		nd		nd		189.6	a	nd	27.9	a	nd		nd		nd		nd		nd	
Hexyl 2-methylbutanoate	nd	nd		nd		nd		nd		20.1	b	44.9	a	20.5	30.9	a	<10		25.5	a	25.7	a	32.2	a	36.1	a
Ethyl octanoate	nd	nd		99.6	a	nd		102.1	a	nd		74.5	b	nd	14.8	ab	48.5	ab	136.8	a	143.4	a	14.0	ab	105.7	a
Hexyl hexanoate	nd	nd		37.6	bc	nd		59.5	b	26.8	c	107.1	a	86.9	79.5	a	21.8	bc	40.4	b	45.0	b	14.4	bc	33.4	b
γ-Hexalactone	nd	21.3	b	34.4	a	<10		15.9	b	nd		42.0	a	15.2	13.5	a	23.8	a	29.1	a	26.5	a	nd		13.5	a
γ-Octalactone	nd	nd		21.3	a	nd		nd		nd		nd		nd	nd		nd		nd		nd		nd		nd	
δ-Decalactone	nd	nd		35.3	a	nd		nd		nd		nd		nd	nd		nd		nd		nd		nd		nd	
2-Ethyl-1-hexenal	32.2	25.4	a	48.1	a	nd		nd		27.2	a	37.5	a	69.4	82.6	a	30.8	a	nd		nd		53.8	a	14.6	a
Hexanal	140.5	204.4	d	189.0	d	141.1	e	325.8	c	489.2	b	826.9	a	224.3	523.4	a	188.5	d	257.1	c	225.8	c	237.5	c	400.0	b
Benzaldehyde	42.9	130.7	a	104.9	a	67.3	b	50.2	b	50.4	b	115.5	a	24.7	123.2	a	23.2	c	48.4	c	30.1	c	48.6	c	78.9	b
2,3-Butanodione	280.9	390.9	c	315.0	c	304.1	c	2118.5	a	603.0	c	1817.1	b	313.3	473.9	b	179.0	c	752.4	a	786.6	a	378.8	b	719.7	a
Acetophenone	114.1	272.8	a	324.7	a	124.7	b	131.1	b	123.0	b	144.9	b	100.6	53.6	ab	78.7	a	113.6	a	111.1	a	70.4	ab	82.4	a
Linalool	43.2	nd		43.8	a	nd		nd		nd		nd		233.5	nd		30.8	a	nd		nd		nd		nd	
Eucalyptol	18.6	19.5	b	28.4	b	17.5	b	15.6	b	252.8	a	184.1	a	15.8	22.9	b	nd		nd		nd		123.5	a	40.6	b
Acetic acid	392.3	808.8	a	961.6	a	1434.6	a	440.9	b	436.0	b	1318.2	a	455.0	838.9	a	493.9	ab	682.2	ab	619.8	ab	423.1	ab	1208.5	a
Decanoic acid	11.5	13.3	b	25.7	a	10.8	b	21.7	a	<10		15.4	b	16.7	15.7	a	11.1	a	14.9	a	11.9	a	nd		11.1	a
Benzoic acid	198.6	307.5	a	311.4	a	222.2	b	209.2	b	220.3	b	251.8	b	211.0	270.9	a	175.6	ab	123.3	ab	237.7	a	206.7	a	196.2	a
2-Methyl-1-butanol	nd	nd		nd		nd		nd		nd		nd		nd	nd		nd		nd		<10		nd		nd	
1-Pentanol	nd	nd		41.9	a	nd		nd		47.9	a	nd		nd	12.5	b	15.6	b	nd		41.0	a	nd		nd	
1-Hexanol	<10	nd		42.9	a	nd		11.9	b	14.5	b	23.2	b	nd	14.2	a	nd		13.4	a	13.1	a	10.1	a	14.3	a
2-Ethyl-1-hexanol	117.7	135.2	c	139.5	c	90.5	d	294.7	b	412.8	b	777.3	a	331.9	627.8	a	185.4	d	299.2	c	302.0	c	270.4	c	438.0	b
Benzylalcohol	22.2	29.0	a	20.2	a	17.5	b	34.3	a	18.9	a	27.8	a	nd	23.9	a	27.2	a	26.6	a	23.3	a	nd		18.0	a
Total Esters	852.4	266.0	b	2299.7	a	127.2	bc	410.0	b	99.2	bc	741.4	b	1135.9	485.0	bc	1551.7	a	898.1	b	832.5	b	175.2	bc	568.5	b
Total Lactones	nd	21.3	c	91.0	a	<10		15.9	c	nd		42.0	b	15.2	13.5	a	23.8	a	29.1	a	26.5	a	nd		13.5	a
Total Aldehydes	215.6	360.4	c	342.0	c	208.4	d	376.0	c	566.8	b	980.0	a	318.4	729.2	a	242.4	c	305.5	c	255.8	c	339.9	c	493.6	b
Total Ketones	395.0	663.7	b	639.7	b	428.8	b	2249.6	a	726.0	b	1962.1	a	413.9	527.5	b	257.7	c	866.0	a	897.7	a	449.2	b	802.1	a
Total Terpenes	61.8	19.5	c	72.2	c	17.5	c	15.6	c	252.8	a	184.1	b	249.3	22.9	b	30.8	b	nd		nd		123.5	a	40.6	b
Total Acids	602.4	1129.5	a	1298.7	a	1667.6	a	671.8	b	665.4	b	1585.3	a	682.7	1125.5	a	680.7	b	820.4	b	869.4	b	629.9	c	1415.9	a
Total Alcohols	147.8	164.2	c	244.5	bc	108.1	c	340.9	b	494.1	b	828.2	a	331.9	678.5	a	228.2	bc	339.2	bc	388.4	b	280.5	bc	470.3	b
Total	2275.0	2624.7	c	4987.6	b	2565.8	c	4079.9		2804.2	c	6323.0	a	3132.1	3568.6	a	2991.5	b	3229.2	ab	3243.8	ab	1998.2	c	3791.0	a

Means within the variety followed by different small letters are significantly different at $p \leq 0.05$ (LSD test). Volatile compounds not detected are indicated by nd.

Table 6. Percentage of Satisfied Consumers of 'Big Top', 'Honey Blaze^{cov}', 'Venus' 'Honey Royale^{cov}', 'August Red', and 'Nectagala^{cov}' Nectarines at Harvest and after Cold Storage for 10, 20, and 40 Days at -0.5 ºC plus Three Days Ripening at 20 ºC.

	Cultivars	Harvest	10 days	20 days	40 days
Satisfied consumers (%)	Big Top	71	79	86	80
	Honey Blaze^{cov}	72	76	67	70
	Venus	53	57	63	61
	Honey Royale^{cov}	75	75	55	45
	August Red	53	70	73	43
	Nectagala^{cov}	70	97	93	53

Figures:

Figure 1. Relative proportions (percent) of the main classes of volatile compounds in 'Big Top®' and 'Honey Blaze^{cov}' nectarines after 10, 20, or 40 days storage at -0.5ºC with or without three days at 20ºC.

Figure 2. Relative proportions (percent) of the main classes of volatile compounds in 'Honey Royale^{cov}' and 'Venus®' nectarines after 10, 20, or 40 days storage at -0.5ºC with or without three days at 20ºC.

Figure 3. Relative proportions (percent) of the main classes of volatile compounds in 'August Red®' and 'Nectagala^{cov}' nectarines after 10, 20, or 40 days storage at -0.5ºC with or without three days at 20ºC.

Figure 4. PLS model using the data of the six nectarines cultivars after cold storage plus 3 days at 20 ºC. A) Scores; B) correlation loadings; C) regression coefficients from a PLS model of variable acceptance.

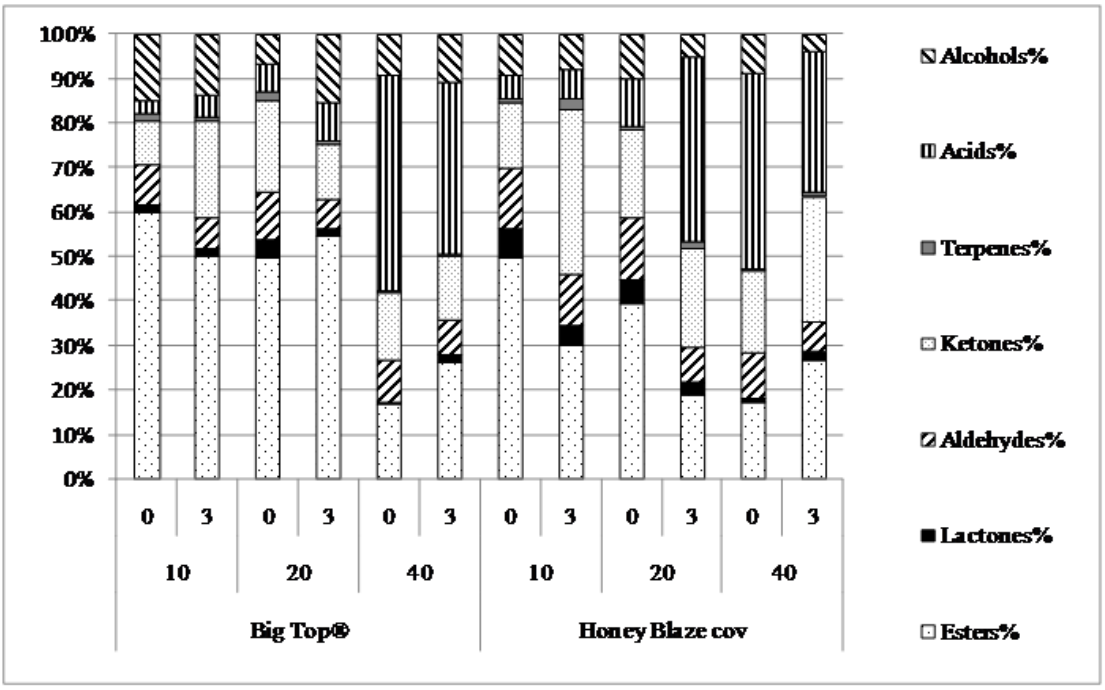


Figure 1.

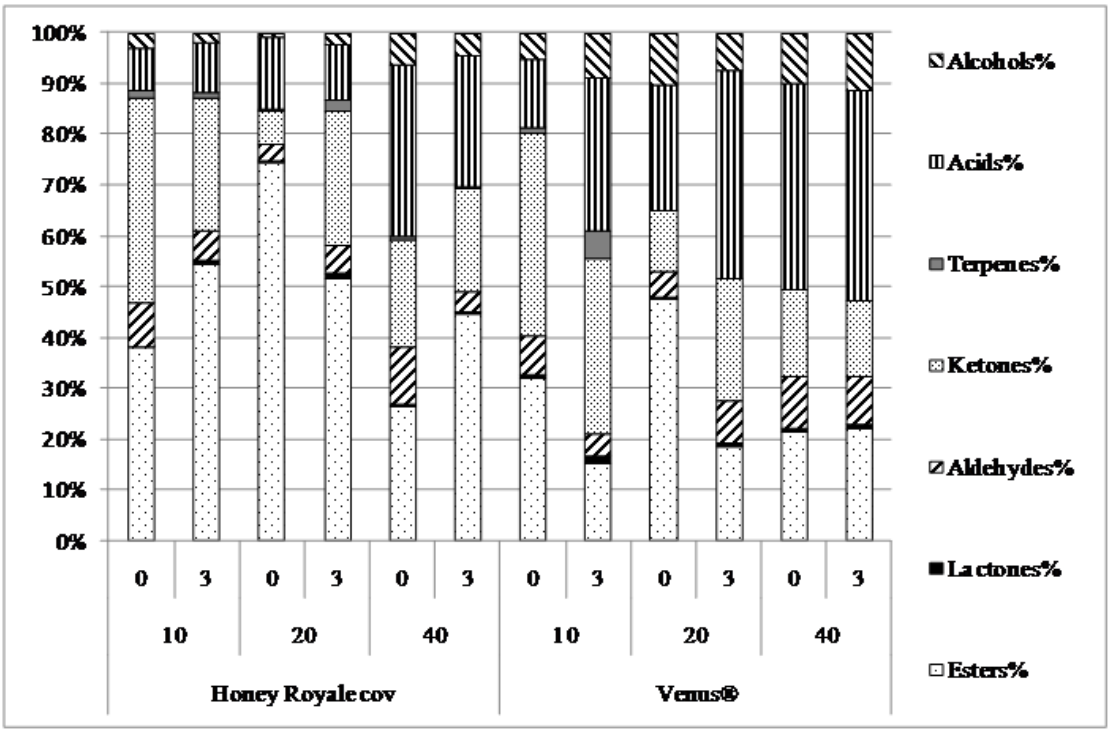


Figure 2.

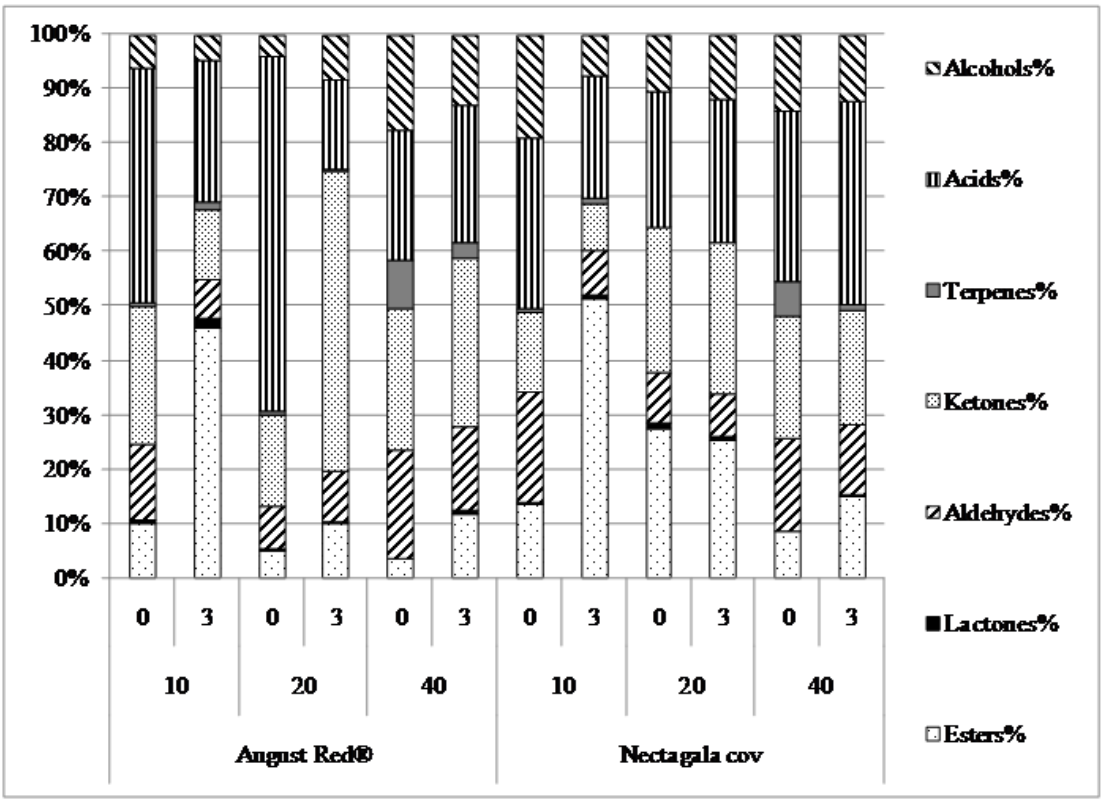
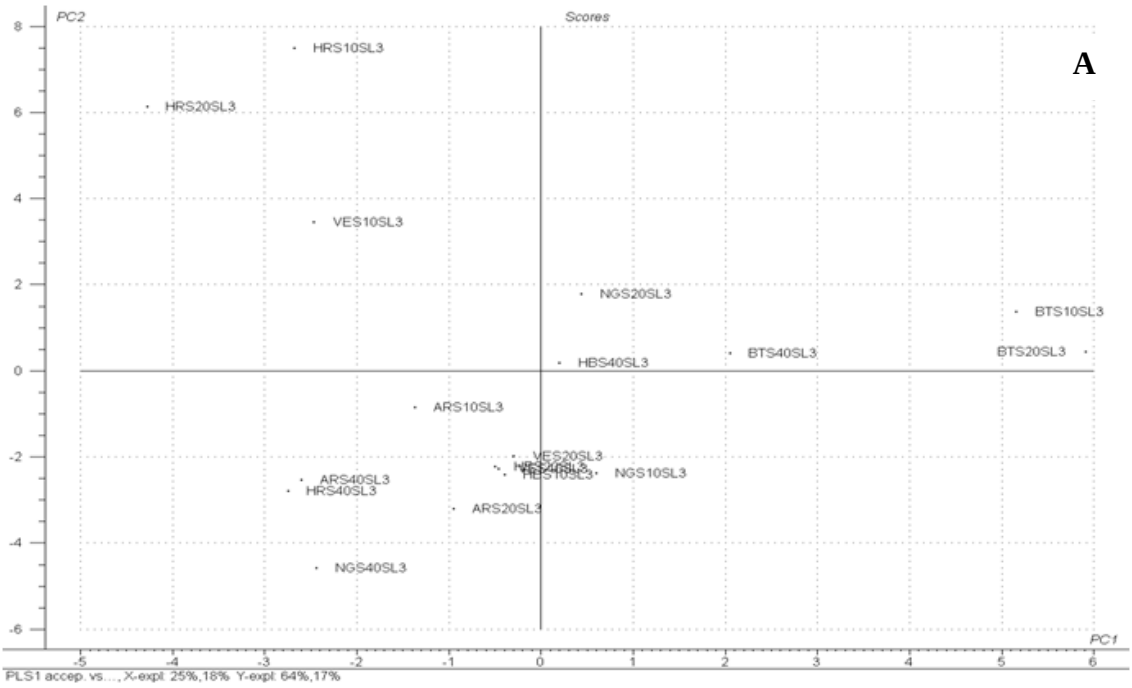
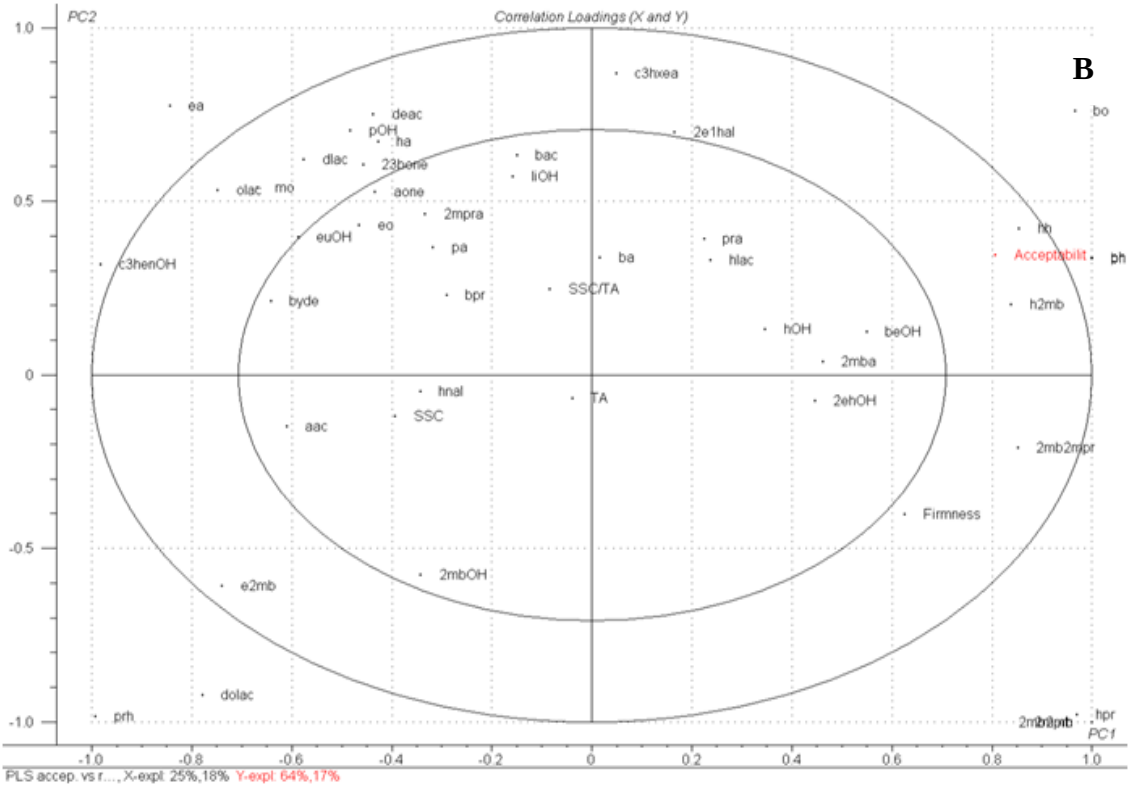

100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
3
0
3
0
3
0
3
0
3
0
3
10
20
40
10
20
40
August Red®
Nectagala cov
Alcohols%
Acids%
Terpenes%
Ketones%
Aldehydes%
Lactones%
Esters%

Figure 3.


PC2
Scores
A
HRS10SL3
HRS20SL3
VES10SL3
NGS20SL3
BTS10SL3
BTS40SL3
BTS20SL3
HBS40SL3
ARS10SL3
VES20SL3
NGS10SL3
ARS40SL3
HRS40SL3
ARS20SL3
NGS40SL3
PC1
PLS1 accep. vs..., X-expl: 25%,18% Y-expl: 64%,17%


PC2
Correlation Loadings (X and Y)
B
c3hxea
ea
deac
pOH
ha
2e1hal
bo
dlac
23bone
bac
liOH
olac
mo
aone
2mpra
eo
euOH
pra
hb
pa
ba
hlac
Acceptabilit
ph
c3henOH
byde
bpr
SSC/TA
h2mb
hOH
beOH
2mba
hnal
TA
2ehOH
SSC
aac
2mb2mpr
Firmness
2mbOH
e2mb
dolac
prh
hpr
PC1
PLS accep. vs r..., X-expl: 25%,18% Y-expl: 64%,17%

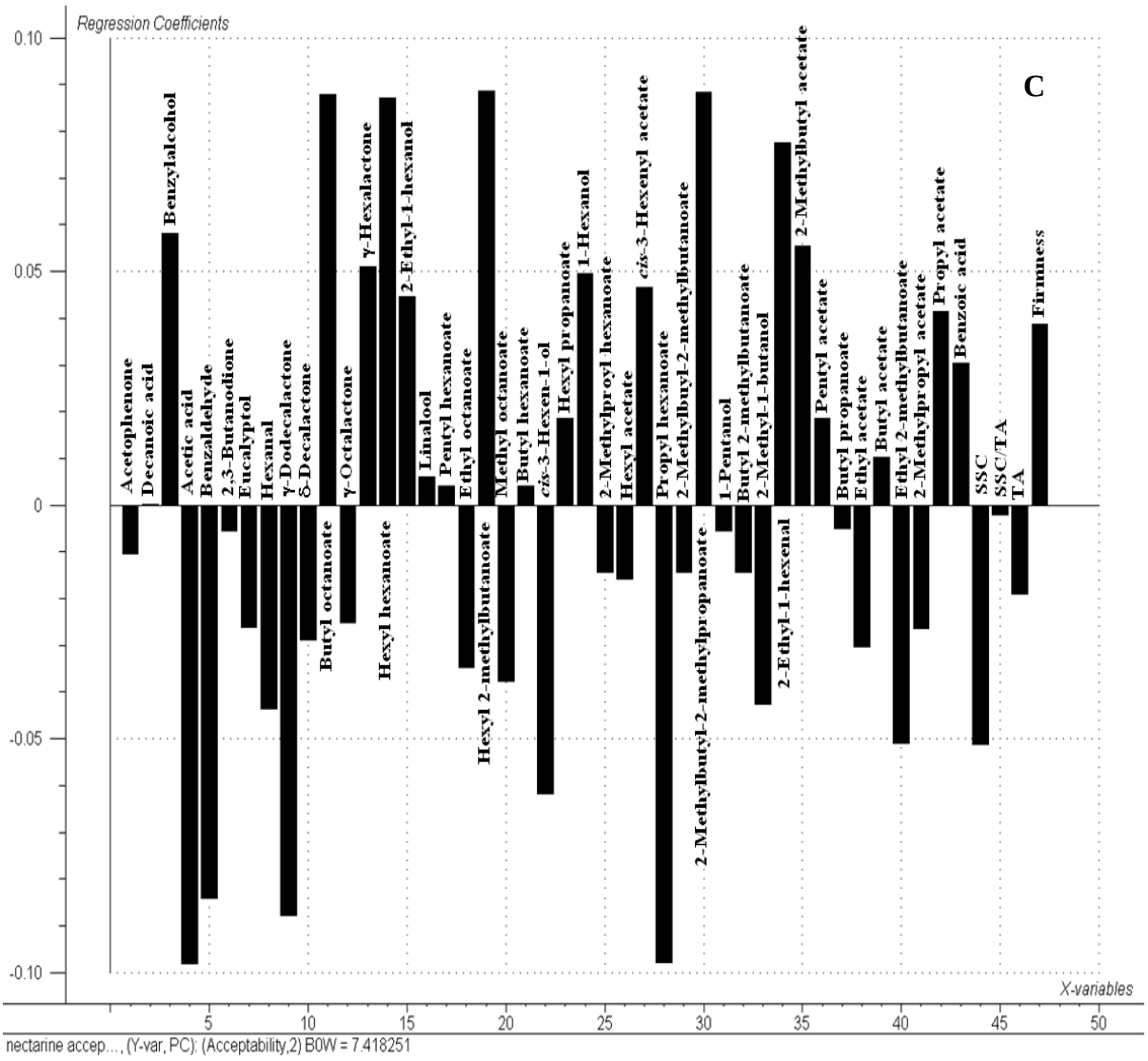

Regression Coefficients
C
0.10
0.05
0
-0.05
-0.10
Acetophenone
Decanoic acid
Benzylalcohol
Acetic acid
Benzaldehyde
2,3-Butanodione
Eucalyptol
Hexanal
γ-Dodecalactone
δ-Decalactone
Butyl octanoate
γ-Octalactone
Hexyl hexanoate
γ-Hexalactone
2-Ethyl-1-hexanol
Linalool
Pentyl hexanoate
Ethyl octanoate
Hexyl 2-methylbutanoate
Methyl octanoate
Butyl hexanoate
cis-3-Hexen-1-ol
Hexyl propanoate
1-Hexanol
2-Methylpropyl hexanoate
Hexyl acetate
cis-3-Hexenyl acetate
Propyl hexanoate
2-Methylbutyl-2-methylbutanoate
2-Methylbutyl-2-methylpropanoate
1-Pentanol
Butyl 2-methylbutanoate
2-Methyl-1-butanol
2-Ethyl-1-hexenal
2-Methylbutyl acetate
Pentyl acetate
Butyl propanoate
Ethyl acetate
Butyl acetate
Ethyl 2-methylbutanoate
2-Methylpropyl acetate
Propyl acetate
Benzoic acid
SSC
SSC/TA
TA
Firmness
X-variables
5
10
15
20
25
30
35
40
45
50
nectarine accep..., (Y-var, PC): (Acceptability,2) B0W = 7.418251

Figure 4.

Estudio 3

Efecto del sistema de conservación frigorífica en atmósfera controlada

CAPITULO III

Relationships between instrumental and sensory characteristics of four peach and nectarine cultivars stored under air and CA-Atmospheres.

J. Cano, M.L. López y G. Echeverría

Enviado a:*Postharvest Biology and Tecnology*

ABSTRACT

In this work, 'Big Top' and 'Venus' nectarines and 'Early Rich' and 'Sweet Dream' peaches were picked at commercial maturity and stored for 20 and 40 days at -0.5 ºC and 92% RH under either air or one of three different controlled atmosphere regimes (2 kPa O_2: 5 kPa CO_2, 3 kPa O_2: 10 kPa CO_2 and 6 kPa O_2: 17 kPa CO_2). Eight sensory attributes were assessed after cold storage plus 3 days at 20 ºC by a panel of 9 trained judges. Standard quality parameters (firmness, soluble solids content (SSC), titratable acidity (TA), their ratio (SSC/TA) and volatile compounds were instrumentally measured in order to determine the relationship between sensory and instrumental parameters and the influence of storage period and cold storage atmosphere composition on this relationship.

A principal component analysis (PCA) was undertaken to characterize the samples according to their sensory attributes. PCA results reflected the main characteristics of the cultivars: 'Big Top' was the cultivar with the highest values for sweetness, juiciness and flavour; 'Sweet Dream' was the sweetest peach and was characterized by high values for crispness and firmness, while 'Venus' and 'Early Rich' were characterized by their sourness. To evidence the influence of storage period and CA composition on sensory properties, a PLS model of the flavour of the different samples was constructed using standard quality parameters and volatile concentrations as the X-variables. The model with 2 factors accounted for more than 80 % of flavour variance. PLS results indicated that the main influence on flavour perception was storage period. Atmosphere composition also had an influence on flavour perception: flavour perception decreased from samples stored in a 2/5 O_2/CO_2 atmosphere composition to those of 3/10 and 6/17. These results can be qualitatively extended to juiciness and sweetness since all these sensory properties were strongly correlated.

Keywords: Aroma volatiles; air storage; controlled atmosphere; flavour perception; quality; nectarines; peaches.

INTRODUCTION

Spain is the third biggest producer of peaches and nectarines in the world. At the European level, Spain is the second biggest producer (only behind Italy) and the biggest exporter of these fruits due to its early season harvest. Peach and nectarine cultivars have a short shelf life potential due to fast softening and overall ripening; this results in a limited period for commercialization before the product reaches the consumer. Refrigeration is a key tool for extending the commercial life of peach and nectarine fruit (Hardenburg et al., 1986), but low temperatures, particularly within the range of 2.2-5 ^{o}C, are associated with a physiological disorder known as internal breakdown (Lurie and Crisosto, 2005). This disorder is a syndrome associated with chilling injury (Lill et al., 1989; Crisosto et al., 1996; Lurie and Crisosto, 2005). Different practices have been studied to reduce the incidence of this postharvest disorder in peach cultivars (Lill et al., 1989; Lurie and Crisosto, 2005), including cold storage under controlled atmosphere (CA). CA storage has been shown to delay or reduce mealiness in peach and nectarine cultivars, particularly with high CO_2 and reduced O_2 levels (Streif et al., 1994; Budde et al., 1999; Roig et al., 2003; Girardi et al., 2005). Although this storage technology is known to have undesirable effects on the aroma profiles of several apple (*Malus* × *domestica* Borkh.) and pear (*Pyrus communis* L.) varieties (Fellman et al., 1993; Chervin et al., 2000; Lara et al., 2003), it has been reported that 'Fantasia' nectarines stored in 10 to 20% CO_2 for 4 weeks were juicier and had better flavour after storage than those kept in cold air (Burmeister and Harman, 1998). A study of the effect of CA storage on peach and nectarine flavour is of huge importance since this is one of the most important characteristics that consumers use to judge the quality of peaches and

nectarines (Bruhn, 1995), together with appearance and texture. Accordingly, consumers often complain about the low quality of these species and this is an obstacle to repeat purchases.

Volatile compound profile and its contribution to the eating quality of fruit is very complex and is influenced by many pre- and post-harvest factors, including cold storage technology (storage time and storage atmospheres) and ripening time at 20 ºC after cold storage. The volatile compounds emitted by peach fruit have been investigated and more than 100 compounds have been identified (Aubert and Milhet, 2007). Abundant information is available on the variability of the volatile profiles of peaches and nectarines as determined by cultivar or maturity stage (Horvat et al., 1990; Chapman et al., 1991; Visai and Vanoli, 1997; Lavilla et al., 2002; Wang et al., 2009). The effects of storage temperature have also been the subject of a number of reports (Robertson et al., 1990; Infante et al., 2008a; Raffo et al., 2008; Cano-Salazar et al., 2012) and it has been shown that the production of volatiles generally decreases during cold storage. However, a small number of research papers have reported CA storage having an effect on the volatile profile of peaches and nectarines (Ortiz et al. 2009; Ortiz et al. 2010).

The effects of CA depend on the fruit variety, physiology state, atmosphere composition, storage temperature and storage time (Kader, 2002). The objective of this work was therefore to assess the influence of different atmospheres, cold storage period and ripening time at 20 ºC on the emission of volatile compounds, physicochemical parameters and sensory attributes of the ‘Big Top’, ‘Venus’, ‘Sweet Dream’ and ‘Early Rich’ cultivars.

MATERIALS AND METHODS

Plant Material and Storage Conditions

Peach and nectarine fruits (*Prunus persica* L. Batsch) of 'Early Rich' (ER) and 'Big Top' (BT) (early-season cultivars) were harvested on June 30th, 2010, (115 and 125 days, respectively, after full bloom) and the fruits of 'Sweet Dream^{cov}' (SD) and 'Venus' (VE) (mid-season cultivars) were harvested on July 31st, 2010, (140 and 145 days, respectively, after full bloom). The four varieties were grown in commercial orchards at Alcarràs, Lleida, Catalonia (northeastern Spain). Immediately after harvest, five lots were selected from each cultivar on the basis of uniformity and the absence of defects. One 25-kg lot was analyzed at harvest and the other four 75-kg lots were stored at -0.5ºC and 92 to 93% relative humidity in cold storage chambers. Four different storage atmospheres were tested: a normal atmosphere: 21 kPa O_2 + 0.03 kPa CO_2, (AIR); and three controlled atmospheres: 2 kPa O_2: 5 kPa CO_2, (2/5), 3 kPa O_2: 10 kPa CO_2, (3/10) and 6 kPa O_2: 17 kPa CO_2 (6/17). Samples were removed from cold storage after 20 (S20), or 40 (S40) days and held at 20ºC to simulate commercial ripening. Analyses were carried out after allowing the fruit to reach 20ºC after each period of cold storage (labelled 0 days at 20ºC, SL0) and also after a further three (SL3) days at 20ºC.

Analysis of physicochemical parameters

Fifteen fruits either at harvest or after each storage atmosphere × storage time at -0.5ºC × ripening time at 20ºC were individually assessed for flesh firmness, soluble solids content (SSC), titratable acidity (TA), and skin color. Flesh firmness was measured on opposite sides of each fruit with a digital penetrometer (Model.***53205***;***TR***, Forlí, Italy) equipped with an 8-mm diameter plunger tip; the results were expressed in N. SSC and TA were measured in juice pressed from whole fruits. SSC was determined

with a Palette-10 hand refractometer (Atago PR-32, Tokyo, Japan) and the results were expressed as % sucrose equivalents. TA was determined by titrating 10 mL juice with 0.1 M ofNaOH to pH 8.1 and the results were given as % malic acid equivalents.

Sensory measurements

Nine panellists (trained according to ISO 1993) assessed and evaluated the sensory attributes of the peach and nectarine samples. The panel evaluated the intensity of the following attributes: crispness (Cr), ease of break down (Eb), flavour (Fv), fibrousness (Fi), hardness (hs), juiciness (Ju), sourness (So) and sweetness (Sw). The intensity of each attribute was recorded on 150 mm unstructured line scales, anchored at 0 = absent and 150 = extreme, with the exception of firmness, which was anchored at 10 = low and 140 = high.

Analysis of volatile compounds

The measurement of volatile compounds was carried out as described Cano-Salazar et al., 2012. Theextraction of compounds from a sample (2 kg × 3 per replicates) of intact fruit was performed by the method of dynamic headspace. The compounds were desorbed into an Agilent 7890A gas chromatograph (Agilent Technologies, Inc., Barcelona, Spain) using an automated UNITY Markes thermal desorption system (Markes International Ltd., Llantrisant, United Kingdom). Identification and quantification of volatile compounds were archived on an Agilent 7890A gas chromatograph (Hewlett-Packard Co., Barcelona, Spain) equipped with a flame ionization detector and a cross-linked free fatty acid phase (FFAP; 50 m × 0.2 mm× 0.33 μm) as the capillary column. Compounds were identified by comparing their respective retention index with those of standards and by enriching peach extract with authentic samples. Quantification was performed using individual calibration curves for

each identified compounds while the concentrations of volatile compounds were expressed as $ng \cdot kg^{-1}$. Compound confirmation was performed in an Agilent 6890N gas chromatograph/mass spectrometer (Agilent Technologies, Inc.), using the same capillary column as in the GC analyses. Spectrometric data were recorded (Hewlett-Packard 3398 GC Chemstation) and compared with those from the original NIST HP59943C library mass spectra.

All of the standards for the volatile compounds studied in this work were analytical grade or the highest quality available. Ethyl acetate, 2,3-butanodione, eucalyptol, butyl acetate, pentyl acetate, acetophenone, and γ-hexalactone were obtained from Fluka (Buchs, Switzerland). 2-Methylpropyl acetate was obtained from Avocado Research Chemicals, Ltd. (Madrid, Spain). 2-Ethyl-1-hexenal, Z-3-hexenyl acetate, methyl octanoate, and decanoic acid were obtained from SAFC Supply Solutions (St. Louis, MO, USA). The rest of the compounds (up to 43) were supplied by Sigma-Aldrich (Steinheim, Germany).

Statistical and multivariate analyses

A multifactor design was used for statistical analysis of the results. The factors considered per cultivar were: atmosphere, storage time at -0.5ºC, and ripening time at 20ºC. All data were tested using analysis of variance (GLM-ANOVA procedure) with the SAS program package (SAS Institute, Inc., 2004). Means were separated by the least significant difference (LSD) test at $p \leq 0.05$. Correlations between experimental variables were made using Spear-man's Rank Correlations and, if required, presented as Spear-man's Correlations Coefficient (r) and P value based on a two-tailed test. Unless otherwise stated, significant differences were $P < 0.05$. Unscrambler version 9.1.2. software (CAMO, 2004) was used to develop two Principal Component Analysis (PCA)

and Partial Least Square Regression model (PLSR). The first PCA was performed to characterize the samples according to sensory attributes. The second one was carried out to identify the correlations between the analyzed variables, as well as, to classify the samples according to all the overall quality (sensory attributes, physicochemical parameters and volatiles compounds emission). The PLSR was used as a predictive method to relate flavour (Y) to a set of explanatory variables (X) which contains the volatile compounds, physicochemical measures and sensory attributes. As a pre-treatment, data were centered and weighted using the inverse of the standard deviation of each variable in order to avoid the influence of the different scales used for the variables (Martens and Naes, 1989). Full cross-validation was run as a validation procedure. Full cross-validation was run as a validation procedure.

RESULTS AND DISCUSSION

Physicochemical parameters at harvest and after cold storage.

Physicochemical parameterssuch as fruit firmness, soluble solids content and titratable acidity are important drivers of consumer preference for peaches and nectarines. However, these parameters do not seem to have the last word in terms of consumer preference (Infante et al., 2008a; Lopez et al. 2011). Modifications to these parameters were therefore assessed, together with the sensory attributes and volatile emissions shown below. Significant changes in some physicochemical parameters were found in response to the post-harvest procedures considered herein (Tables 1 and 2).

No significant differences in flesh firmness were observed owing to the effect of ripening at 20 ºC for 3 days; the only exception was for 'Early Rich' fruits, which became softer after 3 days at 20 ºC (Table 1).

'Big Top' and 'Venus' nectarines kept in cold storage for 20 and 40 days did not exhibit significant differences in firmness values for the different atmospheres; the only exception was 'Big Top' nectarines kept in cold storage for 40 days under a 6/17 atmosphere, whose fruits were firmer than those stored under AIR atmosphere. However, the influence of storage period and atmosphere on 'Early Rich' and 'Sweet Dream^{cov}' peaches was a little different. 'Early Rich' peaches kept in cold storage for 20 days exhibited no differences in firmness between the atmospheres studied, while those kept for 40 days under CA atmosphere conditions maintained higher firmness values than fruits stored under AIR atmosphere. In contrast, 'Sweet Dream^{cov}' peaches kept for 20 days under CA atmospheres softened less than those stored in AIR atmosphere, while after 40 days of cold storage no significant differences were observed between the different atmospheres. This retention of flesh firmness could be a symptom of a typical

chilling injury called leatheriness (Table 2). The obtained results corroborate the argument that, regardless of the CA atmosphere, nectarines are better at retaining their firmness than peaches.

With respect to ripening after removal from cold storage, it was observed that when 'Venus' nectarines and 'Sweet Dream^{cov}' peaches were kept in cold storage for 40 days, CA atmospheres played an important role in maintaining flesh firmness (Table 2). However, for 'Early Rich' peaches, no differences in flesh firmness were observed between atmospheres, and for 'Big Top' nectarines, the only CA atmosphere that showed significant differences was the 6/17 atmosphere (higher CO_2 concentration). Whatever the treatment combined with post-storage ripening, there was generally a very notable decrease in flesh firmness; the exceptions were 'Venus' nectarines and 'Sweet Dream^{cov}' peaches kept in cold storage for 40 days followed by a further 3 days at 20 ºC under CA atmosphere conditions. These fruits maintained their flesh firmness values with respect to fruit stored for 0 days at 20 ºC after removal and exhibited higher firmness values than fruits kept in cold storage under AIR atmosphere. Other reports (Zhou et al., 2000; Rombaldi et al., 2002; Girardi et al., 2005; Giehl, 2008) reported less degradation of flesh firmness in ripe fruits after cold storage under CA than in those stored in AIR atmosphere.

In this study, no significant differences for titratable acidity values were found between the different atmospheres analysed. This was even true for differences between CA atmospheres and between CA and AIR atmospheres for titratable acidity, regardless of the storage period. The exception was 'Early Rich' fruits kept in cold storage for 40 days, regardless of the ripening time at 20 ºC (Table 2). In this last case, fruits stored under AIR atmosphere produced lower TA values than those kept under CA atmospheres. Similar tendencies were found by other authors (Nava and Brackmann,

2002; Girardi et al., 2005) in their studies on acidity of peaches after cold storage under CA; in post-storage ripening no difference was detected between treatments. In contrast, Lurie (1992) found the CA storage retards respiration and consequently inhibits TA decline in storage.

In the case of SSC, no significant differences were observed for 'Big Top' and 'Venus' nectarines, regardless of the storage period and cold storage atmosphere. However, for 'Early Rich' and 'Sweet Dream^{cov}' peaches, some differences were observed. 'Early Rich' fruits kept in cold storage under a 6/17 atmosphere for 40 days exhibited lower SSC values than those stored under the other atmospheres analysed. 'Sweet Dream^{cov}' kept in cold storage under a 2/5 atmosphere for 20 days plus 3 days of ripening, and for 40 days both with and without ripening days at 20 ºC, also exhibited lower SSC values than those observed in fruits kept in cold storage in AIR atmosphere (Table 2). Lurie and Crisosto (2005) reported that CA atmospheres were able to delay the onset of changes in chemical and biochemical attributes in peach fruits. Other studies into CA cold storage involving different peach and nectarine cultivars (Zhou et al., 2000; Girardi et al., 2005) mentioned that fruits stored in CA were associated with lower SSC values than those found in control fruit.

'Sweet Dream^{cov}' peaches and 'Venus' nectarines did not show any variations in the SSC/TA ratio either attributable to storage period or to storage atmosphere. The SSC/TA ratio increased with ripening in 'Big Top' nectarines kept in cold storage for 40 days, but no storage atmosphere influence was observed. 'Early Rich' peaches kept in cold storage for 40 days under CA atmospheres exhibited lower SSC/TA relations than fruits stored in AIR atmosphere, regardless of ripening time.

Sensory attributes at harvest and after cold storage

At harvest, 'Big Top' and 'Sweet Dream^{cov}' fruits were perceived to be sweeter and less sour than 'Early Rich' and 'Venus' fruits, as expected since they had lower TA values. 'Venus' and 'Sweet Dream^{cov}' fruits were perceived to be firmer than 'Big Top' and 'Early Rich' fruits. No significant differences in juiciness or ease of breakdown were detected. The cultivars that provided the most intense peach/nectarine flavour were 'Big Top' and 'Sweet Dream^{cov}'. 'Big Top' fruits produced the highest crispness scores and 'Sweet Dream^{cov}' were the most fibrous fruits (Table 3).

In this work, 'Big Top' and 'Venus' nectarines that were kept in cold storage under a 6/17 atmosphere were significantly firmer and crisper than those subjected to the AIR treatment (Table 4). 'Early Rich' peaches stored for 20 days did not show any differences in firmness or crispness between different atmospheres. However, extending the storage period to 40 days produced some differences in crispness, with fruits from the 6/17 atmosphere being perceived as being more crispy than those from the AIR atmosphere. No significant differences were observed between the CA treatments. For the 'Sweet Dream^{cov}' cultivar stored for 20 days, the AIR storage atmosphere produced fruits that were perceived to be more crispy, but without any significant differences with respect to those from the 6/17 atmosphere. However, extending the storage period did have a significant impact on the crispness and firmness of 'Sweet Dream^{cov}' fruits. For all the atmospheres studied, crispness and firmness were perceived to increase with longer storage periods (Table 4). This result could be explained by the lengthening of the storage time resulting in leatheriness developing in 'Sweet Dream^{cov}' fruits.

In the case of perceived sweetness and sourness, no differences were observed between different atmospheres or storage periods for either 'Big Top' or 'Venus'

nectarines. However, 'Early Rich' and 'Sweet Dream^{cov}' peaches behaved differently. 'Early Rich' fruits stored for 40 days under a 6/17 atmosphere presented higher levels of sourness than those from AIR atmosphere, while 'Sweet Dream^{cov}' fruits stored for 20 days under a 3/10 atmosphere presented greater perceptions of sweetness than those kept under a 2/5 atmosphere.

No differences in fibrousness were detected for either different storage periods or different atmospheres for any of the cultivars analysed. In this work, the sensation of juiciness was not affected by the stimulation of saliva production – linked to a greater perception of acidity – as it was by Wantabe and Dawes (1988). For the majority of fruits 'juiciness' is a principal texture attribute. There are few, if any, other foods that can match most fruits for the intensity of this attribute. Consumers expect fruit to provide a sensation of juiciness irrespective of whether the product in question has a soft melting texture, as in the case of peach (Harker et al., 2002). A marked reduction in juiciness is often associated with texture disorders in stone fruit (Harker et al., 1997a). Table 4 shows that storage period and atmosphere did not alter the perception of juiciness for any of the cultivars analysed except 'Big Top' nectarines stored for 20 days under AIR atmosphere. Fruit from the CA treatment showed significantly increased juiciness, while fruit from the AIR treatment did not exhibit any such beneficial effects. This seems to confirm the findings of Lurie (1992) and Zhou et al. (2000b), who observed that higher CO_2 levels are more effective for controlling losses of juiciness.

For 'Big Top' and 'Venus' nectarines, regardless of the storage period, and for 'Early Rich' and 'Sweet Dream^{cov}' peaches stored for 40 days, fruit stored in AIR exhibited the same flavour as fruit from a CA. Even so, for these latter peach cultivars, fruits stored for 20 days under a 3/10 atmosphere were perceived to have a more intenseflavour. With respect to ease of breakdown, decreases were observed in both

'Sweet Dream^{cov}' peaches and 'Venus' nectarines stored for 40 days as opposed to 20 days.

Relationships between samples and variables after cold storage

Because of the large amount of information obtained, principal component analysis (PCA) was used to help interpret data. A PCA was applied that characterized the different cold storage samples by their sensory attributes (Figure 1). Principal components 1 (PC1) and 2 (PC2) explained together 73% of the total variability. The corresponding biplot reflects the main characteristics of the cultivars studied: 'Big Top' was the cultivar with the highest values for sweetness, juiciness and flavour; 'Sweet Dream' was the sweetest peach and was characterized by high values of crispness and firmness; 'Venus' and 'Early Rich' were characterized by their sourness.

A full-data PCA model was developed in order to know which factor was most influential in characterizing the overall quality of the peaches and nectarines studied. This PCA model, which included the emission of volatile compounds, physicochemical parameters and sensory attributes, was used to characterise the different cold storage samples (Figure 2). Principal components 1 (PC1) and 2 (PC2) together explained 47% of total variability. This relatively low explained variance was mainly due to an overlap in the information relating to volatile compounds included in the PCA; even so, it was enough for our qualitative purposes. The corresponding biplot shows that the main factor accounting for sample differentiation was the cold storage atmosphere; this finding is consistent with the higher firmness of the fruits stored for 40 days under the 6/17 atmosphere. Figure 2 also shows the correlations between the different variables. A negative correlation was observed between sweetness and sourness (r = -0.63). To the best of our knowledge, few other peach and nectarine cultivars present such strong link

between sweetness and sourness (Esti et al., 1997). Sweetness was also negatively correlated with titratable acidity (r = -0.46), as had already been demonstrated in peach and nectarine fruit (Colaric et al., 2005). It could be assumed that a high organic acid concentration may mask the perception of sweetness as it has already been proved that citric acid alters the perception of sucrose (Bonnans and Noble, 1993; Schifferstein and Frijters. 1990). In contrast, a high correlation was detected between sweetness and SSC (r = 0.83). Although positive, the correlation between sweetness and the SSC/TA ratio was not so good (r = 0.61). Juiciness had a positive correlation with sweetness (r = 0.60). Similar relationships had also been previously observed (Infante et al. 2008a, 2011). The relationship between juiciness and sweetness could, in part, be explained by the fact that juicier fruit releases more amount of sugars in the mouth than that less juicy. Sweetness and flavour were highly correlated (r = 0.82); their relation to acceptability has already been reported in other peach and nectarine cultivars (Infante et al. 2008a,b; Ortiz et al. 2009; Di Miceli et al. 2010). Flavour perception was also correlated to SSC (r = 0.74) but not to either TA or firmness, as had previously been reported by Ortiz et al. (2009). Positive correlations were observed between firmness (measured instrumentally) and sensory firmness (r = 0.73) as well as crispness(r = 0.71).

Perception of flavour has been reportedly linked with consumer acceptance in other peach and nectarine cultivars such as 'Autumn Red', 'September Sun', 'Maria Dolce', 'Sweet September', and 'Rich Lady' (Infante et al. 2008a,b; Ortiz et al. 2009; Di Miceli et al. 2010). Previous studies have also reported that certain volatiles are correlated with sweet taste as well as flavour (Ortiz et al., 2009; Cano-Salazar et al., 2012). It can be consequently deduced that some volatiles could also have had an influence on sensory assessment of the taste and flavour of the peaches and nectarines examined in the

present study. We therefore focused on correlation analysis, which we applied to variables susceptible to having some influence on the perception of peach flavour after storage. Partial least squares regression (PLSR) was used to correlate this attribute (*Y* variable) with a set of potentially explanatory variables (*X* variables) which included: emissions of volatile compounds, physicochemical parameters and sensory attributes. These variables accounted for 84% of the variability in flavour perception (Figure 3). Up to 43 compounds (25 esters, five alcohols, four lactones, one terpene, three acids, three aldehydes and two ketones) were identified and labelled in the volatile fraction emitted by fruit (Table 5). Fruit of each cultivar stored for 40 days under the 6/17 atmosphere were located more on the left side of the PC1, which explained alone 67% of total variance, if compared to the same cultivar but stored under other storage conditions (Figure 3A). The corresponding loadings plot (Figure 3B) shows that these samples, stored for 40 days under the 6/17 atmosphere, were perceived by the trained panel as being less flavourful, juicy and sweet and as being crisper and firmer than the rest of the samples. The PLS results indicated that the second main influence on flavour perception was storage period, as flavour decreased over storage period. The composition of the storage atmosphere also had an influence on flavour perception; the perception of flavour decreased from samples stored in the 2/5 atmosphere to those stored in 3/10 and 6/17 atmospheres. These results could be qualitatively extended to juiciness and sweetness since all these sensory properties appeared to be strongly correlated.

Figure 4 shows the regression coefficients for flavour versus the rest of the variables. It can be seen that the perception of peach flavour was related to SSC, sweetness, juiciness and ease of breakdown; this indicates that flavour was associated with normal fruit ripening and softening (Crisosto et al., 1999). Flavour perception was

also related to emissions of certain esters (Ethyl 2-methylbutanoate, 2-methylbutyl acetate, hexyl acetate and pentyl hexanoate), one aldehyde (2-ethyl-1-hexanal), one acid (decanoic acid), and several lactones (γ-octalactone, δ-decalactone and γ-dodecalactone) (Figure 4). This last result is in agreement with several previous reports (Aubert et al., 2003; Lavilla et al., 2002; Rizzolo et al., 2006; Ortiz et al., 2009) in which lactones, and particularly γ- and δ-decalactones and γ- and δ-dodecalactones, were identified as character impact compounds in peach aroma, often in association with other volatiles such as C_6 aldehydes, aliphatic alcohols, and terpenes.

Acknowledgements

This work was supported through project RTA 2008-00055-00-00 and financed by Spain's *Instituto Nacional de Investigación Agraria* (INIA). J. Cano is the recipient of a PhD grant from the *Agència de Gestió d'Ajuts Universitaris i Recerca* (AGAUR), Generatitat de Catalonia (Spain). The authors are indebted to Mr. F. Florensa for technical assistance.

References

Aubert, C., Günata, Z., Ambid, C., Baumes, R., 2003. Changes in physicochemical characteristics and volatile constituents of yellow- and white-fleshed nectarines during maturation and artificial ripening. J. Agric. Food Chem. 51, 3083-3091.

Aubert, C., Milhet, C., 2007. Distribution of the volatile compounds in the different parts of a white-fleshed peach (Prunus persica L. Batsch). Food Chem. 102, 375-384.

Bonnans, S., Noble, A.C. 1993. Effect of sweetener type and of sweetener and acid levels on temporal perception of sweetness, sourness and fruitiness. Chem Senses, 18, 273–283.

Budde, C.O., Murray, R.E., Polenta G., Lucangeli, C. 1999. Jugosidad de los frutos de durazneros de la cv. Ginart en almacenaje prolongado. XXIII Congreso Argentino de Horticultura. Actas en CDROM. Asociaci´on Argentina de Horticultura.

Burmeister, D.M., Harman, J.E. 1998. Effect of fruit maturity on the success of controlled atmosphere storage of 'Fantasia' nectarines. Acta Hort. 464, 363-369.

Bruhn, C.M. 1995. Consumer and retailer satisfaction with the quality and size of California peaches and nectarines. J. Food Qual. 18, 241-256.

Cano-Salazar, J.A., Echeverría, G., Crisosto, C.H., López, M.L. 2012. Cold-storage potential of four yellow-fleshed peach cultivars defined by their volatile compound emissions, standard quality parameters, and consumer acceptance. J. Agric. Food Chem., 60, 1266−1282.

CAMO ASA. 2004. Unscrambler Users Guide, ver. 9.1.2. Programme Package for Multivariate Calibration. Trondheim, Norway.

Chervin, C., Speirs, J., Loveys, B., Patterson, B.D. 2000. Influence of low oxygen storage on aroma compounds of whole pears and crushed pear flesh. Postharvest Biol. Technol. 19, 279–285.

Colaric, M., Veberic, R., Stampar, F., Hudina, M. 2005. Evaluation of peach and nectarine fruit quality and correlations between sensory and chemical attributes. J. Sci. Food Agric. 85, 2611–2616.

Crisosto, C.H., Mitcham, E.J., Kader, A.A. 1996. Peaches and nectarines. Recommendations for maintaining postharvest quality. Perishables Handling Nwslt. 86, 17–18.

Crisosto, C.H., Mitchell, F.G., Ju, Z. 1999. Susceptibility to chilling injury of peach, nectarine and plum cultivars grown in California. HortScience, 34, 1116-1118.

Di Miceli, C., Infante, R., Inglese, P. 2010. Instrumental and sensory evaluation of eating quality of peaches and nectarines. European J. Hort. Sci. 75:97-102.

Esti, M., Messia, M.C., Sinesio, F., Nicotra, A., Conte, L., La Notte, E., Palleschi, G. 1997. Quality evaluation of peaches and nectarines by electrochemical and multivariate analyses: relationships between analytical measurements and sensory attributes. Food Chem. 60:659-666.

Fellman, J.K., Matthinson, D.S., Bostick, B.C., Mattheis, J.P., Patterson, M.E. 1993. Ester biosynthesis in ‘Rome’ apples subjected to low-oxygen atmospheres. Postharvest Biol. Technol. 3, 201–214.

Giehl, R.F.H., Brackmann, A., Eisermann, A.C., Weber, A., Neuwald, D.A. 2008. CA affects juiciness in peaches due to an earlier post-storage ethylene production. Acta Hortic., 796, 185-189.

Girardi, C.L., Corrent, A.R., Lucchetta, L., Zanuzo, M.R., Costa, T.S., Brackmann, A., Twyman, R.M., Nora, L., Silva, J.A., Rombaldi, C.V. 2005. Effect of ethylene, intermittent warming and controlled atmosphere on postharvest quality and the occurrence of woolliness in peach (Prunus persica cv. Chiripá) during cold storage. Postharvest Biol. Technol., 38, 25-33.

Hardenburg, R.E., Watada, A.E., Wang, C.Y. 1986. The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Stocks. USDA-ARS Handbook No. 66, pp. 12, 62.

Harker, F.R., Redgwell, R.J., Hallet, I.C., Murray, S., Carter, G. 1997. Texture of fresh fruit. Hort. Rev., 20, 212–224.

Harker, F.R., Maindonald, J., Murray, S.H., Gunson, F.A., Hallett, I.C., Walker. S.B. 2002a. Sensory interpretation of instrumental measurements 1: texture of apple fruit. Postharvest. Biol. Technol. 24:225-239.

Harker F.R., Marsh, K.B., Young, H., Murray, S.H., Gunson, F.A., Walker. S.B. 2002b. Sensory interpretation of instrumental measurements 2: sweet and acid taste of apple fruit. Postharvest. Biol. Technol. 24:241-250.

Horvat, R.J., Chapman, G.W., Jr., Robertson, J.A., Meredith, F.I., Scorza, R., Callahan, A.M., Morgens, P. 1990. Comparison of the volatile compounds from several commercial peach cultivars. J. Agric. Food Chem. 38, 234-237.

Infante, R., Meneses, C., Defilippi, B.G. 2008a. Effect of harvest maturity stage on the

sensory quality of 'Palsteyn' apricot (Prunus armeniaca L.) after cold storage. J. Hortic. Sci. Biothech. 83:828-832.

Infante, R., Farcuh, M., Meneses, C. 2008b. Monitoring the sensorial quality and aroma through an electronic nose in peaches during cold storage. J. Sci. Food Agric. 88, 2073–2078.

Infante, R., Rubio, P., Meneses, C., Contador, L. 2011. Ripe nectarines segregated through sensory quality evaluation and electronic nose assessment. Fruits 66:109-119.

Kader, A.A. 2002. Methods of gas mixing, sampling and analysis. In: KADER, A.A. (Ed.). Postharvest technology of horticultural crops. Berkeley: University of California, p.145-148.

Lara, I., Miró, R.M., Fuentes, T., Sayez, G., Graell, J., López, M.L. 2003. Biosynthesis of volatile aroma compounds in pear fruit stored under long-term controlled-atmosphere conditions. Postharvest Biol. Technol. 29, 29-39.

Lavilla, T., Recasens, I., López, M.L., Puy, J. 2002. Multivariate analysis of maturity stages, including quality and aroma, in ‘Royal Glory’ peaches and ‘Big Top’ nectarines. J. Sci. Food Agric. 82, 1842-1849.

Lill, R.E., O’Donaghue, E.M., King, G.A. 1989. Postharvest physiology of peaches and nectarines. Horticultural Review, 11, 413-452.

Lopez, G., Behboudian, M.H., Echeverria, G., Mata, M., Girona, J., Marsal, J. 2011. Instrumental and sensory evaluation of fruit quality for 'Ryan's Sun' peach grown under deficit irrigation. Horttechnology, 21(6), 712-719.

Lurie, S. 1992. Controlled Atmosphere Storage to Decrease Physiological Disorders in Nectarines. Intern. J. Food Sci. and Tech. 27: 507-514.

Lurie, S., Crisosto, C.H. 2005. Chilling injury in peach and nectarine. Postharvest Biol. Technol., 37, 195-208.

Nava, G.A., Brackmann, A. 2002. Armazenamento de pêssegos (Prunus persica (L.) Batsch), cv. 'Chiripá', em atmosfera controlada. Revista Brasileira de Fruticultura, 24, 328-332.

Ortiz, A., Echeverría, G., Graell, J., López, M.L., Lara, I. 2009. Overall quality of 'Rich Lady' peach fruit after air- or CA storage. The importance of volatile emission. LWT-Food Sci. Technol., 42(9): 1520-1529.

Ortiz, A., Graell, J., López, L., Echeverría, G., Lara, I. 2010. Volatile ester-synthesising capacity in 'Tardibelle' peach fruit in response to controlled atmosphere and 1-MCP treatment. Food Chem., 123: 698-704.

Raffo, A., Nardo, N., Tabilio, M.R., Paoletti, F. 2008. Effects of cold storage on aroma compounds of white- and yellow-fleshed peaches. Eur. Food Res. Technol. 226, 1503–1512.

Rizzolo, A., Eccher Zerbini, P., Grassi, M., Cambiagui, P., Bianchi, G. 2006. Effect of 1-methylcyclopropene on aroma compounds in 'Big Top' nectarines after shelf life. J. Food Qual. 29, 184-202.

Robertson, J.A., Meredith, F.I., Horvat, R.J., Senter, S.D. 1990. Effect of cold storage and maturity on the physical and chemical characteristics and volatile constituents of peaches (Cv. Cresthaven). J. Agric. Food Chem. 38, 620-624.

Roig, I., Vendrell, M., Lara, I. 2003. Use of CA, MA, shocks of CO2 and heat treatments to improve storage of two peach cultivars grown in Lleida, Spain. Acta Hortic. 600, 289-295.

Rombaldi, C.V., Silva, J.A., Parussolo, A., Lucchetta, L., Zanuzo, M.R., Girardi, C.L., Flores, R.F. 2002. Armazenamento de pêssegos (Prunus persica L.), cultivar Chiripá, em atmosfera controlada. Ciência Rural, 32, 43-47.

SAS Institute, Inc., 2004. SAS/STAT© 9.1 User's Guide. SAS Institute, Inc., Cary, N.C.

Schifferstein, H.N.J., Frijters J.E.R. 1990. Sensory integration in citric acid/sucrose mixtures. Chem. Senses, 15, 87–109.

Song, J. 2007. Flavour volatile production and regulation in apple fruit. Stewart Postharvest Review 2, 2.

Streif, J., Retamales, J., Cooper, T. 1994. Preventing Cold Storage Disorders in Nectarines. Acta Hortic., 368:163-166.

Visai, C., Vanoli, M. 1997. Volatile compound production during growth and ripening of peaches and nectarines. Sci. Hortic-Amsterdam, 70, 15–24.

Watanabe, S., Dawes. C. 1988. A comparison of the effects of tasting and chewing foods on the flow rate of whole saliva in man. Arch. Oral Biol., 33, 761–764.

Wang, Y.J., Yang, C.X., Li, S.H., Yang, L., Wang, Y.N., Zhao, J.B., Jiang, Q. 2009. Volatile characteristics of 50 peaches and nectarines evaluated by HP-SPME with GC–MS. Food Chem. 116, 356–364.

Zhou, H., Lurie, S., Lers, A., Khalchitski, A., Sonego, L., Ben-Arie, R. 2000a. Delayed storage and controlled atmosphere storage of nectarines: two strategies to prevent woolliness. Postharvest Biol. Technol., 18, 133-141.

Zhou, H., Sonego, L., Khalchitski, A., Ben-Arie, R., Lers, A., Lurie, S. 2000b. Cell wall enzymes and cell wall changes in 'Flavortop' nectarines: mRNA abundance, enzyme activity, and changes in pectic and neutral polymers during ripening and in woolly fruit. J. Am. Soc. Hortic. Sci., 125, 630–637.

Table 1. Physicochemical parameters of 'Big Top', 'Early Rich', 'Venus' and 'Sweet Dream^{cov}' cultivars at harvest.

Cultivar	Big Top		Early Rich		Venus		Sweet Dream^{cov}	
Ripening time [a]	**0**	**3**	**0**	**3**	**0**	**3**	**0**	**3**
Firmness (N)	40.4a	33a	43.9a	20.9b	52.9a	41.2a	35.9a	42.2a
SSC%	13.7a	14.4a	10.5a	10.6a	11.2a	11a	10.6a	10.5a
TA%	0.5a	0.6a	1a	1a	1.1a	1.2a	0.3a	0.5a
SSC/TA	27.5a	23.5b	10.7a	10.6a	9.7a	9.3a	34.8a	22.3b

Values represent means of twenty replicates. Means followed by different letters for a given parameter and cultivar are significantly different at $p \leq 0.05$ (LSD test).

Table 2. Physicochemical parameters of 'Big Top', 'Early Rich', 'Venus' and 'Sweet Dream[cov]' cultivars after cold storage plus 0 and 3 days at 20 ºC.

Cultivar	Storage period[a]	Ripening time[b]	Atmosphere[c]	Firmness	SSC	TA	SSC/TA
Big Top	S20	SL0	AIR	46.7 Aa	12.8 Aa	0.3 Aa	44.3 Aa
			2/5	42.6 Aa	12.8 Aa	0.3 Aa	42.2 Aa
			3/10	38.4 Aa	13.6 Aa	0.3 Aa	55.7 Aa
			6/17	43.8 Aa	12.3 Aa	0.3 Aa	45.8 Aa
		SL3	AIR	20.9 Ab	13.5 Aa	0.3 Aa	42.2 Aa
			2/5	14.9 Ab	14.4 Aa	0.3 Aa	44.6 Aa
			3/10	13.3 Bb	13.0 Aa	0.3 Aa	47.6 Aa
			6/17	31.7 Aa	13.2 Aa	0.3 Aa	39.7 Aa
	S40	SL0	AIR	35.5 Bb	14.1 Aa	0.2 Ba	64.4 Ba
			2/5	38.3 Aab	13.1 Aa	0.2 Ba	59.0 Ba
			3/10	39.2 Aab	13.2 Aa	0.2 Ba	62.6 Ba
			6/17	45.7 Aa	13.1 Aa	0.2 Ba	64.6 Ba
		SL3	AIR	20.4 Ab	13.6 Aab	0.3 Aa	43.4 Aa
			2/5	18.6 Ab	12.6 Bb	0.3 Aa	37.1 Aa
			3/10	22.7 Ab	14.6 Aa	0.3 Aa	45.8 Aa
			6/17	32.1 Aa	13.8 Aab	0.3 Aa	41.6 Aa
Early Rich	S20	SL0	AIR	38.7 Aa	10.6 Aa	0.8 Aa	13.8 Aa
			2/5	36.9 Aa	11.2 Aa	0.7 Aa	16.3 Aa
			3/10	39.2 Aa	10.3 Aa	0.8 Aa	13.6 Aa
			6/17	40.1 Aa	10.2 Aa	0.8 Aa	13.3 Aa
		SL3	AIR	12.0 Aa	11.3 Aa	0.6 Aa	20.0 Aa
			2/5	9.9 Aa	10.9 Aa	0.5 Aa	20.1 Aa
			3/10	8.6 Aa	10.7 Aa	0.6 Aa	18.1 Aa
			6/17	12.7 Aa	10.9 Aa	0.6 Aa	19.2 Aa
	S40	SL0	AIR	24.5 Bb	10.9 Aa	0.5 Ab	22.8 Aa
			2/5	39.2 Aa	10.5 Aab	0.6 Aa	17.2 Ab
			3/10	41.1 Aa	10.0 Aab	0.6 Aa	16.5 Ab
			6/17	43.0 Aa	9.5 Ab	0.6 Aa	16.6 Bb
		SL3	AIR	19.7 Aa	11.4 Aa	0.5 Ab	23.5 Aa
			2/5	18.1 Aa	10.5 Aa	0.6 Aa	17.7 Ab
			3/10	15.2 Aa	10.6 Aa	0.5 Ba	19.8 Ab
			6/17	17.7 Aa	10.8 Aa	0.6 Aa	18.2 Ab
Sweet Dream[cov]	S20	SL0	AIR	31.8 Ab	11.3 Aa	0.2 Aa	51.6 Aa
			2/5	40.3 Aa	10.6 Aa	0.2 Aa	47.6 Aa
			3/10	39.6 Ba	11.4 Aa	0.3 Aa	42.5 Aa
			6/17	40.5 Ba	11.1 Aa	0.2 Aa	49.9 Aa
		SL3	AIR	16.7 Ab	11.4 Aa	0.3 Aa	41.7 Aa
			2/5	20.4 Bab	9.8 Ab	0.3 Aa	35.1 Aa
			3/10	23.9 Aab	10.8 Aab	0.3 Aa	35.9 Aa
			6/17	26.9 Ba	10.6 Aab	0.3 Aa	40.3 Aa
	S40	SL0	AIR	30.4 Aa	11.7 Aa	0.2 Aa	55.9 Aa
			2/5	29.7 Ba	10.0 Ab	0.2 Aa	49.6 Aa
			3/10	29.2 Aa	10.9 Aab	0.2 Aa	62.0 Aa
			6/17	30.6 Aa	10.8 Aab	0.2 Aa	51.5 Aa
		SL3	AIR	20.1 Ab	11.2 Aa	0.2 Aa	45.7 Aa
			2/5	29.2 Aa	10.1 Ab	0.3 Aa	41.7 Aa
			3/10	29.9 Aa	10.5 Aab	0.3 Aa	40.3 Aa
			6/17	35.3 Aa	10.5 Aab	0.2 Aa	51.8 Aa
Venus	S20	SL0	AIR	37.4 Aa	11.7 Aa	0.9 Aa	13.7 Aa
			2/5	43.8 Aa	11.1 Aa	0.8 Aa	13.6 Aa
			3/10	43.9 Aa	10.5 Aa	0.9 Aa	11.5 Aa
			6/17	45.4 Aa	10.6 Aa	0.8 Aa	13.7 Aa
		SL3	AIR	11.6 Aa	11.2 Aa	0.8 Aa	20.5 Aa
			2/5	16.5 Aa	10.9 Aa	0.8 Aa	13.8 Aa
			3/10	20.1 Aa	11.0 Aa	0.8 Aa	14.2 Aa
			6/17	12.0 Ba	11.0 Aa	0.7 Aa	16.8 Aa
	S40	SL0	AIR	36.3 Aa	12.2 Aa	0.8 Aa	14.9 Aa
			2/5	34.7 Aa	11.7 Aa	0.8 Aa	14.4 Aa
			3/10	34.9 Aa	11.2 Aa	0.8 Aa	13.9 Aa
			6/17	31.7 Ba	10.4 Aa	0.7 Aa	14.2 Aa
		SL3	AIR	14.0 Ab	11.2 Aa	0.7 Aa	15.3 Aa
			2/5	25.4 Aab	11.4 Aa	0.7 Aa	15.5 Aa
			3/10	32.5 Aa	10.7 Aa	0.7 Aa	14.7 Aa
			6/17	37.3 Aa	10.3 Aa	0.7 Aa	13.4 Aa

Values represent means of 20 replicates. Means for a given cultivar and atmosphere within the same column followed by different capital letters and for a given cultivar and storage period followed by small letters are significantly different at $p \leq 0.05$ (LSD test).

[a]20 or 40 days at -0.5 ºC.

[b] AIR: 20% O_2 and 0.03% CO_2; 2/5: 2% O_2 and 5% CO_2; 3/10: 3% O_2 and 10% CO_2;and 6/17: 6% O_2 and 17% CO_2.

Table 3. Sensory attributes of 'Big Top', 'Early Rich', 'Venus' and 'Sweet Dream[cov]' cultivars at harvest plus 3 days at 20 ºC.

Sensory attributes	Big Top	Venus	Early Rich	Sweet Dream[cov]
Sweetness	9.1 a	4.4 b	5.0 b	9.7 a
Sourness	4.2 b	9.7 a	10.4 a	2.6 b
Firmness	6.4 b	10.2 a	3.6 c	8.6 a
Juiciness	6.9 a	7.2 a	9.3 a	9.6 a
Fibrousness	0.0 b	2.1 b	1.3 b	6.1 a
Crispness	9.4 a	5.2 b	6.5 b	1.8 c
Ease of Breakdown	8.2 a	9.1 a	8.0 a	10.6 a
Peach/Nectarine flavour	8.2 a	5.2 b	8.9 b	9.2 a

Values represent means of nine panellists. Means followed by different letters for a given attribute are significantly different at $p \leq 0.05$ (LSD test).

Table 4. Sensory attributes of 'Big Top', 'Early Rich', 'Venus' and 'Sweet Dream[cov]' cultivars after cold storage plus 3 days at 20 ºC.

Cultivar	Storage period[a]	Atmosphere[b]	Sweetness	Sourness	Crispness	Firmness	Juiciness	Fibrousness	Ease of Breakdown	Flavour
Big Top	S20	AIR	9.9Aa	2.9Aa	2.0Ab	4.4Ab	4.0Ab	2.5Aa	10.2Aa	8.0Aa
		2/5	9.8Aa	2.4Aa	1.7Ab	4.7Ab	8.5Aa	3.0Aa	11.3Aa	7.8Aa
		3/10	8.1Aa	4.3Aa	2.8Aa	6.0Aab	7.8Aa	1.3Aa	9.9Aa	8.4Aa
		6/17	8.2Aa	3.3Aa	6.6Aa	8.3Aa	7.4Aa	0.9Aa	8.3A	6.3Aa
	S40	AIR	9.7Aa	3.1Aa	4.0Ab	4.3Ab	8.1Aa	1.2Aa	7.6Aa	9.5Aa
		2/5	9.8Aa	2.7Aa	3.2Ab	5.7Ab	7.5Aa	4.0Aa	8.7Aa	8.8Aa
		3/10	10.1Aa	2.4Aa	5.1Aab	7.0Aab	8.3Aa	3.1Aa	8.2Aa	7.8Aa
		6/17	8.9Aa	2.5Aa	7.8Aa	9.4Aa	7.4Aa	1.5Aa	6.4Aa	7.1Aa
Early Rich	S20	AIR	5.7Aa	9.1Aa	2.2Aa	4.2Aa	6.4Aa	2.4Aa	9.9Aa	5.5Ab
		2/5	5.3Aa	9.3Aa	3.1Aa	5.0Aa	4.9Aa	1.7Aa	7.9Aa	4.2Ab
		3/10	6.8Aa	8.1Aa	2.4Aa	4.5Aa	6.5Aa	1.5Aa	9.3Aa	7.0Aa
		6/17	5.8Aa	8.8Aa	2.2Ba	4.1Aa	6.1Aa	0.5Aa	9.7Aa	4.5Ab
	S40	AIR	6.3Aa	4.7Bb	2.6Ab	6.3Aa	3.2Ba	2.4Aa	8.1Aa	4.1Aa
		2/5	4.8Aa	5.9Bab	4.2Aab	6.8Aa	4.8Aa	4.5Aa	9.1Aa	4.9Aa
		3/10	4.3Aa	5.2Bab	4.7Aab	5.8Aa	2.4Ba	4.6Aa	8.9Aa	2.4Ba
		6/17	5.9Aa	7.7Aa	6.2Aa	6.9Aa	3.6Aa	3.6Aa	7.9Aa	3.8Aa
Sweet Dream[cov]	S20	AIR	6.6Aab	3.6Aa	7.3Ba	5.3Ba	5.0Aa	1.4Aa	8.5Aa	5.9Ab
		2/5	5.3Ab	1.9Aa	3.9Bb	4.8Bb	6.0Aa	2.8Aa	8.0Aa	3.7Ab
		3/10	8.2Aa	2.8Aa	3.4Bb	5.0Bab	6.6Aa	4.0Aa	9.9Aa	6.8Aa
		6/17	7.1Aab	2.9Aa	5.0Bab	6.9Ba	5.9Aa	4.8Aa	9.0Aa	4.4Ab
	S40	AIR	6.8Aa	3.4Aa	10.8Aa	10.1Aa	4.8Aa	1.9Aa	5.1Ba	3.2Aa
		2/5	6.9Aa	3.9Aa	9.0Aa	9.5Aa	6.3Aa	2.7Aa	6.0Aa	4.1Aa
		3/10	6.3Aa	3.2Aa	10.7Aa	9.5Aa	5.1Aa	2.2Aa	6.1Ba	4.3Aa
		6/17	4.6Aa	4.2Aa	10.7Aa	9.9Aa	5.3Aa	2.4Aa	5.7Ba	2.8Aa
Venus	S20	AIR	6.3Aa	8.6Aa	1.9Ab	3.3Ab	5.3Aa	2.5Aa	11.5Aa	6.2Aa
		2/5	4.5Aa	9.1Aa	3.1Aab	3.6Ab	6.1Aa	2.1Aa	9.3Aa	5.8Aa
		3/10	7.1Aa	8.8Aa	2.8Bab	4.0Bb	6.1Aa	3.1Aa	10.6Aa	7.1Aa
		6/17	5.4Aa	10.0Aa	4.6Aa	6.5Ba	5.8Aa	1.9Aa	10.9Aa	5.1Aa
	S40	AIR	4.9Aa	8.4Aa	5.4Ab	6.4Ab	4.1Aa	4.2Aa	8.6Ba	3.9Ba
		2/5	6.0Aa	7.2Aa	6.7Aab	7.9Aab	4.9Aa	3.9Aa	7.7Aa	5.7Aa
		3/10	4.4Aa	8.4Aa	6.3Aab	7.5Aab	4.6Aa	2.1Aa	6.3Ba	4.6Aa
		6/17	6.1Aa	7.3Aa	8.1Aa	9.0Aa	5.8Aa	1.8Aa	7.0Ba	4.9Aa

Values represent means of 9 trained panellists. Means for a given cultivar and atmosphere within the same column followed by different capital letters and for a given cultivar and storage period followed by small letters are significantly different at $p \leq 0.05$ (LSD test).

[a]20 or 40 days at -0.5 ºC.

[b] AIR: 20% O_2 and 0.03% CO_2; 2/5: 2% O_2 and 5% CO_2; 3/10: 3% O_2 and 10% CO_2;and 6/17: 6% O_2 and 17% CO_2

Table 5. Volatile compounds emitted by 'Early Rich', 'Sweet Dream[cov]', 'Big Top' and 'Venus' cultivars at harvest and after cold storage under AIR and CA conditions.

Volatile compounds	**Codes[a]**	**Volatile compounds**	**Codes[a]**
Ethyl acetate	**ea**	1-Hexanol	**hOH**
Propyl acetate	**pra**	Methyl octanoate	**mo**
2,3-Butanodione	**23bone**	Z-3-hexen-1-ol	**c3henOH**
2-Methylpropyl acetate	**2mpra**	Butyl hexanoate	**bh**
Ethyl 2-methylbutanoate	**e2mb**	Hexyl butanoate	**hb**
Butyl acetate	**ba**	Hexyl 2-methylbutanoate	**h2mb**
Hexanal	**hnal**	Ethyl octanoate	**eo**
2-Methylbutyl acetate	**2mba**	Acetic acid	**aac**
Butyl propanoate	**bpr**	2-Ethyl-1-hexanol	**2ehOH**
Pentyl acetate	**pa**	Pentyl hexanoate	**ph**
2-Ethyl-1-hexenal	**2e1hal**	Benzaldehyde	**byde**
2-Methylbutyl-2-methylpropanoate	**2mb2mpr**	Linalool	**liOH**
2-Methyl-1-butanol	**2mbOH**	Hexyl hexanoate	**hh**
Butyl 2-methylbutanoate	**b2mb**	Butyl octanoate	**bo**
Ethyl hexanoate	**eh**	Acetophenone	**aone**
1-Pentanol	**pOH**	ɣ-Hexalactone	**hlac**
Hexyl acetate	**ha**	Benzyl alcohol	**beOH**
2-Methylbuyl-2-methylbutanoate	**2mb2mb**	ɣ-Octalactone	**olac**
Propyl hexanoate	**prh**	δ-Decalactone	**dlac**
Z-3-hexenyl acetate	**c3hxea**	Decanoic acid	**deac**
Hexyl propanoate	**hpr**	ɣ-Dodecalactone	**dolac**
2-Methylpropyl hexanoate	**2mprh**		

[a] Codes used for multivariate analysis.

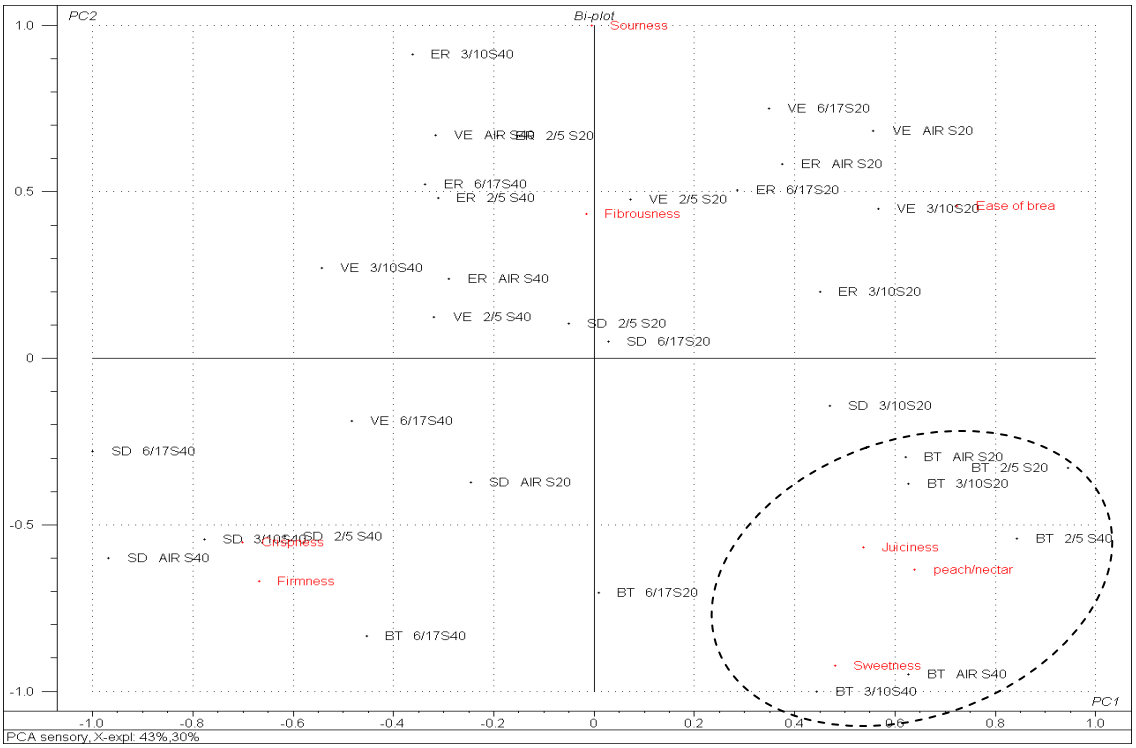


Figure 1. Biplot of PC1 vs. PC2 corresponding to a PCA model for sensory attributes after cold storage ("peach/nectar": perception of flavour; "Ease of brea": ease of breakdown).

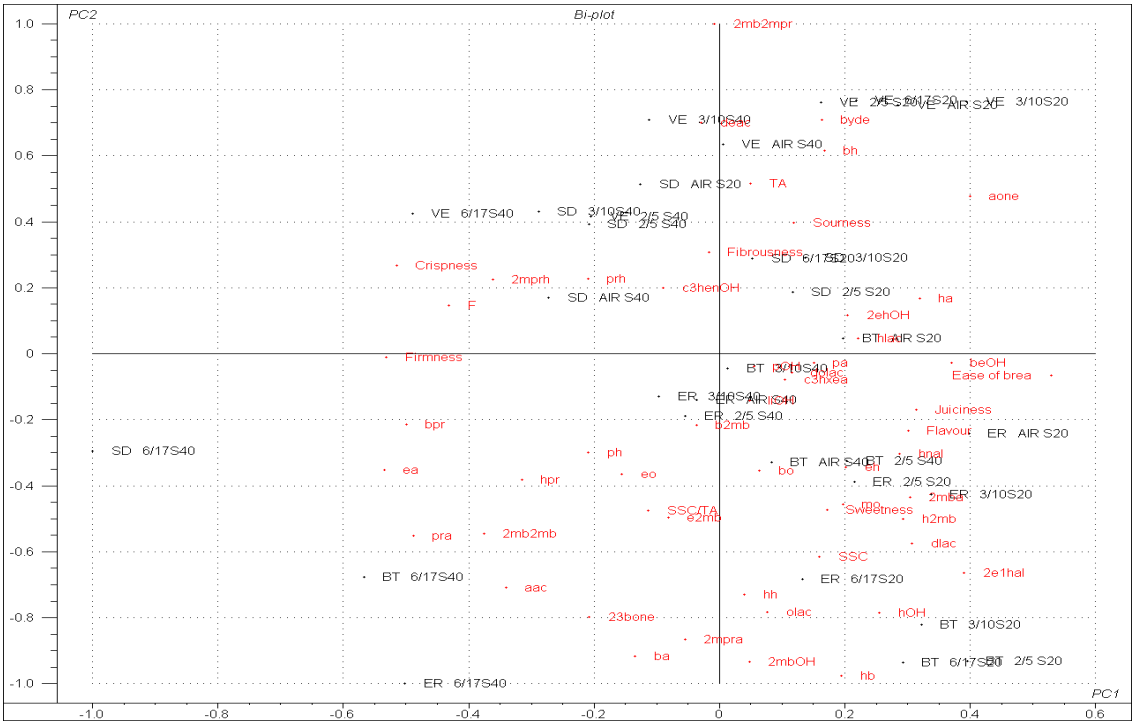


Figure 2. Biplot of PC1 vs. PC2 corresponding to a PCA model for all the variables (volatile compounds, physicochemical parameters and sensory attributes) after cold storage. Codes for samples are defined in the material and methods section. Volatile compounds are labelled as indicated in Table 5 and "Ease of brea" means ease of breakdown.

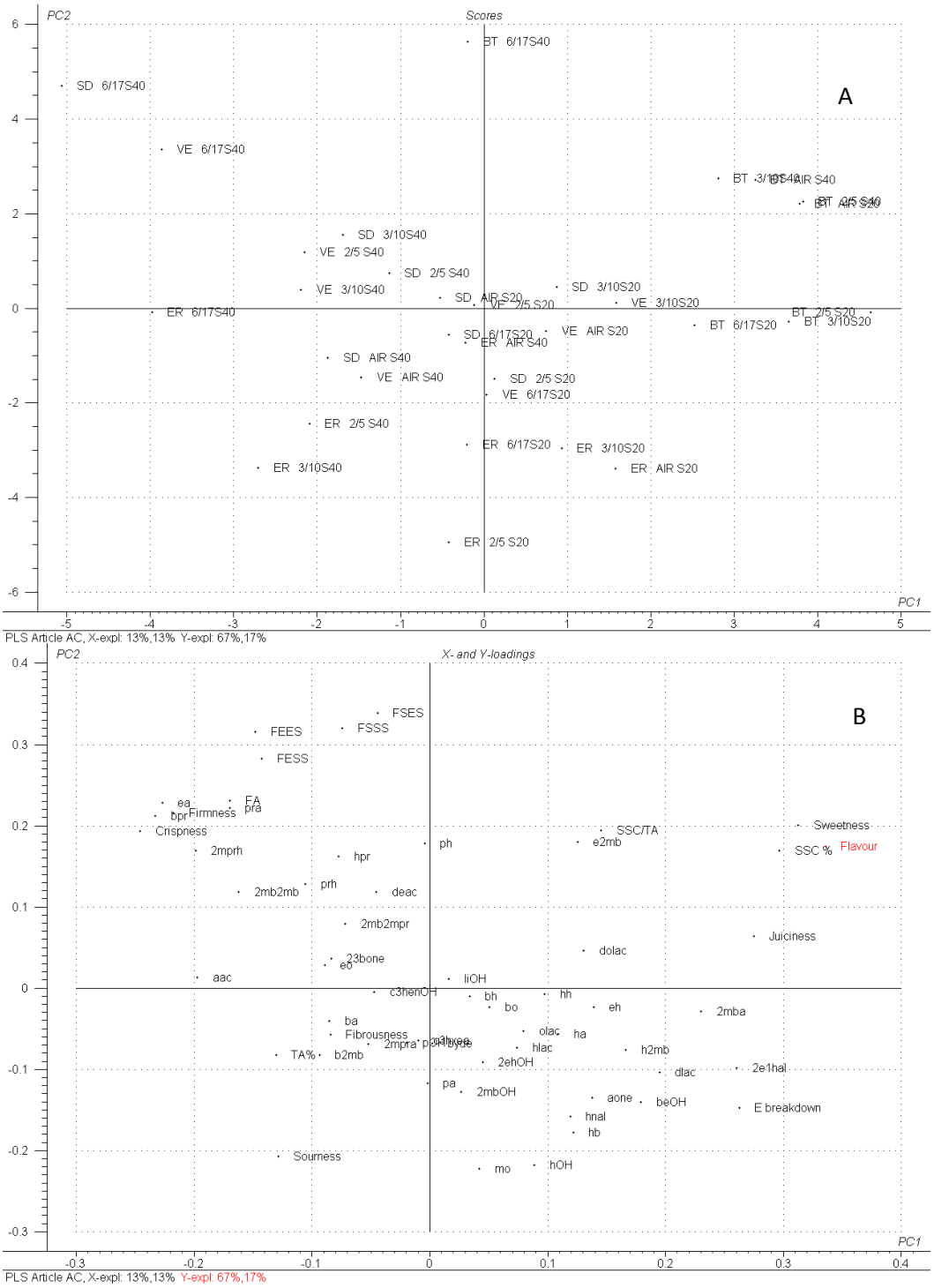


Figure 3. Scores (**A**) and loadings (**B**) plot of PC1 vs. PC2 corresponding to a PLSR model for flavour perception vs. emissions of volatile compounds, physicochemical parameters and sensory attributes. The sample codes are defined in the material and methods section. Volatile compounds are labelled as indicated in Table 5 and E breakdown means ease of breakdown.

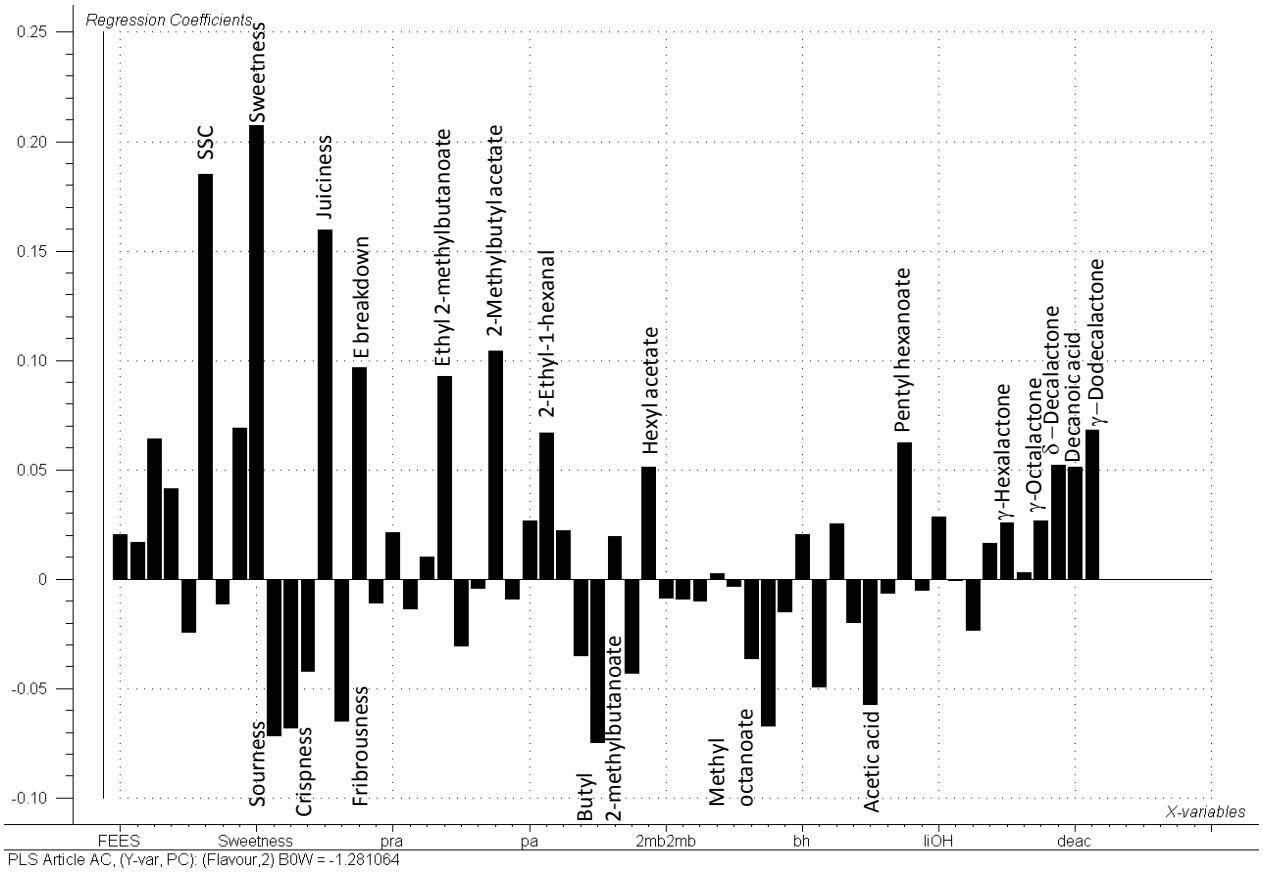


Figure 4. Regression coefficients corresponding to a PLSR model for flavour perception vs. emissions of volatile compounds, physicochemical parameters and sensory attributes.

Estudio 4

Efecto del sistema de pre-acondicionado previo a la conservación frigorífica.

CAPITULO IV

Volatile compound emissions and sensory attributes in 'Big Top' nectarine and 'Early Rich' peach fruits in response to pre-storage treatment before cold storage and subsequent shelf life.

Jaime Cano-Salazar,Gemma Echeverría,Carlos H. Crisosto y Luisa López

Enviado a: Food Chemistry

ABSTRACT

The aim of this work was to assess whether pre-storage treatment at 20 ºC before cold storage could improve volatile compound emissions without negatively affecting standard quality parameters and sensory attributes in 'Big Top' nectarine and 'Early Rich' peach fruits. Commercially harvested fruits were subjected to pre-storage treatment at 20 ºC for 0, 10, 24 or 36 hours and then stored at -0.5 ºC for 10, 20 and 40 days. After cold storage, the fruits were kept at 20 ºC for up 3 days. 'Big Top' nectarines from the 10-hour pre-storage treatment followed by 20 days of cold storage were associated with perceptions of greater flavour, juiciness and sweetness and higher soluble solid contents and butyl propanoate, 2-methybutyl-2-methylpropanoate and 2-methyl-1-butanol concentrations than the control fruit. 'Early Rich' peaches from the 36-hour pre-storage treatment followed by 20 days of cold storage were associated with perceptions of greater sweetness and higher propyl acetate, pentyl acetate and 2-methyl-1-butanol concentrations than the control fruit.

Keywords:Pre-storage treatment, cold storage, shelf life, instrumental analysis, sensory analysis, volatile compounds.

INTRODUCTION

Spain's increasing production of peaches and nectarines means that an ever-larger part of the harvest will have to be stored in order to regulate commercial availability. Harvesting at a slightly unripe stage may make such fruits more resistant to post-harvest handling, but these fruits tend not adequately develop their sensory attributes and therefore consumer acceptance significantly decreases. Pre-storage treatment involves storing these stone fruits at 20 ºC for up to 48 hours after harvest before placing them in cold storage (Zhou et al., 2000; Crisosto et al., 2004). Although this can produce weight loss and softening of the fruit, it does not usually have any negative effects on the quality of nectarine and peach fruit (Lurie and Crisosto, 2005). Furthermore, it has been reported that pre-stored peaches maintained their sensory characteristics for longer during cold storage than control fruits (Infante et al., 2009). Nevertheless, if pre-storage treatments are not appropriately monitored, fruit quality diminishes and excessive flesh softening may occur (Girardi et al., 2005). Not surprisingly, the efficacy of this treatment depends on fruit variety and the period of exposure. Thus, for 'Flavortop' nectarines, a pre-storage treatment of two days prior to storage at 0 ºC for 42 days prevented chilling injury (Zhou et al., 2000). Symptoms of the onset of chilling injury determine postharvest storage potential because this injury reduces consumer acceptance. Along these lines, significantly lower levels of aroma volatile compounds were observed when chilling injury was found in cold-stored peaches of the 'Hujingmilu' variety (Zhang et al., 2011). Although the use of storage temperatures of between -0.5 and +0.5 °C can help to control associated with cold (Robertson et al., 1990; Ceretta et al., 2000), it is very important to carefully control this treatment in order to optimize fruit quality for fresh consumption and thereby satisfy consumers.

Any positive effects relating to storage potential or quality attributes derived from a given post-harvest procedure must therefore be globally evaluated. Flavour is particularly relevant in this regard, as it has been reported that sensory acceptance of peach fruit is strongly associated with perception of its characteristic flavour (Ortiz et al., 2009) which, in turn, is related to the γ and δ-lactones compounds that are responsible for characteristic fruity flavours in peach and nectarine fruits (Spencer et al., 1978; Engel et al., 1988). Furthermore, their composition and content largely depend on their genetic background (Wang et al., 2009). The favourable effects of the maturation and ripening periods of γ and δ-lactones have been reported by numerous researchers (Robertson et al., 1990; Chapman et al., 1991; Visai and Vanoli, 1997; Lavilla et al., 2002; Aubert et al., 2003; Rizzolo et al., 2006; Zhang et al., 2010). Cold storage alters of flavour volatiles and the partial inhibition of ester synthesis is thought to be largely due to a deficiency in substrates caused by the suppression of oxidative processes in the peach fruit during storage (Robertson et al., 1990; Raffo et al., 2008; Ortiz et al., 2009). Even so, shelf life at 20 °C after cold storage at 0 ºC can increase the total lactone content of 'Hujimail' peaches (Zhang et al., 2011). A combination of instrumental and sensory analyses should help to define the roles of particular volatile compounds and/or maturity parameters in the perception of flavour by consumers. Our group had previously established the participation of the specific volatile compounds that most consistently exhibited a positive correlation with peach consumer preferences, regardless of the variety in question (Ortíz et al., 2009; Cano-Salazar et al., 2012). Despite the importance of aroma as one of the most essential factors that contribute to nectarine and peach quality (Aubert et al., 2003; Infante et al., 2008), to the best of our knowledge, no previous studies have been published that examine the relationships between volatile compoundsand sensory evaluation in pre-stored treatment peaches and

nectarines. The main purpose of this work was therefore to assess the influenceof a pre-storage treatment at 20 ºC on volatile compound emissions, standard quality measures and sensory attributes in 'Big Top'nectarines and 'Early Rich' peaches cold stored at -0.5 ºC followed by shelf life at 20 ºC. Another objective was to assess the relationships between sensory and instrumental parameters of fruits using multivariate analysis. 'Big Top' was chosen for this study because it is the most grown nectarine variety in Europe and 'Early Rich' was chosen as it has a higher yield than many other peach varieties.

MATERIAL AND METHODS

Plant materials and storage treatments. Peach (*P. persica* L, Batsch, cv 'Early Rich') and nectarine (*P. persica* L, Batsch, cv 'Big Top') fruits were hand-picked on 30th June 2009 (115 and 125 days, respectively, after full bloom) when most of the fruit had turned went from green to yellow and flesh firmness was ≥42 N. The two cultivars were grown in commercial orchards at Alcarràs, Lleida, Catalonia (north-eastern Spain). Immediately after harvest, three 50 kg lots of each fruit variety were pre-stored at 20 ºC for 0 (0h), 10 (10h), 24 (24h) or 36 (36h) hours. These lots were then placed in a 22 m^3 cold-storage chamber (21 kPa O_2/0.03kPa CO_2) at -0.5 ºC and 92 to 93% relative humidity for 10 (S10), 20 (S20) and 40 (S40) days. Samples were then transferred at 20 ºC and analyses were carried out after 0 (SL0) and 3 (SL3) days.

Chemicals. All of the standards for the volatile compounds studied in this work were analytical grade or the highest quality available. Ethyl acetate, 2,3-butanodione, eucalyptol, butyl acetate, pentyl acetate, acetophenone, and γ-hexalactone were obtained from Fluka (Buchs, Switzerland). 2-Methylpropyl acetate was obtained from Avocado Research Chemicals, Ltd. (Madrid, Spain). 2-Ethyl-1-hexenal, Z-3-hexenyl acetate, methyl octanoate, and decanoic acid were obtained from SAFC Supply Solutions (St.

Louis, MO, USA). The rest of the compounds (up to 43) were supplied by Sigma-Aldrich (Steinheim, Germany).

Analysis of standard quality parameters. Fifteen fruits at harvest and per combination of factors (pre-storage period× cold-storage period× shelf-life period) were individually assessed for flesh firmness, soluble solid content (SSC), titratable acidity (TA), and skin colour. Flesh firmness was measured on opposite sides of each fruit with a digital penetrometer (Model.*53205*;*TR*, Forlí, Italy) equipped with an 8 mm diameter plunger tip; the results were expressed in newtons. SSC and TA were measured in juice pressed from whole fruits. SSC was determined with a Palette-10 hand refractometer (Atago PR-32, Tokyo, Japan), and the results were expressed as percent sucrose in an equivalent solution. TA was determined by titrating 10 mL of juice with 0.1 M NaOH to pH 8.1, and the results were given as $g \cdot L^{-1}$ malic acid. Fruit epidermis colour was determined with a portable tristimulus colorimeter (chroma meter CR-400, Konica Minolta Sensing, Inc., Osaka, Japan) using CIE illuminant D_{65} and with an 8 mm measuring aperture diameter. The skin colour was measured at two points on the equator of each fruit which were 180º apart: one on the side exposed to sunlight (ES) and the other on the shaded side (SS). Hue angle was determined on both the exposed and the shaded sides, and the resulting values were used as measurements of superficial and background colour, respectively.

Analysis of volatile compounds. The measurement of volatile compounds was carried out as described Cano-Salazar et al., 2012. Theextraction of compounds from a sample (2 kg × 3 per replicates) of intact fruit was performed by the method of dynamic headspace. The compounds were desorbed into an Agilent 7890A gas chromatograph (Agilent Technologies, Inc., Barcelona, Spain) using an automated UNITY Markes thermal desorption system (Markes International Ltd., Llantrisant, United Kingdom).

Identification and quantification of volatile compounds were archived on an Agilent 7890A gas chromatograph (Hewlett-Packard Co., Barcelona, Spain) equipped with a flame ionization detector and a cross-linked free fatty acid phase (FFAP; 50 m × 0.2 mm × 0.33 μm) as the capillary column. Compounds were identified by comparing their respective retention index with those of standards and by enriching peach extract with authentic samples. Quantification was performed using individual calibration curves for each identified compounds while the concentrations of volatile compounds were expressed as $ng \cdot kg^{-1}$. Compound confirmation was performed in an Agilent 6890N gas chromatograph/mass spectrometer (Agilent Technologies, Inc.), using the same capillary column as in the GC analyses. Spectrometric data were recorded (Hewlett-Packard 3398 GC Chemstation) and compared with those from the original NIST HP59943C library mass spectra.

Sensory analyses. For the sensory evaluation test, fruit samples from each pre-storage and cold storage period were kept in a room at 20 ºC for 3 days. Prior to sensory evaluation, colour and flesh firmness were measured and registered for both sides of each fruit. Two longitudinal wedges were then instrumentally analysed in relation to standard quality parameters, as explained in the previous section. The rest of the fruit was used for the sensory evaluation. Two pieces of fruit were placed on white plates and immediately presented to a tasting panel. Nine panelists (trained according to ISO 1993) assessed and evaluated the sensory attributes of the nectarine and peach samples. The panel evaluated the intensity of the following properties: crispness (Cr), ease of break down (Eb), flavour (Fv), fibrousness (Fi), hardness (hs), juiciness (Ju), sourness (So) and sweetness (Sw). The intensity of each attribute was recorded on a 150 mm unstructured linear scale, anchored at 0 = absent and 150 = extreme, with the exception

of firmness, which was anchored at 10 = low and 140 = high. All the evaluations were conducted in individual booths under white-light illumination and at room temperature.

Statistical analyses. A multifactorial design was used to statistically analyze the results. The factors considered were cultivar, pre-storage treatment period, cold-storage period, and shelf-life period. All the data were tested using analysis of variance (GLM-ANOVA procedure) with the SAS program package (SAS, 2004). Means were separated by the least significant difference (LSD) test at $p \leq 0.05$. Unscrambler vers. 9.1.2., software (Camo, 2004) was used for the development of a partial least-square regression models (PLSR). These PLSR were run to correlate volatile compound emissions and standard quality parameters, as X-variables, to consumer acceptance, the Y-variable, to find the variables that had most weight for discriminating among treatments for each cultivar. The samples were coded as explained in the Plant Material section and Tables 3-5 for individual volatile compounds.

RESULTS AND DISCUSSION

Standard quality parameters at harvest and after storage.

Significant changes in some quality parameters were found in response to the different post-harvest procedures considered (**Table 1**).The combination of 36 hours of pre-storage treatment plus 3 days of shelf life increased the soluble solid content in 'Early Rich' fruits after all cold-storage periods with respect to the control samples. In contrast, Infante et al.(2009) reported no influence of pre-storage at 20 ºC for 24-48 hours in another yellow-flesh peach variety cold stored at 0 ºC for up to 40 days plus shelf life at 20 ºC. In general, in nectarines pre-stored for 10 or 24 hours, there was an increase in the solids content after 40 days plus 3 days at 20 °C compared to the control fruit. The firmness of 'Big Top' nectarines remained stable during 20 and 40 days of cold storage when the fruits were not subjected to shelf life. These positive effects with regard to

firmness retention would extend marketing possibilities because a rapid loss of firmness is the main factor that limits the commercial life of stone fruit (Murray et al., 2007). Weight loss after 3 days at 20 ºC was significantly greater than in immediately cold-stored fruits, regardless of the pre-storage treatment; this effect was most intense in 'Early Rich' peaches. The decrease in TA throughout the cold storage period was no more evident in pre-storage fruits than previously reported for other peach and nectarine varieties (Crisosto and Crisosto, 2005; Infante et al., 2009). The SSC/TA ratio increased during longer cold-storage periods in pre-stored 'Big Top' and 'Early Rich'. In general, 'Early Rich' fruits subjected to pre-treatment for 36 hours before cold storage followed by a shelf-life period at 20 °C had higher SSC/TA values than control fruits. Aubert et al. (2003) observed that there was a high level of consumer acceptance for nectarines with high SSC/TA ratios and that this ratio increased over the ripening period; other authors had observed in peaches (Crisosto and Crisosto, 2005).

Volatile compound emissions in response to pre-storage treatment before cold storage.

The effects of pre-storage on volatile compounds were dependent on the cultivar and on the cold-storage and shelf-life periods (**Table 2**). Generally speaking, the total volatile contents decreased with long periods of low temperature storage; this was consistent with previous studies on peach fruit (Robertson et al., 1990; Infante et al., 2009; Zhang et al., 2010). Even so, ‘Early Rich’ peaches and 'Big Top' nectarines subjected to 36 hours of pre-storage followed by 20 days of cold storage exhibited the highest concentrations of total volatile compounds (16766.5 and 8633.7 ng/kg, respectively); these contrasted with levels of 9398.1 and 2193.6 ng/kg found in control fruits. This increase in total volatile emissions was mainly due to a rise in the concentration of total

esters; this was due to the fact that esters tended to predominate in the volatile profiles of both varieties at harvest and after cold storage. Acids were only the predominant volatile class, accounting for 48% of total volatile compounds, in the control for 'Big Top' fruit after 40 days of cold storage. In this case, 24 hours of pre-storage resulted in the percentage of total acid compounds falling by up to 10% in these nectarines.

In 'Big Top' nectarines, this combination of 36-hours of pre-storage treatment at 20 ºC followed by 20 days of cold storage at -0.5 ºC increased the concentrations of: propyl, pentyl and hexyl acetates, butyl propanoate and butyl hexanoate (**Table 3**) and 2-methylpropyl acetate, 2-methybutyl-2-methypropanoate, butyl 2-methylbutanoate and 2-methybutyl-2-methybutanoate (**Table 4**) with respect to those in the control fruit. These nine esters quantitatively represented more than 41% of the total volatile compounds found in this nectarine variety. Significant increases in the concentrations of ethyl, propyl, butyl, pentyl and hexyl acetates, butyl hexanoate and ethyl octanoate (**Table 3**), 2-methylpropyl and 2-methylbutyl acetates (**Table 4**) were also observed in 'Early Rich' peaches. These ten esters constituted >79% of the total volatile compounds emitted by 'Early Rich' peaches. A strong association has already been reported between consumer acceptance and high values for propyl acetate, butyl hexanoate and ethyl octanoate in this variety after cold storage at the same temperature and in the same atmosphere (Cano-Salazar et al., 2012).

There was also a significant increase in total alcohols and aldehydes for ‘Big Top’ nectarines after 36 hours of pre-storage treatment followed by 20 days of cold storage compared with the control fruit (**Table 2**). These conditions produced the highest levels of 1-hexanol, 2-methyl-1-butanol and 2-ethyl-1-hexanol (**Table 5**) and the concentrations of hexanal, 2-ethyl-1-hexanal and benzaldehyde were also higher than in the control fruits. Benzaldehyde, C_6 aldehydes and alcohols are known to be products of

the enzyme-catalyzed breakdown of unsaturated fatty acids (Sumitani et al., 1994). In this regard, Zhang et al., 2010 reported finding higher contents of unsaturated fatty acids in peach fruit cold stored at 0 ºC for up 21 days.

In control peaches and nectarines, the production of total esters decreased in response to 40 days of cold storage, but no significant differences were observed when 'Early Rich' peaches were subjected to pre-storage for 10 hours at 20 ºC (**Table 2**). When the pre-storage period was extended to 24 hours, there was a significant increase in total esters, alcohols, aldehydes and lactones in 'Big Top' nectarines with respect to the control treatment. In many types of fruit, esters are important flavour-giving compounds and be subdivided into straight-chain and branched-chain esters. There was an increase of 57% in straight-chain esters and of 56% in branched-chain esters in 'Big Top', while favourable increases of 21% in straight-chain esters and 33% in branched-chain esters were observed in 'Early Rich' fruits (**Tables 3** and **4**). Even so, in both varieties, significant increases were observed in the concentrations of propyl acetate, butyl acetate, 2-methylpropyl acetate, butyl 2-methybutanoate and 2-methylpropyl hexanoate. Lavilla et al. (2002) had previously reported that these acetate esters are important volatile compounds in mature 'Big Top' nectarines. γ-Hexalactone and γ-octalactone also quantified and the pre-storage treatment was shown to produce a favourable effect on concentrations of two varieties that were extracted from fruits immediately after this long period of cold storage (Table 4). This result is particularly relevant given that several previous studies involving peaches reported decreases in γ-Hexalactone content after 7 or 21 days of cold storage without pre-storage at 20 ºC (Raffo et al., 2008; Yang et al., 2009; Zhang et al., 2011). γ-Hexalactone was shown to be most stable during cold storage, but while it took in 'Early Rich' samples are required 10 hours at 20

ºC to increase the concentration of γ-Hexalactone with respect to the control fruits, 24 hours were needed to obtain the same result in 'Big Top' samples.

After 10 days of cold storage, pre-storage for 36 hours increased the production of total alcohols and terpenes in ‘Big Top’ nectarines, while in ‘Early Rich’ peaches the same treatment produced an increase in total alcohols and lactones (**Table 2**). This increase in total alcohols was mainly due to corresponding increases in the concentrations of 1-hexanol and 2-ethyl-1-hexanol (Table 5); these alcohols have also been reported to contribute green and slightly floral sensory notes in peach fruits (Zhang et al., 2010; Burdok, 2002), while terpenes combined with lactones are considered responsible for the characteristically fruity aromas of both nectarines and peaches (Engel et al., 1988; Visai and Vanoli, 1997). Pre-storage period was likely to have favoured the flavour profiles of both these varieties of stone fruit. In 'Early Rich' peaches, concentrations of γ-Hexalactone, γ-octalactone and δ-decalactone significantly increased with respect to the control fruits when the samples were pre-stored 36 hours after 10 days of cold storage (**Table 4**). Linalool was the major terpene compound found (**Table 5**) and this pre-storage period had a favourable effect on fruit. Robertson et al. (1990) and Ortiz et al. (2009) reported that linalool concentrations in 'Creshaven' and 'Rich Lady' peaches decreased throughout storage at 0 ºC; in 'Big Top' nectarines pre-stored for 24 hours before being cold stored for 40 days at -0.5 ºC showed the highest levels of linalool.

Relationships between sensory attributes and instrumental parameters after cold storage following ripening at 20 ºC.

Given the large quantity of measurements obtained, principal component analysis (PCA) was used to interpret the data. A full-data PCA model, focusing on samples held for 3 days at 20 ºC after harvest and cold storage, was separately developed for each of

the cultivars considered. In it, emissions of volatile compounds, standard quality parameters and sensory attributes were used to characterise each sample. For both cultivars, samples from harvest plus 3 days at 20 ºC were found to group separately to those that had been subjected to cold storage (data not shown); cold storage therefore appeared to be the main factor that accounted for sample differentiation. Since one objective of this work was to evaluate whether pre-storage at 20 ºC could offer an appropriate way to improve and/or preserve overall fruit quality during the cold-storage period, we preferred to leave harvest fruits out of the set of samples and to focus on differentiating between different pre-storage times at 20 ºC or/and different cold-storage periods.

Figure 1 shows a PCA model for 'Big Top' samples pre-stored at 20 ºC for 0, 10, 24 and 36 h and then kept in cold storage for 10, 20 and 40 days plus 3 days al 20 ºC. A combination of principal components 1 (PC1) and 2 (PC2) explained 49% of total variability. Although this percentage is not very high, the degree of variance encountered was sufficient for the qualitative purpose of this plot. We should recall that the variances explained by emissions of different volatile compounds tend to overlap because of the repeated information that they provide to the PCA model. The figure shows four well-distinguished groups. Three of these groups (to the right of the plot) correspond to samples pre-stored after 0, 10 or 24 hours at 20 ºC before cold storage for 10 or 20 days. These results show the clear influence of the pre-storage treatment at 20 ºC on 'Big Top' nectarines kept in cold storage for 10 or 20 days. This indicates that for short (10 day) or medium (20 day) cold-storage periods, the pre-storage times at 20 ºC had the greatest influence on the differences between samples. Conversely, for samples that were kept in cold storage for 40 days, this separation was not so clear; even so, it

was possible to observe a separation between these samples for pre-storage times at 20 ºC along PC2 axis.

'Big Top' fruit that was kept in cold storage for 10 or 20 days and pre-stored for 10 h at 20 ºC mainly correlated with 2-methylbutyl 2-methylpropanoate (2mb2mpr), 2-methyl-1-butanol (2mbOH) and butyl propanoate (bpr) as volatile compounds; sweetness and peach/nectarine flavour, as sensory attributes, and SSC. Along the same lines, 'Big Top' fruit that was kept in cold storage for 10 or 20 days and pre-stored for 24 h at 20 ºC mainly correlated with 2-methylbutyl-2-methylpropanoate (2mb2mpr), 2-methyl-1-butanol (2mbOH) and decanoic acid (deac), as volatile compounds; and juiciness, peach/nectarine flavour and ease of breakdown, as sensory attributes.

Perception of sweetness showed a significant positive correlation coefficient with the emission of certain volatile compounds, such as acetophenone (aone), butyl propanoate (bpr) and 2,3-butanodione (23bone). However, no correlation was found between sweetness perception and SSC. In contrast, a significant correlation was found between peach/nectarine flavour and SSC, together with 2-methylbutanol (2mOH), 2-methylbutyl-2-methylpropanoate (2mb2mpr) and butyl propanoate (bpr). The results obtained also showed that most of the volatiles emitted by 'Big Top' nectarines, including γ-hexalactone (hlac), γ-octalactone (olac),δ-decalactone(dlac),ethyl 2-methylbutanoate (e2mb) and propyl hexanoate (prh), had no direct influence on flavour perception.

Figure 2 shows a PCA model that considers 'Early Rich' samples pre-stored at 20 ºC for 0, 10, 24 and 36 h and then kept in cold storage for 10, 20 and 40 days plus 3 days al 20 ºC. Principal components 1 (PC1) and 2 (PC2) together explained 60% of total variability. This figure shows two well-separated groups: samples corresponding to 10 days of cold storage without pre-storage are clustered to the left of the plot, whereas

those samples kept in cold storage for 20 or 40 days were located to the right of the plot. These results show the clear effect of cold-storage time on 'Early Rich' peach segregation. Within the group of samples located on the right of the plot, the sample pre-treated at 20 ºC for 36 h and then kept in cold storage for 20 days appeared at the top and was clearly separated from the rest of the samples. For this cultivar, perception of sweetness was not in perfect agreement with the SSC values obtained with the hand-held refractometer because neither of the measures appeared close to the biplot. This could have been due to the fact that perceptions of sweetness can be affected by certain volatile compounds (Baldwin and others 1998). Thus, fruit kept in cold storage for 20 days and pre-treated at 20 ºC for 36 h showed the highest total volatile emissions (**Table 2)**, although their SSCs were similar to those of the rest of the samples (**Table 1**). However, most of the volatile compounds identified were associated with fruit stored for 10 days. These samples were also perceived as being more full of flavour and acidic. A lengthening of the cold-storage period produced a decrease in emissions of most of the volatile compounds (**Tables 3-5**).

These results suggest that most of the compounds that contribute to flavour and sweetness in 'Big Top' and 'Early Rich' fruits are enhanced by this procedure and that this may be a suitable way of improving the aroma and acceptance of these fruits after cold storage.

ACKNOWLEDGEMENTS

This work was supported through project RTA 2008-00055-00-00 and financed by Spain's *Instituto Nacional de Investigación Agraria* (INIA). J. Cano is the recipients of a PhD grant from the *Agència de Gestió d'Ajuts Universitaris i Recerca* (AGAUR), Generalital de Catalonia (Spain).

LITERATURE CITED

Aubert, C.; Günata, Z.; Ambid, C.; Baumes, R. Changes in physicochemical characteristics and volatile constituents of yellow- and white-fleshed nectarines during maturation and artificial ripening. *J. Agric. Food Chem.***2003**, *51*, 3083–3091.

Aubert , C.; Milhet, C.Distribution of the volatile compounds in the different parts of a white-fleshed peach (Prunus persica L. Batsch).*Food Chem.***2007**,*102*, 375–384.

Burdock. G.A. *Handbook of Flavor Ingredients*. 4th ed. CRC Pres. Washington. USA. 2002.

Ceretta, M., Antunes, P.L., Brackmann, A., Nakasu, B.H. Controlled atmosphere storage of the peach cultivar Eldorado. *Ciencia Rural.***2000**, *30*, 73–79.

Chapman,G.W.; Horvat, R. J.; Forbus, W.R. Physical and chemical changes during the maturation of peaches (cv. Majestic). *J. Agric. Food Chem.***1991**, *39*, 867–870

Crisosto, C.H.; Garner, D.; Andris, H.L.; Day, K.R. Controlled delayed cooling extends peach life. *HortTechnol.***2004**. 14, 99–104.

Crisosto, C.H.; Crisosto, G.M.Relationship between ripe soluble solids concentration (RSSC) and consumer acceptance of high and low acid melting flesh peach and nectarine (Prunus persica(L.) Batsch) cultivars. *Postharvest Biol. Technol*. **2005**, *38*, 239–246.

Camo ASA. *Unscrambler Users Guide*, ver. 9.1.2. Programme Package for Multivariate Calibration. Trondheim, Norway, **2004**.

Cano-Salazar, J.; Echeverría, G.; Crisosto, C.H.; López, M.L. Cold-storage potential of four yellow-flesh peach cultivars defined by their volatiles compounds emissions,

standard quality parameters, and consumer acceptance. *J. Agric. Food Chem.*, **2012**, 60, 1266–1282.

Engel, K.H.; Flath, R.A.; Buttery, R.G.; Mon, T.R.; Ramming, D.W.; Teranashi, R. Investigation of volatile constituents in nectarines. 1. Analytical and sensory characterization of aroma components in some nectarine cultivars. *J. Agric. Food Chem*. **1988**, *36*, 549–533.

Girardi, C.L.; Corrent, A.R.; Lucchetta, L. Effect of ethylene, intermittent warmuing and controlled atmosphere on postharvest quality and the occurrence of woolliness in each (*Prunus persica* cv. Chiripá) during cold storage. *Postharvest Biol. Technol.***2005**. 38, 25–33.

Infante, R.; Farcuh, M.; Meneses, C. Monitoring the sensorial quality and aroma through an electronic nose in peaches during cold storage. *J. Sci. Food Agric.* **2008**,*88*,2073–2078.

Infante, R,; Meneses, Cl.; Crisosto, C.H. Preconditioning treatment maintains taste characteristic perception of ripe ‘Setember Sun’ peach following cold storage. *Int. J. Food Sci. Technol.***2009,***44*, 1011–1016.

ISO. Sensory Analysis. General Guidance for the Selection, Training and Monitoring of Assessors. Part 1. Selected Assessors. Standard No. 8586-1, International Organization for Standardization, Geneva, **1993**.

Lavilla, M.T.; Recasens,I.; López, M.L.; Puy, J. Multivariate analysis of maturity stages, including quality and aroma, in 'Royal Glory' peaches and 'Big Top' nectarines. *J. Sci. Food Agric.***2002**, *82*, 1842–1849.

Lurie, S.; Crisosto, C. H. Review. Chilling injury in peach and nectarine.*Postharvest Biol. Technol.***2005,** *37*, 195–208.

Murray, R., Lucangeli, C., Polenta, G., & Budde, C. Combined pre-storage heat treatment and controlled atmosphere storage reduced internal breakdown of 'Flavorcrest' peach. *Postharvest Biol. Technol.***2007**, *44*, 116–121.

Ortiz, A.; Echeverría, G.; López M.L.; Graell, J.; Lara, I. Overall quality of 'Rich Lady' peach fruit after air- or CA storage. The importance of volatile emission. LWT-Food Sci. Tecnol. **2009**, *42*, 1520–1529.

Ortiz, A.; Graell, J.; López, M.L.; Echeverría, G.; Lara, I. Volatile ester-synthesising capacity in 'Tardibelle' peach fruit in response to controlled atmosphere and 1-MCP treatment. *Food Chem*. **2010**, *123*, 698–704.

Raffo, A.; Nardo, N.; Tabilio, M.R.; Paoletti, F. Effect of cold storage on aroma compounds of white-and yellow-fleshed peaches. Eur. Food Res. Technol. **2008**, *226*, 1503–1512.

Rizzolo, A.; Eccher Zerbini, P.; Grassi, M.; Cambiaghi, P.; Bianchi, G. Effect of 1-methylcyclopropene on aroma compounds in "Big Top" nectarines after shelf life. *J. Food Qual*. **2006**, *29*, 184–202.

Robertson, J. A.; Meredith, F. I.; Horvat, R. J.; Senter S.D.Effect of cold storage and maturity on the physical and chemical characteristics and volatile constituents of peaches (cv. Cresthaven) *J. Agric. Food Chem.***1990,** *38*, 620–624.

SAS Institute, Inc. SAS 9.1. *Qualification Tools User's Guide*. SAS Institute: Cary, NC, **2004**.

Spencer, M.D.; Pangborn, R.M.; Jennings, W.G.Gas Chromatographic and Sensory Analysis of Volatiles from Cling Peaches.*J. Agric. Food Chem.***1978,** *26*, 725–732.

Sumitani, H.; Suekane, S.; Nakatani, A.; Tatsukat, K. Changes in Composition of Volatile Compounds in High Pressure Treated Peach. *J. Agric. Food Chem*. **1994**, *42*, 785–790.

Visai, C., Vanoli, M.,. Volatile compound production during growth and ripening of peaches and nectarines. *Sci. Hortic*. **1997**, *70*, 15–24.

Wang, Y.; Yang , C.; Li S.; Yang , L.; Wang, Y.; Zhao , J.; Jiang, Q.Volatile characteristics of 50 peaches and nectarines evaluated by HP-SPME with GC-MS.*Food Chem.***2009**, 116, 356–364.

Zhang, B.; Shen, J.Y.; Wei, W.W.; Xi, W.P.; Xu, C.J.; Ferguson, I.; Chen, K. Expression of genes associated with aroma formation derived from the fatty acid pathway during peach fruit ripening. *J. Agric. Food Chem*. **2010**, *58*, 6157–6165.

Zhang, B., Xi, W., Wei, W., Fergusoon, I., & Chen, K. . Changes in aroma-related volatiles and gene expression during low temperature storage and subsequent shelf-life of peach fruit. *Postharvest Biol. Technol.* **2011,** *60*, 7–16.

Zhou, H.W.; Lurie, S.; Lers, A.; Khatchitski, A.; Sonego, L., Ben Arie, R. Delayed storage and controlled atmosphere storage of nectarines: two strategies to prevent woolliness. *Postharvest Biol. Technol.***2000**. 18, 133-141.

Yang, D.S.; Balandrán-Quintana, R.R.; Ruíz, C.F.; Toledo, R.T.; Kays, S.J. Effect of hyperbaric controlled and UV treatments of peach volatiles. *Postharvest Biol. Technol*. **2009**, *51*, 334–341.

Table 1. Standard quality parameters at harvest and after pre-storage at 20 ºC following cold storage at -0.5 ºC plus 0 and 3 days at 20 ºC.

	Hours at 20ºC	Big Top nectarine												Early Rich peach											
		Harvest	Days -0.5 ºC + days at 20 ºC											Harvest	Days -0.5 ºC + days at 20 ºC										
			10+0		10+3		20+0		20+3		40+0		40+3		10+0		10+3		20+0		20+3		40+0		40+3	
SSC	0	11.3	11.6	ABa	11.1	ABab	11.4	ABa	12.2	Aa	11.5	ABa	10.6	Bb	10.4	10.9	Ab	10.9	Ab	11.1	Ab	11.1	Ab	10.9	Ab	10.7	Ac
(ºBrix)	10		11.6	BCa	11.7	Bab	10.6	Ca	12.8	Aa	12.5	ABa	12.3	ABa		11.7	Aa	11.5	Aab	11.3	Ab	11.7	Aa	11.4	Ab	11.1	Abc
	24		11.9	Aa	12.1	Aa	10.6	Ba	11.7	ABab	12.4	Aa	12.1	Aa		11.3	Bab	11.3	Bb	12.5	Aa	11.8	Ba	11.6	Bab	11.4	Bb
	36		11.6	ABa	10.8	ABb	10.8	ABa	10.7	ABb	12.1	Aa	10.3	Bb		11.1	Bab	11.7	ABa	11.6	ABb	11.7	ABa	12.1	Aa	12.2	Aa
TA	0	6.9	6.0	Abc	5.9	ABb	5.1	Cb	4.9	Db	5.2	Ca	5.8	Ba	9.8	8.3	Cc	9.0	Ba	9.2	Aa	7.3	Ea	8.2	Cb	7.6	Da
(g malic acid/l)	10		6.3	Ba	6.5	Aa	5.0	Db	4.5	Ec	5.3	Ca	5.3	Cb		8.9	Aa	7.8	Cb	7.9	Cc	5.7	Eb	8.5	Ba	7.0	Db
	24		5.9	Bc	6.4	Aa	5.1	Cb	4.7	Db	4.6	Db	5.8	Ba		8.6	Bb	5.9	Dc	8.8	Ab	4.9	Fc	7.2	Cd	5.3	Ed
	36		6.1	Ab	5.7	Bc	5.3	Da	5.5	Ca	3.8	Fc	4.4	Ec		6.6	Bd	5.6	Cd	6.6	Bd	4.8	Dc	8.0	Ac	5.5	Cc
SSC/TA	0	16.3	19.4	BCa	18.6	BCa	22.1	ABa	24.9	Aa	22.3	ABc	18.2	Cb	10.9	13.2	ABb	12.1	Bc	12.0	Bb	15.2	Ac	13.2	ABb	14.1	Ab
	10		18.4	Ca	18.0	Ca	21.3	BCa	28.4	Aa	23.8	Bbc	23.3	Ba		13.1	Db	14.7	BCb	14.2	BCDb	20.4	Ab	13.4	CDb	15.8	Bb
	24		20.0	Ca	18.7	Ca	20.8	Ca	24.7	ABa	26.8	Ab	20.9	BCab		13.1	Eb	18.6	Ca	14.2	DEb	24.0	Aa	16.0	Da	21.4	Ba
	36		19.2	Ca	18.9	Ca	20.3	BCa	19.3	Cb	32.0	Aa	23.5	Ba		16.8	CDa	21.0	Ba	17.6	Ca	24.6	Aa	15.1	Dab	22.1	Ba
Firmness	0	43.1	37.6	Aab	26.2	Ba	43.0	Aa	29.4	Ba	42.2	Aa	29.2	Ba	41.8	35.4	Aa	7.2	Ba	38.2	Aa	15.4	Ba	39.9	Aa	14.9	Ba
(N)	10		42.0	Aa	29.5	Ba	44.2	Aa	26.1	Bab	41.1	Aa	27.7	Ba		35.4	Aa	6.5	Ba	31.1	Aa	9.0	Ba	32.9	Aa	12.1	Bab
	24		33.6	BCb	28.6	CDa	43.2	Aa	27.4	CDab	40.2	ABa	23.9	Da		25.6	Ab	6.0	Ba	28.9	Aa	8.5	Ba	25.0	Ab	6.0	Bab
	36		37.4	Bab	23.3	Ca	44.4	Aa	23.8	Cb	38.9	ABa	25.7	Ca		18.9	Ab	5.8	Ba	12.1	ABb	9.8	ABa	12.2	ABc	4.5	Bb
HUE flesh ES	0	18.6	87.2	ABa	87.1	ABa	88.1	ABb	88.4	Aa	85.5	Ba	86.3	ABab	80.9	77.4	Ba	82.5	ABa	81.3	ABa	79.7	ABab	86.8	Aa	76.9	Ba
	10		85.7	Ca	87.3	ABCa	89.2	ABab	89.7	Aa	86.7	BCa	86.4	Cab		80.6	ABa	78.1	Ba	75.9	Ba	75.6	Bb	86.8	Aa	63.9	Cb
	24		87.7	Ba	87.1	Ba	91.6	Aa	88.3	Ba	86.0	Ba	87.0	Ba		74.7	Aa	77.4	Aa	77.7	Aa	82.7	Aab	77.6	Ab	64.1	Bb
	36		87.5	ABa	86.5	BCa	90.2	Aab	88.9	ABa	87.0	Ba	84.1	Cb		78.5	Aa	79.4	Aa	83.4	Aa	85.2	Aa	77.0	Ab	81.1	Aa
HUE flesh SS	0	43.2	91.3	Aa	90.1	ABa	90.2	ABb	90.2	ABa	87.7	ABa	87.5	Bab	89.1	87.1	Aa	85.8	ABa	88.1	Aa	88.3	Aab	83.1	Ba	82.9	Bab
	10		89.1	ABa	89.2	ABa	91.5	Ab	90.9	Aa	88.1	Ba	88.0	Bab		88.0	Aa	85.7	ABa	88.5	Aa	87.2	Abab	77.4	Cb	79.1	BCb
	24		89.6	BCa	90.0	BCa	94.2	Aa	91.6	ABa	88.0	Ca	89.6	BCa		87.7	Aa	86.2	Aa	86.8	Aa	86.1	Ab	85.3	Aa	71.6	Bc
	36		90.7	ABa	89.9	ABa	92.5	Aab	91.8	Aa	88.9	BCa	86.5	Cb		87.6	ABa	85.1	Ba	87.9	ABa	90.2	Aa	86.7	ABa	86.0	Ba

Means within the same hours at 20º C followed by the same capital letters and means within the same days -0.5ºC+days at20ºC followed the same small letters are not significantly different at $p \leq 0.05$ (LSD test).

Table 2. Total classes of volatile compounds emitted (nanograms per kilogram) by two fruit varieties and relative proportions (percentages) at harvest and after pre-storage at 20 ºC following cold storage at -0.5 ºC plus 0 and 3 days at 20 ºC.

	Big Top nectarine															Early Rich peach													
		Hours	Days at -0.5 ºC + days at 20 ºC														Hours	Days at -0.5 ºC + days at 20 ºC											
	Harvest	at 20ºC	10+0		10+3		20+0		20+3		40+0		40+3			Harvest	at 20ºC	10+0		10+3		20+0		20+3		40+0		40+3		
Esters	867.9	0	2550.0(60.0)	Aa	2678.7 (49.9)	Aa	1086.4 (49.5)	Bb	3144.4 (54.7)	Aa	431.4 (16.8)	Bb	1094.9 (26.2)	Ba		1749.0	0	3385.2 (42.7)	ABa	4490.9 (48.3)	ABa	6235.1 (66.5)	Abc	2119.4 (33.1)	Bb	620.5 (16.6)	Ba	2281.8 (34.7)	Ba	
		10	1152.7 (44.2)	Ab	1283.7 (22.0)	Ab	1252.4 (51.6)	Ab	1184.8 (44.6)	Ab	1377.2 (41.6)	Ab	594.6 (34.5)	Aa			10	2578.6 (47.6)	Aa	3365.4 (49.9)	Aa	3202.0 (45.6)	Ac	1407.3 (27.7)	Ab	868.5 (14.1)	Aa	2356.2 (38.9)	Aa	
		24	1001.8 (45.7)	Bb	924.2 (24.4)	Bb	591.4 (46.3)	Bb	1047.3 (43.8)	Bb	3048.0 (48.8)	Aa	919.5 (26.3)	Ba			24	2539.8 (60.9)	BCa	5677.1 (56.9)	ABa	6991.5 (68.4)	Ab	2021.4 (32.7)	Cb	1027.8 (17.1)	Ca	1290.6 (27.2)	Ca	
		36	3157.2 (53.3)	Aa	1345.8 (42.8)	Bb	3994.6 (46.3)	Aa	1667.1 (44.5)	Bb	1071.9 (32.7)	Bb	1340.9 (38.1)	Ba			36	4658.5 (43.3)	BCa	3532.6 (42.1)	CDa	14086.5 (84.0)	Aa	7217.0 (58.5)	Ba	609.9 (14.1)	Da	1792.6 (32.8)	CDa	
Alcohols	307.7	0	635.6(14.9)	ABCb	763.7 (14.2)	ABa	149.1 (6.8)	Cb	882.0 (15.3)	Aa	237.7 (9.2)	BCb	461.6 (11.1)	ABCa		711.5	0	1586.5 (20.4)	Ab	1138.4 (12.5)	ABa	735.0 (7.9)	BCa	709.6 (11.3)	BCa	629.6 (16.7)	Ca	680.4 (10.2)	BCa	
		10	317.2 (12.2)	Ab	324.7 (5.6)	Aa	514.9 (21.2)	Ab	291.1 (11.0)	Ab	364.6 (11.0)	Ab	222.8 (12.9)	Aa			10	1205.1 (22.3)	Ab	909.4 (13.5)	ABCa	1040. 7 (14.8)	ABa	551.9 (10.9)	BCa	515.1 (8.3)	Ca	484.2 (8.0)	Ca	
		24	191.5 (8.7)	Bb	226.4 (6.0)	Ba	150.8 (11.8)	Bb	194.7 (8.1)	Bb	1310.0 (21.0)	Aa	508.8 (14.6)	Ba			24	535.5 (12.8)	Bc	1206.5 (12.1)	Aa	597.5 (5.8)	Ba	468.6 (7.6)	Ba	786.8 (13.1)	ABa	533. 9 (11.3)	Ba	
		36	1425.0 (24.1)	Ba	524.4 (16.7)	Ca	2267.4 (26.3)	Aa	660.3 (17.6)	Cab	199.4 (6.1)	Cb	184.3 (5.2)	Ca			36	2118.0 (19.7)	Aa	1041.6 (12.4)	Ba	769.6 (4.6)	Ba	789.3 (6.4)	Ba	558.4 (12.9)	Ba	607. 8 (11.1)	Ba	
Aldehydes	469.0	0	381.9 (9.0)	Aa	376.5 (7.0)	Ab	230.0 (10.5)	Ab	376.4 (6.5)	Aa	246.2 (9.6)	Ab	325.3 (7.8)	Aab		1004.8	0	1661.2 (21.3)	Aab	1123.5 (12.3)	Ba	632.3 (6.4)	Cab	817.0 (12.9)	BCa	619.0(16.4)	Ca	654.5 (10.1)	BCa	
		10	265.8 (10.2)	Ba	1020.1 (17.5)	Aa	240.9 (9.9)	Bb	309.1 (11.6)	Ba	290.3 (8.8)	Bab	135.1 (7.8)	Bb			10	928.2 (17.1)	Abc	615.2 (13.8)	ABCb	874.4 (12.4)	Aa	450.5 (17.2)	BCab	831.8 (13.5)	ABa	338.3 (13.7)	Ca	
		24	230.9 (10.5)	BCa	466.2 (12.3)	ABb	125.0 (9.8)	Cb	172.2 (7.2)	Ca	526.6 (8.4)	Aa	468.6 (13.4)	ABa			24	522.1 (12.5)	ABCc	813.1 (5.2)	Aab	242.9 (2.4)	Cb	271.7 (3.9)	BCb	921.4 (15.3)	Aa	531. 3 (19.4)	ABa	
		36	449.1 (7.6)	Ba	425.1 (13.5)	Bb	1094.3 (12.7)	Aa	287.7 (7.7)	BCa	154.8 (4.7)	Cb	217.1 (6.2)	BCab			36	1959.8 (18.2)	Aa	987.0 (23.4)	Bab	518.0 (3.1)	Cab	467.4 (4.2)	Cab	578.5 (13.4)	Ca	564. 6(10.6)	Ca	
Acids	244.2	0	117.7 (2.8)	Ba	259.1 (4.8)	Bb	138.6 (6.3)	Ba	492.3 (8.6)	Ba	1243.4 (48.3)	Aa	1602.4 (38.4)	Aa		863.3	0	102.9 (1.3)	Ca	354.5 (3.9)	BCa	1130.3 (12.1)	ABCa	1927.8(30.4)	Aab	1260.2 (33.3)	ABc	1798.1 (27.6)	Aa	
		10	115.6 (4.4)	Ba	1315.4 (22.6)	Aa	86.6 (3.6)	Ba	240.7 (9.1)	Ba	769.2 (23.2)	ABa	428.8 (24.9)	Bb			10	145.6 (2.7)	Da	243.0(3.6)	CDa	1233. 9 (17.6)	BCa	1572.2 (30.9)	Bb	2889.3 (46.7)	Aa	1592.7 (26.3)	Ba	
		24	127.4 (5.8)	Ba	1387.0 (36.6)	Aa	128.4 (10.0)	Ba	201.5 (8.4)	Ba	657.5 (10.5)	Ba	715.7 (20.5)	ABb			24	nd		655.4 (6.6)	Ba	1644.3 (16.1)	ABa	2649.9 (42.9)	Aa	2300.2 (38.2)	Aab	1237. 1 (26.1)	Ba	
		36	180.4 (3.0)	Ba	163.6 (5.2)	Bb	223.7 (2.6)	Ba	205.0 (5.5)	Ba	1269.5 (38.7)	Aa	1251.9 (35.5)	Aa			36	392.7 (3.7)	Ca	216.8 (2.6)	Ca	763. 7 (4.6)	BCa	2243. 6 (18.2)	Aab	1698.3 (39.3)	ABbc	1531. 6 (28.1)	ABa	
Terpenes	600.4	0	73.2 (1.7)	Ab	54.5 (1.0)	Ab	40.5 (1.8)	Aa	60.7 (1.1)	Aa	10.2 (0.4)	Ab	22.1 (0.5)	Aa		38.3	0	32.89 (0.4)	Aa	36.0 (0.4)	Ab	nd		nd		nd		nd		
		10	200.2 (7.7)	ABa	240.5 (4.1)	Aa	35.6 (2.8)	Da	53.1 (2.0)	CDa	120.4 (3.6)	BCa	37.0 (2.1)	Da			10	nd		36.0(0.5)	Ab	nd		nd		nd		nd		
		24	85.6 (3.9)	Bb	64.5 (1.7)	Bb	31.0 (0.4)	Ba	72.2 (3.0)	Ba	176.7 (2.8)	Aa	14.9 (0.4)	Ba			24	nd		69.1 (0.7)	Aa	nd		18.3 (0.3)	Ba	nd		nd		
		36	112.9 (1.9)	Aa	94.5 (3.0)	Ab	34.7 (2.0)	ABa	111.5 (3.0)	Aa	37.8 (1.2)	ABb	13.1 (0.4)	Ba			36	89.1 (0.8)	Aa	5.5(0.1)	Cc	nd		38. 4 (0.3)	Ba	nd		nd		
Ketones	458.2	0	431.9 (10.1)	BCa	1151.6 (21.5)	Ab	455.3 (20.8)	Ca	709.5 (12.3)	Ba	392.0 (15.2)	BCa	602.8 (14.4)	BCa		274.1	0	904.0 (11.6)	BCa	1691.6 (18.5)	Aa	436.3 (4.7)	Da	574.3 (9.1)	CDb	567.8 (15.1)	CDa	1034.9 (15.9)	Ba	
		10	490.8 (18.8)	Ba	1566.3 (26.9)	Aa	206.5 (16.2)	Ba	511.9 (19.3)	Ba	245.5 (7.4)	Ba	219.8 (12.7)	Ba			10	310.2 (5.7)	Cc	776.1(11.5)	ABc	646.8 (9.2)	ABCa	536.9 (10.6)	BCb	943.5 (15.3)	Aa	679. 1 (11.2)	ABCab	
		24	510.8 (23.3)	BCa	684.5 (18.1)	ABc	1001.1 (11.6)	Aa	654.6 (27.3)	ABCa	283.7 (4.5)	Ca	795.9 (22.8)	ABa			24	428.1 (10.3)	Cbc	1308.0 (13.1)	Aab	608.6 (6.0)	BCa	594.9 (9.6)	BCb	911.0(15.1)	ABa	629.8 (13.3)	BCb	
		36	510.8 (8.6)	Aa	424.3 (13.5)	Ac	446. 6 (26.0)	Aa	616.9 (16.5)	Aa	492.8 (15.0)	Aa	444.2 (12.6)	Aa			36	1017.9 (9.5)	BCa	1185. 9 (14.1)	ABb	551.4 (3.3)	Da	1417. 6 (11.5)	Aa	701.9 (16.2)	CDa	806.8 2(14.8)	BCDab	
Lactones	37.9	0	66.8 (1.6)	Aa	76.0 (1.4)	Ab	93.8 (4.3)	Aa	82.2 (1.4)	Ab	12.7 (0.5)	Ac	62.6 (1.5)	Aa		167.6	0	173.3 (2.3)	Bb	371.7 (4.2)	Aa	229.2 (2.5)	ABa	203.9 (3.2)	Ba	74.9 (2.0)	Ba	95.4 (1.5)	Ba	
		10	66.4 (2.5)	Ba	73.4 (1.3)	Bb	40.7 (3.2)	Ba	66.8 (2.5)	Bb	145.1 (4.4)	Ab	86.3 (5.0)	ABa			10	235.3 (4.3)	Bb	484.4(7.2)	Aa	30.3 (0.4)	Cb	140.0(2.8)	BCa	132.8 (2.1)	BCa	106.3 (1.8)	BCa	
		24	41.8 (1.9)	Ba	38.5 (1.0)	Bb	21.6 (0.3)	Ba	51.3 (2.1)	Bb	248.3 (4.0)	Aa	66.5 (1.9)	Ba			24	144.7 (3.5)	Bb	541.3 (5.4)	Aa	131.7 (1.3)	Bab	177. 2 (2.9)	Ba	74.2(1.2)	Ba	124. 8(2.6)	Ba	
		36	87.5 (1.5)	Ba	168.9 (5.4)	Aa	69.9 (4.1)	Ba	200.6 (5.4)	Aa	52.4 (1.6)	Bc	72.2 (2.0)	Ba			36	520.0 (4.8)	Aa	447.8 (5.3)	Aa	77.1 (0.5)	Bab	106.4 (0.9)	Ba	172.8 (4.0)	Ba	142.8 (2.6)	Ba	
Total	2985.3	0	4257.1	ABab	5360.1	Aab	2193.6	Bb	5747.5	Aa	2573.7	Bb	4171.7	ABa		4848.6	0	7845.9	Aab	9206.7	Aab	9398.1	Ab	6352.0	ABb	3772.0	Ba	6545.2	ABa	
		10	2608.7	BCbc	5824.2	Aa	2463.7	Bb	2657.5	BCb	3312.3	Bb	1724.5	BCb			10	5412.8	Ab	6429.7	Ab	7028.2	Ab	4658.9	Ab	6181.0	Aa	5557.0	Aa	
		24	2189.9	Cc	3791.4	Cbc	1299.3	Cb	2393.7	Cb	6250.7	Ba	3490.0	Cab			24	4170.1	Bb	10270.5	Aa	10216.4	Ab	6201.9	Bb	6021.3	Ba	4347.5	Ba	
		36	5922.8	Ba	3146.6	Cc	8633.7	Aa	3749.1	Cab	3278.4	Cb	3523.8	Cab			36	10756.0	BCa	7417.2	CDb	16766.5	Aa	12279.6	Ba	4319.7	Da	5446.2	Da	

Means within the same hours at 20º C followed by the same capital letters and means within the same days -0.5ºC+days at20ºC followed the same small letters are not significantly different at $p \leq 0.05$ (LSD test).

Table 3. Straight-chain esters ($ng \cdot kg^{-1}$) by 'Big Top' nectarine and 'Early Rich' peach, PCA analysis codes in brackets, retention index (IR) at harvest and after pre-storage at 20 ºC following cold storage at -0.5 ºC plus 0 and 3 days at 20 ºC.

			Big Top												Early Rich											
	Hours	IR	Days -0.5 ºC + days at 20 ºC												Days -0.5 ºC + days at 20 ºC											
	at 20ºC		Harvest	10+0		10+3		20+0		20+3		40+0		40+3		Harvest	10+0		10+3		20+0		20+3		40+0		40+3	
Ethyl acetate	0	911	n.d.	17.5	Aa	22.8	Aa	n.d.		21.4	Aa	n.d.		n.d.		n.d.	47.9	Ba	n.d.		4643.9	Ab	n.d.		n.d.		n.d.	
	10			18.2	Aa	20.3	Aa	n.d.		17.5	Aa	n.d.		n.d.			n.d.		n.d.		1908.5	Ac	n.d.		n.d.		n.d.	
	24			35.0	Aa	32.0	Aa	n.d.		34.9	Aa	n.d.		n.d.			n.d.		n.d.		4828.9	Ab	n.d.		n.d.		n.d.	
	36			n.d.		n.d.		n.d.		n.d.		n.d.		n.d.			n.d.		n.d.		10348.1	Aa	n.d.		n.d.		n.d.	
Propyl acetate	0	995	<10	488.2	ABa	516.1	Aa	171.9	Bb	601.9	Aa	n.d.		n.d.		18.9	1098.0	Aa	231.1	Bab	66.7	Bb	103.1	Bc	n.d.		n.d.	
	10			459.1	Aa	507.6	Aa	63.3	Bb	462.1	Aab	96.4	Ba	33.0	Ba		662.6	Ab	150.4	BCab	44.5	Cb	93.5	Cc	122.9	BCa	367.7	Ba
	24			260.3	Aa	240.4	Aab	62.2	Ab	268.3	Abc	109.6	Aa	71.3	Aa		1130.7	Aa	391.3	Ba	259.9	BCb	360.2	Bb	48.0	Ca	138.4	Bca
	36			230.2	Ba	30.3	Bb	564.4	Aa	35.4	Bc	137.3	Ba	93.1	Ba		938.7	Ba	80.8	Db	649.6	Ca	1265.3	Aa	47.5	Da	147.9	Da
Butyl acetate	0	1183	42.1	97.7	ABa	103.9	Aab	30.6	Ca	120.4	Aa	n.d.		36.1	BCa	51.6	34.9	BCc	66.6	ABa	24.2	Cc	56.7	ABCb	n.d.		75.5	Aa
	10			114.9	Aa	126.9	Aa	17.0	Ca	115.9	Aa	98.4	ABa	41.6	BCa		198.3	Aa	49.9	BCa	23.7	Cc	40.2	Cb	25.0	Ca	79.3	Ba
	24			44.5	Ba	41.0	Bbc	21.4	Ba	45.7	Bb	129.4	Aa	45.5	Ba		120.6	Ab	80.9	Ba	62.7	BCb	70.8	Bb	34.8	Ca	55.4	BCa
	36			63.4	Aa	21.1	Ac	72.0	Aa	25.4	Ab	67.9	Aa	55.5	Aa		144.3	Ab	56.6	Ca	110.1	Ba	135.6	ABa	31.3	Ca	62.3	Ca
Pentyl acetate	0	1307	10.0	<10		<10		<10		<10		<10		12.1	Ac	15.9	19.8	Ba	52.1	Aa	11.2	Bc	26.1	Abc	<10		19.1	Ba
	10			<10		<10		<10		<10		63.1	Ab	25.9	Ba		10.0	Ba	33.9	Ba	92.9	Aab	82.7	Ab	n.d.		31.5	Ba
	24			<10		<10		<10		<10		146.7	Aa	13.1	Bc		11.0	Ba	56.3	Aa	76.0	Ab	76.1	Ab	n.d.		n.d.	
	36			10.3	Ca	<10		46.4	Aa	11.5	Ca	n.d.		17.2	Bb		31.6	Ba	34.5	Ba	120.5	Aa	114.4	Aa	n.d.		26.4	Bca
Hexyl acetate	0	1393	45.1	73.2	ABb	79.5	Aa	37.3	Cb	90.2	Aa	43.6	BCc	95.5	Aa	127.9	128.1	Bb	336.5	Ab	64.2	Cb	149.1	Bab	49.1	Ca	119.4	Ba
	10			32.2	Bc	35.5	Bbc	39.8	Bb	32.7	Bb	115.3	Ab	57.9	Bb		77.0	Bc	270.4	Ac	62.7	Bb	103.5	Bb	n.d.		n.d.	
	24			21.1	Bc	19.5	Bc	28.3	Bb	21.7	Bb	213.3	Aa	n.d.			78.6	Cbc	397.4	Aa	110.7	Cab	176.7	Ba	n.d.		94.2	Ca
	36			115.4	Ba	69.9	CDa	557.7	Aa	85.1	BCa	44.4	Dc	69.1	CDab		211.9	ABa	247.0	Ac	151.7	CDa	194.2	BCa	n.d.		105.8	Da
Butyl propanoate	0	1257	113.1	17.9	Aa	19.3	Aa	28.2	Ab	22.0	Aab	n.d.		n.d.		37.1	20.1	Ab	11.2	Aa	n.d.		n.d.		n.d.		n.d.	
	10			28.9	Aa	31.9	Aa	23.4	Ab	29.1	Aa	n.d.		n.d.			27.2	Ab	<10		12.5	Ba	n.d.		n.d.		n.d.	
	24			26.7	Aa	24.6	Aa	13.0	Ab	27.3	Aab	n.d.		n.d.			19.6	Ab	<10		16.9	Aa	n.d.		n.d.		n.d.	
	36			34.3	Ba	<10		222.8	Aa	10.2	Bb	n.d.		n.d.			52.3	Aa	<10		n.d.		n.d.		n.d.		n.d.	
Propyl hexanoate	0	1440	12.0	12.0	Ab	11.1	Ab	<10		14.9	Ab	n.d.		n.d.		39.1	25.3	Ba	1056.5	Ab	17.5	Ba	68.0	Ba	n.d.		n.d.	
	10			<10		<10		n.d.		<10		n.d.		n.d.			17.1	Ba	1041.7	Ab	13.5	Ba	20.6	Ba	n.d.		n.d.	
	24			<10		<10		13.6	Aa	<10		n.d.		n.d.			47.3	Ba	2305.0	Aa	28.9	Ba	316.8	Ba	n.d.		n.d.	
	36			25.7	Ca	142.7	Ba	n.d.		172.0	Aa	n.d.		n.d.			106.5	Ba	1234.0	Ab	90.1	Ba	155.0	Ba	n.d.		n.d.	
Pentyl hexanoate	0	1637	n.d.	34.9	Aa	36.2	Aa	<10		43.1	Aa	n.d.		11.4	Aa	26.6	32.7	Ab	32.4	Aa	23.3	Aa	33.7	Aa	n.d.		n.d.	
	10			n.d.		n.d.		29.3	Aa	n.d.		n.d.		27.0	Aa		25.9	Ab	18.5	Ab	n.d.		n.d.		n.d.		n.d.	
	24			n.d.		n.d.		n.d.		n.d.		198.1	Aa	n.d.			<10		21.6	Aab	n.d.		n.d.		n.d.		n.d.	
	36			58.4	Aa	43.7	Aa	n.d.		54.8	Aa	n.d.		n.d.			57.9	Aa	n.d.		n.d.		n.d.		n.d.		n.d.	
Butyl hexanoate	0	1533	<10	179.8	Ab	185.7	Aa	n.d.		221.9	Aa	n.d.		56.7	Ba	53.8	70.5	Ab	79.3	Aa	27.0	Bb	27.2	Ba	<10		11.7	Ba
	10			n.d.		n.d.		90.9	Ab	n.d.		n.d.		n.d.			57.0	Ab	36.3	ABb	56.8	Aa	19.0	Ba	n.d.		n.d.	
	24			n.d.		n.d.		n.d.		n.d.		161.6	Aa	44.9	Ba		25.9	Ac	36.3	Ab	24.7	Ab	27.4	Aa	n.d.		n.d.	
	36			294.0	Aa	131.3	Ca	228.8	ABa	164.6	Ba	8.9	Db	n.d.			99.0	Aa	25.8	Cb	75.2	Ba	39.6	Ca	n.d.		n.d.	
Hexyl hexanoate	0	1736	22.0	314.5	ABa	331.4	ABa	19.3	Ca	387.8	Aa	13.4	Ca	146.8	BCa	330.6	605.2	Aa	411.5	Ba	241.8	BCa	377.7	Ba	164.5	Ca	252.9	BCa
	10			35.5	Ab	39.3	Ab	225.5	Aa	35.5	Ab	n.d.		n.d.			372.9	Ab	266.3	ABa	152.6	BCab	17.5	Cb	n.d.		132.7	BCa
	24			26.3	Ab	24.2	Ab	21.4	Aa	26.9	Ab	n.d.		n.d.			177.2	ABc	270.5	Aa	18.6	Bb	17.0	Bb	n.d.		135.6	ABa
	36			331.8	Aa	140.4	Aab	n.d.		174.9	Aab	n.d.		n.d.			888.8	Aa	366.0	Ba	43.2	Cb	38.0	Cb	n.d.		304.6	Ba
Hexyl propanoate	0	1730	n.d.	100.2	ABa	92.6	ABa	n.d.		124.0	Aa	16.3	Bb	n.d.		n.d.	63.0		n.d.		n.d.		n.d.		n.d.		n.d.	
	10			n.d.		n.d.		41.3	Aa	n.d.		n.d.		n.d.			n.d.		n.d.		n.d.		n.d.		n.d.		n.d.	
	24			n.d.		n.d.		n.d.		n.d.		293.0	Aa	n.d.			n.d.		n.d.		n.d.		n.d.		n.d.		n.d.	
	36			151.4	Aa	n.d.		n.d.		n.d.		17.0	Bb	n.d.			n.d.		n.d.		n.d.		n.d.		n.d.		n.d.	
Methyl octanoate	0	1511	33.0	<10		<10		<10		11.0	Aa	<10		13.2	Ab	38.5	27.3	BCab	118.0	Ac	50.9	BCa	65.2	ABb	n.d.		n.d.	
	10			<10		<10		12.5	Ca	5.1	Ca	149.7	Ab	57.7	Ba		12.9	Bb	66.5	Ac	n.d.		33.9	ABb	n.d.		37.6	ABb
	24			n.d.		n.d.		18.6	Ba	n.d.		244.3	Aa	10.2	Bb		41.3	Cab	402.8	Aa	18.0	Ca	128.0	Ba	n.d.		96.2	Ba
	36			18.1	Aa	<10		n.d.		<10		n.d.		n.d.			68.0	Ba	190.5	Ab	47.6	Ba	40.5	Bb	34.6	Ba	82.0	Bab
Ethyl octanoate	0	1555	229.0	81.1	ABa	84.3	ABa	329.0	Aa	100.1	ABa	26.8	Bb	86.5	ABb	376.7	172.1	Ba	643.3	ABa	230.6	Bc	305.6	Bb	60.3	Ba	1148.2	Aa
	10			69.0	Aa	76.4	Aa	73.0	Aa	69.1	Aa	139.2	Aab	87.2	Ab		139.0	Ba	449.1	Ba	82.7	Bc	445.1	Bb	n.d.		1098.5	Aa
	24			278.2	Aa	258.5	Aa	166.2	Aa	292.4	Aa	165.4	Aab	123.0	Ab		368.5	ABa	428.3	ABa	937.0	Ab	n.d.		n.d.		385.0	ABb
	36			235.6	Ba	159.0	Ba	n.d.		186.2	Ba	302.4	Ba	758.4	Aa		538.4	Ca	453.6	Ca	1597.8	Ba	3936.3	Aa	n.d.		500.7	Cb
Butyl octanoate	0	1740	25.4	56.2	ABa	59.9	ABa	11.4	Ca	69.3	Aa	n.d.		21.4	BCa	68.9	90.7	Aab	70.2	ABa	51.4	ABa	64.1	ABa	23.5	Bd	30.9	ABa
	10			56.2	ABa	59.9	ABa	11.4	Ca	69.3	Aa	n.d.		21.4	BCa		73.8	Bb	53.2	BCa	35.1	BCa	n.d.		256.6	Ab	n.d.	
	24			56.2	ABa	59.9	ABa	11.4	Ca	69.3	Aa	n.d.		21.4	BCa		43.3	Bb	45.7	Ba	n.d.		n.d.		329.9	Aa	24.3	Ba
	36			60.1	Aa	23.3	Aa	n.d.		29.0	Aa	31.1	Aa	44.5	Aa		154.0	Aa	73.0	Ba	n.d.		n.d.		165.3	Ac	40.4	Ba

Means within the same hours at 20º C followed by the same capital letters and means within the same days -0.5ºC+days at20ºC followed the same small letters are not significantly different at $p \leq 0.05$ (LSD test).

Table 4. Branched-chain esters (ng·kg^{-1}) by 'Big Top' nectarine and 'Early Rich' peach, PCA analysis codes in brackets, retention index (IR) at harvest and after pre-storage at 20 ºC following cold storage at -0.5 ºC plus 0 and 3 days at 20 ºC.

			Big Top												Early Rich											
	Hours at 20ºC	IR	Days -0.5 ºC + days at 20 ºC												Days -0.5 ºC + days at 20 ºC											
			Harvest	10+0		10+3		20+0		20+3		40+0		40+3	Harvest	10+0		10+3		20+0		20+3		40+0		40+3	
2-Methylpropyl acetate	0	1052	21.5	40.7	Ba	42.7	Ba	55.0	ABb	50.2	ABa	n.d.		116.1	Aa	25.7	87.6	Cab	504.7	Aa	47.8	Cb	314.0	Bbc	n.d.		327.7	Bab
	10			46.1	Aa	50.9	Aa	25.7	Ab	46.6	Aa	68.3	Aa	46.0	Ab		75.1	Cb	380.2	Ab	61.7	Cb	269.4	Bc	88.9	Ca	394.1	Aa
	24			41.0	Ba	37.9	Ba	29.9	Bb	42.3	ABa	110.5	Aa	91.5	ABab		80.6	Cb	683.1	Ab	115.1	Cab	370.0	Bb	89.5	Ca	297.8	Bb
	36			57.7	Ba	33.5	Ba	374.2	Aa	40.1	Ba	66.6	Ba	71.0	Bab		158.8	CDa	343.7	Bb	184.9	Ca	528.3	Aa	87.9	Da	299.6	Bb
2-Methylbutyl acetate	0	1240	29.7	109.5	Ca	117.9	Ca	261.1	Aa	134.9	BCa	231.2	ABa	273.4	Aa	96.4	254.7	Bb	199.5	Bab	443.5	Aa	178.6	Bb	210.9	Ba	77.1	Ca
	10			116.9	Aa	129.3	Aa	131.5	Ab	117.5	Aa	149.2	Aab	74.7	Ab		356.5	Aa	227.3	Ba	429.7	Aa	115.0	Cb	201.4	Ba	66.8	Ca
	24			60.4	Ba	55.6	Ba	119.3	ABb	61.8	Ba	219.1	Aab	185.2	Aa		158.2	BCc	217.6	Ba	339.9	Ab	188.4	Bb	94.4	Ca	n.d.	
	36			132.0	Aa	121.1	Aa	79.2	Ab	147.0	Aa	120.0	Ab	58.4	Ab		326.7	Bab	119.0	CDb	407.3	ABab	477.8	Aa	134.5	Cab	48.8	Da
Z-3-Hexenyl acetate	0	1457	58.4	70.6	Aa	92.1	Aa	43.6	Aa	86.5	Aa	n.d.		n.d.		89.1	32.2	Bab	208.8	Aa	32.7	Ba	64.8	Ba	n.d.		n.d.	
	10			74.6	Aa	83.3	Aa	n.d.		71.6	Aa	n.d.		n.d.			41.0	Aa	n.d.		n.d.		n.d.		n.d.		n.d.	
	24			43.5	Aa	40.3	Aa	50.4	Aa	45.2	Aa	n.d.		n.d.			23.9	Ab	n.d.		25.6	Aa	82.9	Aa	n.d.		n.d.	
	36			n.d.		69.8	Aa	n.d.		84.2	Aa	32.7	Aa	22.4	Aa		43.3	Aa	n.d.		36.3	Aa	60.7	Aa	n.d.		n.d.	
2-Methylbutyl-2-methylbutanoate	0	1397	n.d.	25.4	Aa	26.7	Aa	n.d.		31.4	Aa	n.d.		n.d.		<10	25.1	Aa	14.2	Ba	12.3	Ba	<10		n.d.		n.d.	
	10			n.d.		n.d.		13.4	Ab	n.d.		n.d.		n.d.			12.4	Ab	<10		n.d.		n.d.		n.d.		n.d.	
	24			n.d.		n.d.		n.d.		n.d.		n.d.		n.d.			<10		15.1	Aa	n.d.		n.d.		n.d.		n.d.	
	36			38.6	Ba	23.9	Ba	1486.8	Aa	28.2	Ba	n.d.		n.d.			n.d.		14.9	Aa	n.d.		n.d.		n.d.		n.d.	
Ethyl 2-methylbutanoate	0	1127	n.d.	<10		<10		18.3	Aa	<10		37.0	Ab	n.d.		<10	10.2	Ca	n.d.		12.0	BCa	20.0	Ba	n.d.		35.5	Aa
	10			<10		10.7	Ba	11.5	Ba	10.3	Ba	71.3	Ab	39.7	ABa		15.9	Ba	35.1	Aa	n.d.		12.8	Ba	33.2	Aa	40.7	Aa
	24			n.d.		n.d.		<10		n.d.		126.9	Aa	33.8	Ba		n.d.		11.2	Ab	n.d.		n.d.		n.d.		n.d.	
	36			n.d.		<10		n.d.		<10		n.d.		58.0	Aa		n.d.		n.d.		n.d.		n.d.		n.d.		21.7	Ab
Butyl 2-methylbutanoate	0	1348	24.5	41.5	Aab	44.8	Aa	n.d.		51.2	Aa	n.d.		n.d.		16.4	26.2	Ab	25.3	Aa	<10		15.0	Bc	n.d.		n.d.	
	10			11.9	Bb	13.1	Bb	14.7	Ba	12.0	Bb	72.4	Ab	27.8	Ba		19.5	Ab	15.1	Ab	n.d.		23.4	Ab	19.5	Aa	25.3	Aa
	24			16.5	Bb	15.2	Bab	16.3	Ba	16.8	Bb	203.8	Aa	13.1	Ba		12.6	Bb	24.5	Ba	n.d.		74.8	Aa	20.5	Ba	n.d.	
	36			60.7	Aa	19.5	Bab	43.8	ABa	24.1	Bab	n.d.		n.d.			41.7	Aa	30.1	ABa	n.d.		11.6	Cc	16.0	BCa	21.0	BCa
2-Methylbutyl-2-methylpropanoate	0	1310	153.9	51.8	Ab	53.7	Aab	36.0	Ab	63.9	Aa	32.4	Ac	50.3	Aa	42.40	71.0	Ab	71.1	Aab	27.7	Bb	36.3	Bab	11.4	Ca	18.0	Ca
	10			77.1	Aab	85.1	Aa	24.6	Bb	78.3	Aa	87.5	Ab	n.d.			39.5	Ac	31.5	ABc	n.d.		20.2	BCb	n.d.		12.4	Ca
	24			81.5	Bab	75.2	Bab	19.3	Cb	83.7	Ba	139.3	Aa	n.d.			27.4	Bc	54.9	Ab	n.d.		22.9	Bb	n.d.		n.d.	
	36			101.4	Ba	43.6	Cb	318.4	Aa	52.9	Ca	54.1	Cbc	n.d.			120.5	Aa	76.8	Ba	49.5	Ca	48.8	Ca	n.d.		n.d.	
Hexyl 2-methylbutanoate	0	1546	12.6	716.3	Aa	737.7	Aa	12.5	Ba	883.7	Aa	17.9	Ba	175.3	Ba	280.7	442.2	Ab	313.5	Ba	182.1	Ca	201.7	BCa	91.7	Ca	121.6	Ca
	10			12.1	Ab	13.4	Ab	403.7	Aa	12.2	Ab	142.4	Aa	54.7	Aa		336.4	Ab	225.5	ABab	225.3	ABa	110.6	BCa	121.0	BCa	69.5	Ca
	24			10.8	Ab	<10		<10		11.0	Ab	242.6	Aa	162.1	Aa		155.8	ABc	228.4	Aab	128.5	ABa	109.3	ABa	119.8	ABa	63.6	Ba
	36			1138.1	Aa	272.6	Ba	n.d.		341.3	Bb	70.7	Ba	43.8	Ba		676.3	Aa	176.6	Bb	174.5	Ba	170.7	Ba	92.8	Ba	131.4	Ba
2-Methylpropyl hexanoate	0	1444	6.6	10.7	Aa	<10		n.d.		13.3	Aa	n.d.		n.d.		n.d.	n.d.		n.d.		n.d.		n.d.		n.d.		n.d.	
	10			<10		<10		<10		<10		124.0	Ab	n.d.			<10		n.d.		n.d.		n.d.		n.d.		n.d.	
	24			n.d.		n.d.		n.d.		n.d.		344.5	Aa	104.4	Ba		n.d.		n.d.		n.d.		n.d.		290.9		n.d.	
	36			n.d.		n.d.		n.d.		n.d.		118.8	Ab	49.5	Aa		n.d.		n.d.		n.d.		n.d.		n.d.		n.d.	
γ-Hexalactone	0	1880	26.5	30.7	ABCb	34.1	ABab	28.7	BCa	37.8	ABb	12.7	Cd	49.7	Aa	99.0	108.39	Bb	155.07	Ab	100.73	BCa	95.12	BCa	74.92	Cb	73.28	Ca
	10			32.6	BCb	36.0	BCab	23.3	Ca	32.9	BCb	96.0	Ab	42.5	Ba		142.69	Aa	158.35	Ab	30.34	Cb	61.27	BCb	132.75	Aa	78.77	Ba
	24			29.6	Cb	27.4	Cb	21.7	Ca	30.5	Cb	196.8	Aa	55.5	Ba		74.31	BCc	192.78	Aa	94.64	Ba	95.05	Ba	60.26	Cb	89.58	BCa
	36			55.9	Aa	49.0	Aa	21.6	Ba	58.9	Aa	52.4	Ac	56.5	Aa		169.81	Aa	110.83	BCc	77.08	Da	68.37	Dab	130.51	Ba	93.05	CDa
γ-Octalactone	0	2111	9.0	12.8	Aa	14.1	Aa	13.2	Aa	15.7	Aab	n.d.		n.d.		42.4	26.90	Bb	42.61	Ab	47.81	Aa	35.05	ABa	n.d.		22.16	Ba
	10			16.2	Ca	17.9	Ca	10.2	Ca	16.4	Cab	49.1	Aa	31.3	Ba		57.88	Aa	65.65	Aa	n.d.		15.06	Bb	n.d.		27.58	Ba
	24			12.1	Ba	11.2	Ba	<10		12.4	Bb	51.4	Aa	n.d.			35.49	Bb	65.81	Aa	20.93	BCb	25.72	BCab	13.89	Cb	35.20	Ba
	36			15.1	Aa	19.5	Aa	n.d.		23.1	Aa	n.d.		n.d.			67.68	Aa	49.72	Bb	n.d.		15.53	Cb	42.29	Ba	23.62	Ca
δ-Decalactone	0	2417	2.4	16.8	Aa	20.6	Ab	51.9	Aa	20.6	Ab	n.d.		12.8	Aa	10.4	38.03	Bb	174.03	Ab	80.65	Ba	73.75	Ba	n.d.		n.d.	
	10			17.6	Aa	19.5	Ab	20.4	Aa	17.5	Ab	n.d.		12.6	Aa		27.63	Bb	232.75	Aa	n.d.		63.66	Ba	n.d.		n.d.	
	24			<10		<10		19.0	Aa	8.5	Ab	n.d.		11.0	Aa		30.16	Bb	265.97	Aa	16.16	Bb	56.39	Ba	n.d.		n.d.	
	36			16.5	Ba	100.4	Aa	n.d.		118.7	Aa	n.d.		15.7	Ba		273.40	Aa	274.66	Aa	n.d.		22.49	Ba	n.d.		26.13	Ba
γ-Dodecalactone	0	2587	n.d.	<10		<10		n.d.		<10		n.d.		n.d.		15.8	<10		<10		n.d.		n.d.		n.d.		n.d.	
	10			<10		<10		n.d.		<10		n.d.		n.d.			<10		27.70	Aa	n.d.		n.d.		n.d.		n.d.	
	24			<10		<10		n.d.		<10		n.d.		n.d.			<10		16.70		n.d.		n.d.		n.d.		n.d.	
	36			<10		n.d.		n.d.		n.d.		n.d.		n.d.			<10		12.61	Ab	n.d.		n.d.		n.d.		n.d.	

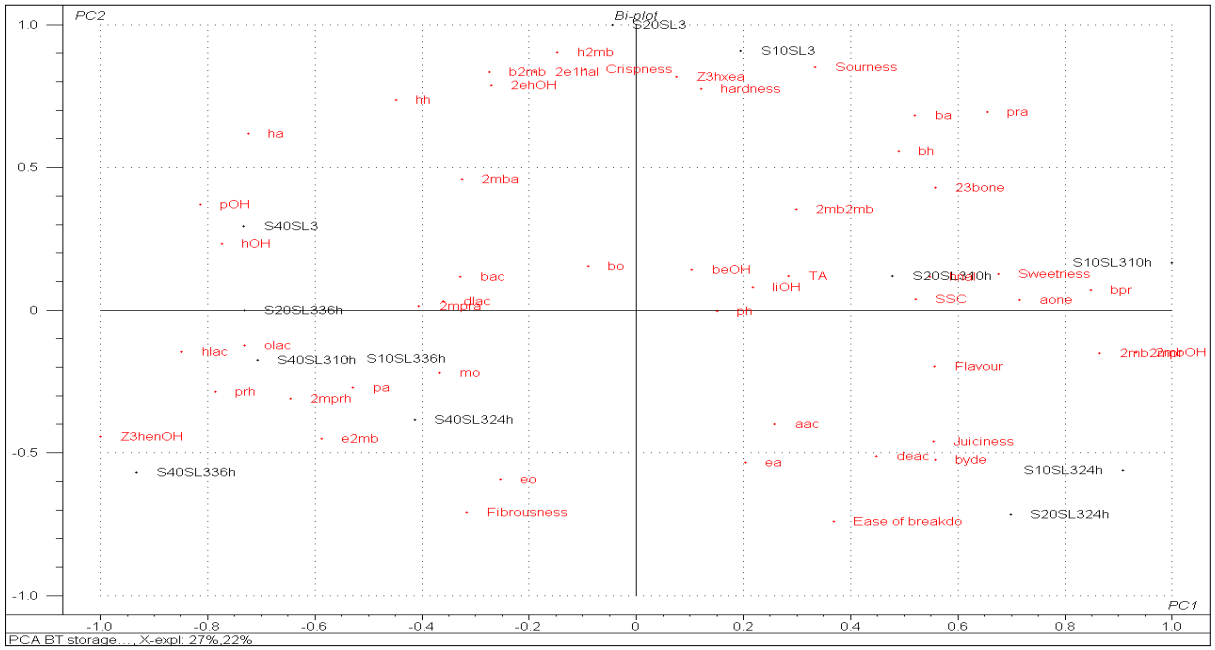
Means within the same hours at 20º C followed by the same capital letters and means within the same days -0.5ºC+days at20ºC followed the same small letters are not significantly different at $p \leq 0.05$ (LSD test).

Table 5. Aldehydes, ketones, terpenes, acids and alcohols (ng·kg^{-1}) by 'Big Top' nectarine and 'Early Rich' peach, codes in brackets and retention index (IR)

	Hours at 20ºC	IR	Big Top													Early Rich											
			Days -0.5 ºC + days at 20 ºC													Days -0.5 ºC + days at 20 ºC											
			Harvest	10+0		10+3		20+0		20+3		40+0		40+3		Harvest	10+0		10+3		20+0		20+3		40+0		40+3	
Hexenal	0	1082	223.3	240.5	Aab	230.4	ABb	101.5	Cb	170.9	ABCa	129.8	Ca	137.2	BCb	672.1	1255.1	Aa	752.4	Ba	367.1	Cbc	529.9	BCa	363.3	Cab	385.1	Ca
	10			170.4	Bb	822.3	Aa	129.2	BCb	166.5	Ba	80.3	BCa	46.8	Cb		571.2	ABb	360.2	Abc	680.4	Aa	357.9	ABab	554.8	ABab	138.6	Ca
	24			157.0	BCb	282.3	Ab	63.9	Cb	118.5	Ca	156.0	BCa	253.2	ABa		357.0	ABb	433.8	ABbc	223.9	Bc	190.6	Bb	595.0	Aa	309.7	Ba
	36			299.6	Aa	306.0	Ab	399.6	Aa	123.2	Ba	95.9	Ba	104.2	Bb		1446.4	Aa	637.7	Bab	451.4	BCab	314.6	Cab	328.3	Cb	302.4	Ca
2-Ethyl-1-hexenal	0	1293	133.7	115.2	ABa	127.7	Aa	77.2	Bbc	141.8	Aa	82.1	Bc	116.2	ABa	240.7	332.3	Aab	273.0	ABa	194.0	BCa	205.3	BCa	149.5	Ca	171.8	Ca
	10			71.1	Bb	78.6	Bb	86.6	Bb	71.7	Bb	167.8	Ab	55.6	Bb		263.8	Ab	185.5	ABb	100.5	CDb	24.8	Db	199.8	ABa	138.0	BCa
	24			52.3	Cb	48.2	Cb	43.7	Cc	53.7	Cb	305.1	Aa	126.5	Ba		131.3	Cc	227.3	ABab	19.0	Dbc	44.6	Db	231.1	Aa	148.3	BCa
	36			149.5	Ba	70.9	Cb	514.5	Aa	87.1	Cb	n.d.		58.6	Cb		382.9	Aa	223.9	Bab	n.d.		76.8	CDb	169.7	Ba	157.0	BCa
Benzaldehyde	0	1521	112.0	26.2	Ba	18.4	Bb	51.3	ABb	63.7	ABa	34.4	ABa	71.8	Aab	92.0	73.8	Bb	98.1	ABbc	71.2	Ba	81.8	ABa	106.3	Aa	97.5	ABab
	10			24.3	Ba	119.3	Aa	25.0	Bb	70.9	Ba	42.3	Ba	32.6	Bb		93.1	Ab	69.4	ABc	93.5	Aa	67.8	ABa	77.1	ABa	61.7	Bc
	24			21.6	CDa	135.7	Aa	17.4	Db	n.d.		65.5	BCa	89.0	ABa		33.8	Cc	152.1	Aa	n.d.		36.5	Cb	95.3	Ba	73.3	Bbc
	36			n.d.		48.1	Bb	180.3	Aa	77.4	Ba	58.9	Ba	54.4	Bab		130.5	Aa	125.3	Aab	66.6	Ca	76.0	BCa	80.5	BCa	105.2	Aba
2,3-Butanodione	0	999	419.8	364.6	Ba	1030.8	Aab	340.6	Bb	660.2	ABa	333.2	Ba	542.4	ABab	240.8	754.7	Bb	1348.8	Aa	283.4	Ca	461.6	Cb	427.2	Cb	944.3	Ba
	10			372.6	Ba	1424.4	Aa	211.7	Bb	460.0	Ba	193.8	Ba	167.6	Bb		310.2	Bc	414.9	Bc	502.8	ABa	437.0	Bb	709.7	Aa	553.5	ABb
	24			421.3	ABa	568.3	ABbc	156.3	Bb	567.4	ABa	220.0	ABa	720.0	Aa		295.0	Cc	566.9	ABc	362.5	BCa	385.6	BCb	779.2	Aa	542.4	ABb
	36			427.2	ABa	373.5	Bc	911.1	Aa	558.7	ABa	449.4	ABa	389.8	Bab		1017.9	Ba	820.3	BCb	412.7	Da	1326.2	Aa	431.9	Db	697.7	Cb
Acetophenone	0	1736	38.4	67.3	ABa	120.8	Aa	114.7	Aa	49.3	Ba	58.8	ABa	60.4	ABa	33.2	149.3	Ba	342.8	Ab	152.8	Ba	112.7	Bab	140.6	Bb	90.6	Ba
	10			118.2	Aa	141.9	Aa	52.6	Bab	51.9	Ba	51.7	Ba	52.2	Ba		n.d.		361.2	Ab	144.1	BCa	99.9	Cab	233.9	Bab	125.6	BCa
	24			89.6	ABa	116.2	Aa	50.2	Bb	87.2	ABa	63.6	ABa	76.0	ABa		133.1	CDa	741.1	Aa	246.1	Ba	209.3	BCa	131.8	CDb	87.4	Da
	36			83.6	Aa	50.8	Ab	90.0	Aab	58.2	Aa	43.3	Aa	54.5	Aa		n.d.		365.6	Ab	138.7	Ba	91.4	BCb	270.0	Aa	109.1	BCa
Linalool	0	1679	574.9	49.3	Ab	54.5	Ab	40.5	ABa	60.7	Ab	10.2	Cd	22.1	BCa	38.3	n.d.		10.2	Aa	<10		n.d.		n.d.		n.d.	
	10			52.4	Bb	57.8	Bb	15.5	Cb	53.1	Bb	120.4	Ab	37.0	BCa		<10		13.4	Aa	n.d.		n.d.		n.d.		n.d.	
	24			69.8	Bb	64.5	Bb	35.6	Cab	72.2	Bb	176.7	Aa	14.9	Ca		n.d.		<10		n.d.		n.d.		n.d.		n.d.	
	36			112.9	Aa	94.5	Aa	31.0	Bab	111.5	Aa	37.8	Bc	13.1	Ba		89.1	Aa	<10		n.d.		13.2		n.d.		n.d.	
Eucalyptol	0	1032	21	23.9	Ab	n.d.		n.d.		n.d.		n.d.		n.d.		n.d.	32.9	Aa	25.8	Ab	n.d.		n.d.		n.d.		n.d.	
	10			147.8	Ba	182.7	Aa	n.d.		n.d.		n.d.		n.d.			n.d.		22.6	Ab	n.d.		n.d.		n.d.		n.d.	
	24			15.8	Ab	n.d.		n.d.		n.d.		n.d.		n.d.			n.d.		63.5	Aa	n.d.		18.3	Ba	n.d.		n.d.	
	36			n.d.		n.d.		n.d.		n.d.		n.d.		n.d.			n.d.		n.d.		n.d.		25.1		n.d.		n.d.	
Acetic acid	0	1432	46.1	n.d.		88.7	Bb	n.d.		159.1	Ba	970.6	Aa	1266.4	Aa	616.4	n.d.		111.6	Ca	998.5	Bab	1730.2	Abc	1026.4	Bc	1495.7	ABa
	10			n.d.		1147.0	Aa	n.d.		n.d.		524.2	ABab	230.8	Bc		n.d.		n.d.		1071.9	Bab	1320.7	Bc	2665.3	Aa	1323.8	Ba
	24			n.d.		1132.8	Aa	n.d.		n.d.		310.3	Bb	345.2	Bbc		n.d.		333.1	Da	1535.9	BCa	2479.1	Aa	1982.6	ABb	1038.6	Ca
	36			n.d.		82.0	Bb	n.d.		n.d.		1018.5	Aa	926.8	Aab		147.1	CDa	n.d.		650.4	Cb	2062.6	Aab	1370.2	Bc	1204.2	Ba
Benzoic acid	0	1560	198.1	117.7	Ca	170.4	BCa	138.6	BCa	316.1	Aa	261.2	ABa	317.8	Aab	246.8	102.9	Db	128.8	CDa	131.8	CDab	157.2	Cb	222.6	Bb	276.9	Aab
	10			115.6	ABa	157.3	ABa	86.6	Ba	228.8	Aab	244.9	Aa	187.0	ABb		145.6	Bb	130.2	Ba	162.0	Ba	204.0	Aa	223.9	Ab	244.0	Ab
	24			127.4	Ba	195.6	Ba	128.4	Ba	164.3	Bb	347.2	Aa	350.9	Aa		n.d.		161.7	Ba	93.7	Cb	117.5	Cb	317.7	Aa	177.2	Cc
	36			180.4	ABa	81.6	Ba	223.7	Aa	182.2	ABab	251.0	Aa	310.4	Aab		210.7	Ba	136.9	CDa	95.9	Db	156.5	Cb	314.1	Aab	300.1	Aa
Decanoic acid	0	2407	n.d.	n.d.		n.d.		n.d.		17.0	Ab	11.6	Aa	18.2	Aa	n.d.	n.d.		114.2	Ab	n.d.		40.3	Bab	n.d.		25.5	Ba
	10			n.d.		11.1	Ab	n.d.		11.9	Ab	n.d.		11.0	Aa		n.d.		112.9	Ab	n.d.		47.4	Ba	n.d.		25.0	Ba
	24			n.d.		58.7	Aa	n.d.		37.2	Ba	n.d.		19.7	Ca		n.d.		160.6	Aa	14.7	Ca	53.3	Ba	n.d.		21.3	Ca
	36			n.d.		<10		n.d.		22.8	Aab	n.d.		14.8	Aa		34.8	Ba	79.9	Ac	17.6	Ba	24.5	Bb	14.0	Ba	27.3	Ba
1-Pentanol	0	1375	12.3	13.2	Aa	15.4	Aa	n.d.		16.3	Aa	9.6	Ab	n.d.		27.2	58.9	Ab	38.1	Ba	16.9	Ca	30.2	BCa	15.4	Ca	18.6	Ca
	10			10.2	Aa	11.2	Aa	10.2	Aa	10.3	Aa	n.d.		n.d.			32.0	Ac	22.7	ABb	15.5	Ba	n.d.		n.d.		15.0	BCab
	24			<10		<10		n.d.		<10		177.6	Aa	n.d.			13.8	Ad	26.3	Aab	n.d.		n.d.		n.d.		n.d.	
	36			22.1	Aa	15.1	Aa	n.d.		18.9	Aa	n.d.		n.d.			85.7	Aa	39.8	Ba	n.d.		n.d.		n.d.		14.8	Cab
1-Hexanol	0	1480	37.1	29.9	ABb	31.9	ABa	11.7	Cb	36.9	Aa	16.0	BCb	26.1	ABCb	64.0	112.2	Ab	127.6	Aa	26.5	Bb	52.9	Ba	33.1	Ba	47.6	Ba
	10			19.2	Bbc	21.2	Bab	15.5	Bb	19.5	Bb	n.d.		46.9	Aa		81.7	Ab	89.8	Ab	41.6	Bb	40.0	Ba	n.d.		38.7	Ba
	24			12.1	Cc	11.2	Cb	10.2	Cb	12.4	Cb	271.7	Aa	40.4	Bab		35.1	Cc	117.9	Aab	29.3	Cb	46.3	BCa	n.d.		70.5	Ba
	36			50.6	Ba	n.d.		571.1	Aa	n.d.		16.7	Cb	n.d.			198.9	Aa	101.3	Bab	78.7	Ba	71.9	BCa	n.d.		40.9	Ca
2-Methyl-1-butanol	0	1329	24.8	34.7	Aa	37.3	Aa	n.d.		42.7	Aa	19.2	Ab	16.4	Aa	n.d.	13.8	Aa	12.2	Aa	23.5	Ac	n.d.		25.5	Aa	26.5	Aa
	10			51.0	Aa	56.4	Aa	n.d.		51.2	Aa	n.d.		n.d.			n.d.		n.d.		134.1	Aa	13.7	Bb	n.d.		n.d.	
	24			n.d.		n.d.		n.d.		n.d.		103.6	Aa	n.d.			n.d.		n.d.		67.2	Ab	47.3	Ab	n.d.		n.d.	
	36			n.d.		n.d.		149.1	Aa	n.d.		n.d.		n.d.			n.d.		n.d.		80.1	Bb	158.5	Aa	n.d.		n.d.	
Z-3-Hexen-1-ol	0	1513	n.d.	<10		<10		n.d.		<10		n.d.		n.d.		n.d.	<10		137.6	Ac	n.d.		<10		n.d.		n.d.	
	10			n.d.		n.d.		n.d.		n.d.		35.9	Ab	n.d.			n.d.		121.2	Ac	n.d.		n.d.		n.d.		n.d.	
	24			n.d.		n.d.		n.d.		n.d.		199.9	Aa	n.d.			<10	Ba	341.8	Aa	n.d.		25.4	Ba	n.d.		n.d.	
	36			<10		19.3	Aa	n.d.		23.3	Aa	n.d.		n.d.			30.2	Ba	202.9	Ab	n.d.		n.d.		n.d.		n.d.	
2-Ethyl-1-hexanol	0	1619	134.2	526.6	Ab	638.4	Aa	97.4	Ab	646.7	Aa	134.1	Aa	361.1	Aa	583.9	1361.6	Ab	769.4	Ba	n.d.	Bab	583.3	Ba	508.7	Ba	532.4	Ba
	10			163.5	Ab	180.5	Aa	465.5	Ab	165.9	Aa	292.3	Aa	119.5	Aa		1032.0	Ac	616.2	BCa	804.7	ABa	457.8	Ca	467.8	Ca	399.6	Ca
	24			125.7	Ab	115.9	Aa	82.2	Ab	129.1	Aa	508.4	Aa	417.7	Aa		448.5	BCd	633.9	ABa	378.4	BCb	323.8	Ca	736.4	Aa	423.3	BCa
	36			1308.3	Aa	460.2	Ba	1453.9	Aa	572.3	Ba	126.4	Ba	99.8	Ba		1721.6	Aa	654.0	Ba	576.9	Bab	527.5	Ba	511.1	Ba	508.8	Ba
Benzylalcohol	0	1869	99.3	24.2	Ba	34.4	Bab	40.0	Bab	130.9	Aa	58.7	Ba	57.9	Ba	36.5	40.0	ABbc	53.5	Ab	24.3	Bb	43.3	ABa	46.9	Aa	39.0	ABa
	10			73.3	Aa	55.4	Aab	23.7	Ab	44.2	Ab	36.4	Aa	56.4	Aa		59.4	Ab	59.5	Ab	44.8	ABb	40.4	ABa	47.4	ABa	30.8	Ba
	24			53.8	Aa	99.3	Aa	58.3	Aab	53.1	Ab	48.8	Aa	50.6	Aa		32.5	CDc	86.5	Ba	122.5	Aa	25.8	Da	50.3	Ca	40.1	CDa
	36			43.9	Aa	29.9	Ab	93.2	Aa	45.8	Ab	56.3	Aa	84.4	Aa		81.6	Aa	43.5	Bb	33.9	Bb	31.3	Ba	47.2	Ba	43.3	Ba

Means within the same hours at 20º C followed by the same capital letters and means within the same days -0.5ºC+days at20ºC followed the same small letters are not significantly different at $p \leq 0.05$ (LSD test).

Figure.1. PCA biplot of volatile compounds emitted from 'Big Top®' nectarine fruit, standard quality parameters and sensory evaluation**.**



Sample names and quality and sensory variables were coded as described in the Materials and Methods section; the numbers correspond to the volatile compounds listed in Tables 3-5.

Figure.2. PCA biplot of volatile compounds emitted by 'Early Rich' peach fruit, standard quality parameters and sensory evaluation**.**

Sample names, quality and sensory variables were coded as described in the Materials and Methods section; the numbers correspond to the volatile compounds listed in Tables 3-5.

5. Discusión general

Discusión general:

La discusión de los resultados presentados en los anteriores puntos se ha estructurado diferenciando cada estudio realizado:

5.1 Estudio 1: Caracterización varietal de melocotón y nectarina en cosecha.

Con el fin de aumentar la satisfacción del consumidor, es importante definir la calidad sensorial de los melocotones y nectarinas frescas. En ella el sabor es clave y depende de un complejo equilibrio entre ácidos, azúcares y compuestos aromáticos volátiles que evolucionan a lo largo de la maduración en campo. Por lo tanto es necesario un conocimiento del grado de maduración del fruto alcanzado en recolección, para ayudar a los productores a tomar decisiones en relación con las prácticas de manipulación de la fruta y ofrecer al consumidor frutos de óptima calidad sensorial. La información recopilada en este estudio podría ser utilizada en el futuro para generar un modelo de predicción en el que se combinen parámetros de madurez que ayuden a la obtención de frutos con mayor calidad sensorial.

Los compuestos volátiles emitidos por los frutos de hueso en este estudio, resultó variable dependiendo de la variedad respecto a la composición de las diferentes familias orgánicas y sus concentraciones totales. De este modo se ratifica la hipótesis de que la fracción volátil y su concentración dependen de factores genéticos como han especificado estudios previos por diversos autores en variedades de melocotón y nectarina (Lavilla y col., 2002; Aubert y col., 2003; Wang y col., 2009). A pesar de ello 16 compuestos orgánicos son comunes en todas las variedades de melocotones y nectarinas estudiadas: acetatos de propilo, butilo y hexilo, 2-metilpropanoato de 2-metillbutilo y acetatos de 2-metilpropilo y 2-methylbutilo, 1-hexanol, 2-etil-1-hexanol, benzaldehído, hexanal, 2-etil-1-hexenal, ácido acético, ácido benzoico, 2,3-butanodiona, acetofenona y naftaleno.

En cuanto a los parámetros físico-químicos evaluados, un descenso en la firmeza se detectó después de su permanencia a 20 ºC en las variedades: `August Red®´, `Elegant Lady®´, `Honey Royale$^{cov}$´, ‘Nectagala$^{cov}$’. `Nectalady^{cov}´ y `Venus®´. Durante el periodo de maduración a 20 ºC, el melocotón `Early Rich®´ y las nectarinas `Big Top®´ y `Honey Blaze^{cov}´ fueron las variedades que presentaron mayores valores de firmeza, obteniendo valores entre 42,4 y 47,1 N. Estos valores obtenidos de firmeza permiten que estos frutos puedan ser almacenados en frío según los baremos recomendado por Lurie y Crisosto, 2005. Respecto a la acidez titulable, el color y el contenido en sólidos solubles no se detectó influencia significativa del periodo de permanencia a 20 ºC. Estos últimos resultados están en concordancia con trabajos realizados por Luchinguer y Reginato en 2001.

La mayor aceptación por parte de los consumidores estuvo influenciada por el contenido en sólidos solubles y la concentración de: δ-decalactona, γ-dodecalactona, 1-pentanol, octanoato de butilo, acetato de pentilo y hexanoato de 2-metilpropilo. Estos resultados confirman la importancia del contenido en sólidos solubles indicado en otros trabajos por Iglesias y Echeverría (2009) y el peso de determinados compuestos volátiles demostrado en otras variedades de melocotón por Ortíz y col., 2009.

5.2 Estudio 2: Efecto del sistema de conservación frigorífica en atmósfera normal.

Se evaluaron diferentes periodos hasta 40 días de almacenamiento bajo la misma condición frigorífica (temperatura de -0.5 ºC) y atmosférica (20.9 kPa O_2 : 0.03 kPa CO_2) para melocotones y nectarinas por separado. Se evaluó la influencia sobre la emisión de compuestos volátiles, los parámetros físico-químicos en el día de salida de cámara en frío y la aceptación sensorial por los consumidores pasados tres días (en cámara de maduración a 20 ºC) posteriores al almacenamiento en frío.

Exceptuando la variedad 'Early Rich®', las demás variedades estudiadas perdieron firmeza durante los diferentes periodos de frío comparando con los valores obtenidos en cosecha. En cuanto al contenido en sólidos solubles, generalmente el periodo de 3 días a 20 ºC no ejerció ningún efecto, sólo un descenso en las variedades 'Early Rich®' y 'Elegant Lady®' tras 40 días de conservación frigorífica. Del mismo modo bajo condiciones de frío, Raffo y col., 2008 detectaron similares comportamientos.

Tanto 'Early Rich®' como 'Elegant Lady®' (ambas variedades consideradas como ácidas) descendieron su valores en acidez titulable durante los días de maduración a 20 ºC, pero no se produjeron diferencias significativas en las variedades consideradas como dulces ('Royal Glory®' y 'Sweet Dream^{cov}'). Estos descensos de la acidez podrían ser debidos a la oxidación de determinados ácidos orgánicos (Crisosto y Crisosto en 2005).

Dado que el aroma es un atributo importante en cuanto a la percepción del sabor, y por tanto que puede influir en la aceptación por los consumidores, se prestó especial atención a la concentración de compuestos volátiles después de la conservación frigorífica a -0.5 ºC. 'Early Rich®' fue la variedad más apreciada por los consumidores, tras 3 días a 20 ºC después de cosecha y presentó altas emisiones de determinados compuestos volátiles tales como: γ-hexalactona, γ-octalactona, δ-decalactona, γ-dodecalactona, acetato de propilo, acetato de 2-metil-propilo, 2-metil-butanoato de etilo, 2-metil-butanoato de hexilo, hexanoato de butilo, hexanoato de pentilo, hexil hexanoato , octanoato de etilo, octanoato de butilo, ácido acético, 1-hexanol y (Z)-3-hexen-1-ol. Del mismo modo, frutos almacenados durante 40 días para la variedad 'Royal Glory®' fueron los más apreciados por parte de el panel de consumidores; presentando elevadas concentraciones de 2-metil-propilo, acetatos de butilo y de pentilo, 2-etil-1-hexanal, 2,3-butanodiona, eucaliptol, ácido benzoico, 1-pentanol y 1-hexanol. Así mismo, para 'Elegant Lady®', frutos almacenados durante 10 días fueron más valorados, con

elevados contenidos en: acetato de etilo y hexilo, ɣ-hexalactona, ɣ -octalactona, 2-etil-1-hexanal, 2,3-butanodiona, ácido decanoico, 1-pentanol, 1-hexanol, y (Z)-3-hexen-1-ol. Finalmente, frutos de la variedad 'Sweet Dream^{cov}' almacenados durante 10 días en frío, fueron los más apreciados por los consumidores, con elevados contenidos en acetatos de etilo y pentilo, propanoato de butilo, 2-metilbutanoato de butilo, 2,3-butanodiona, acetofenona, ácido acético y (Z)-3-hexen-1-ol.

Respecto a las 6 nectarinas evaluadas ('Big Top$^{®}$', 'Honey Blaze^{cov}', 'Honey Royale^{cov}', 'Venus$^{®}$', 'August Red$^{®}$' and 'Nectagala^{cov}') después de cada período de almacenamiento en frío, la pérdida de firmeza durante la vida útil a 20 ºC fue uno de los efectos más importantes encontrados, la única variedad que mantuvo firmeza a lo largo de los diferentes periodos de conservación en frío fue 'Nectagala^{cov}'. Inmediatamente después de la salida de cámara frigorífica, todas las variedades presentan una firmeza bastante estable, a excepción de 'Honey Royale^{cov}' variedad que mostró un descenso significativo respecto a la entrada en cámara. Después de un periodo de maduración de tres días a 20 º C, la firmeza osciló entre valores 7,0 N en la variedad 'Venus$^{®}$' y 32,1 N para 'Big Top$^{®}$'. Este resultado encontrado para la variedad 'Big Top$^{®}$' coincide con resultados previos (Kader y col., 1992 y Ghiani y col., 2011).

Diferencias entre variedades en las emisiones de volátiles se encuentran tanto antes como después de almacenamiento en frío. Los compuestos volátiles totales emitidos por 'Venus$^{®}$' en recolección fueron tres veces mayores a los correspondientes encontrados en las variedades 'Big Top$^{®}$', 'Honey Royale^{cov}', 'August Red$^{®}$' y 'Nectagala^{cov}'. Después de 10 días de almacenamiento en frío y tres días a 20 º C, los compuestos volátiles totales de 'Honey Royale^{cov}' fueron mayores que las concentraciones totales obtenidas en 'Big Top$^{®}$','Venus$^{®}$'

y‘August Red®’ y aproximadamente cuatro veces mayor que los obtenidos en ‘Nectagala^{cov}’ y ‘Honey Blaze^{cov}’.

Con relación a algunos compuestos volátiles individuales, cabe señalar que la máxima producción de los mismos tiene lugar en períodos distintos, en función de cada variedad. Así mismo, podemos señalar que los criterios cuantitativos no aseguran el aporte de compuestos volátiles más importantes a la aceptación del consumidor. En nuestro estudio, las nectarinas más aceptadas por los consumidores fueron influenciadas por concentraciones de octanoato de etilo, hexanoato de hexilo, γ-hexalactona, 2-metilbutanoato de hexilo, 2-metilpropanoato de 2-metilbutilo, acetato de 2-metilbutilo, 1-hexanol, alcohol benzílico y 2-etil-1-hexanol. Sin embargo, estos compuestos volátiles no son los más importantes cuantitativamente en la fracción volátil de todas las variedades estudiadas.

Con respecto a la aceptación por parte de los consumidores, en cosecha porcentajes del 70%, se asociaron con las variedades dulces ‘Honey Royale^{cov}’, ‘Honey Blaze^{cov}’, ‘Big Top®’ y ‘Nectagala^{cov}’. En contraste, las variedades ‘Venus®’ y ‘August Red®’ sólo fueron aceptadas por el 50% de los consumidores. Las seis variedades mostraron diferencias en la aceptación del consumidor a lo largo de los diferentes periodos de almacenamiento en frío. ‘Big Top®’ fue la variedad que mejor aceptación presentó para largos periodos de conservación en frío, mientras que en ‘Venus®’ la aceptación se mantuvo con menos variación durante los periodos de conservación estudiados. El porcentaje de aceptación por el consumidor para la variedad ‘Honey Royale^{cov}’ disminuyó después de 10 días de conservación en frío. Para ‘Nectagala^{cov}’ y ‘August Red®’, estos porcentajes aumentaron cuando los frutos procedían de 10 y 20 días, pero se redujeron para los frutos conservados 40 días.

5.3 Estudio 3: Efecto del sistema de conservación frigorífica en atmósfera controlada.

El uso de atmósferas controladas (AC), especialmente concentraciones elevadas de CO_2, es otra de las técnicas recomendadas en la conservación de la calidad global en melocotón y nectarina (Zhou et al., 2000, Girardi et al., 2005, Lurie y Crisosto, 2005, Murray et al., 2007). Esta conservación de la calidad del fruto se debe principalmente a una reducción de las pérdidas de peso y de firmeza, y a que se mantiene el color de fondo (Zhou et al., 2000, Girardi et al., 2005, Lurie y Crisosto, 2005). En los últimos años, se ha demostrado que unos niveles de CO_2 altos ayudan a mejorar el control de algunos desordenes fisiológicos (DF) que se producen especialmente en variedades sensibles. Así, una atmósfera 10% O_2 + 10% CO_2 resultó eficaz en prevenir el desarrollo de DF en los cultivares de nectarina 'Fantasía', 'Flavortop' y 'Flamekist' (Dong et al., 2001). En el caso de melocotones y nectarinas producidos en Chile, la atmósfera recomendada es de 6% O_2 + 17 % CO_2 (Retamales et al., 1992; Streif et al., 1992). De los estudios citados se desprende que la eficacia de las AC depende de múltiples factores, como el cultivar, factores pre-cosecha, tamaño del fruto, temperatura y periodo de almacenamiento, de transporte y de comercialización (Crisosto et al., 1997, 1999a y 1999b). En general, la vida poscosecha de un producto basada en la calidad visual, frecuentemente es más extensa que la vida poscosecha basada en el mantenimiento del buen aroma y sabor (Kader, 2008). Por ello, deben conjugarse concentración de gases de la atmósfera y tiempo de almacenamiento a fin de conseguir fruta de calidad. En este sentido, Ortiz et al. (2009), encontraron una mayor aceptación en melocotones 'Rich Lady' almacenados en AC (3kPa O_2 y 10kPa CO_2) durante 15 días frente a aquéllos almacenados en refrigeración y atmósfera normal, debido principalmente a un adecuado balance de emisión de compuestos volátiles y una relación elevada de sólidos solubles totales/acidez.

En esta tesis se estudió el efecto de algunos de los factores indicados (variedad, atmósfera gaseosa, periodo de conservación en frío y periodo de permanencia a 20 ºC) sobre los parámetros físico-químicos, la emisión de compuestos volátiles y algunos atributos sensoriales de las variedades 'Early Rich' y 'Big Top'. En relación con los parámetros de calidad, la firmeza es el que se ve más afectado por la conservación en AC, especialmente en la atmósfera (6 % O_2 y 17 % de CO_2). Dicha atmósfera produjo un mejor mantenimiento de la firmeza, principalmente en frutos conservados en más largos periodos de conservación. Otros autores (Girardi et al., 2005; Giehl, 2008) también han encontrado una menor degradación de la pulpa en frutos conservados en AC respecto a aquellos conservados en atmósfera normal. Respecto a la influencia de la AC en los atributos sensoriales de las variedades estudiadas, los resultados mostraron una mayor firmeza y crocanticidad en los frutos conservados en AC (6 % O_2 y 17 % de CO_2), aunque estos resultados dependieron de la variedad y del periodo de conservación. Los frutos conservados en AIR y AC (2 % O_2 y 5 % de CO_2), concretamente para la variedad 'Big Top®' y 'Sweet Dream^{cov}', fueron percibidos como más dulces, jugosos y con mayor intensidad de sabor. Estos últimos resultados se contradicen con los resultados proporcionados por Lurie (1992) y Zhou et al. (2000) quienes determinaron una mayor jugosidad en frutos conservados en AC con altos niveles de CO_2. Acerca de los compuestos volátiles emitidos, se ha observado que algunos de estos tienen una importante influencia en la percepción de sabor a melocotón y/o nectarina. Así, han mostrado una influencia positiva el 2-metilbutanoato de etilo, acetato de 2-metilbutilo, acetato de hexilo, pentil hexanoato, 2-etil-1-hexanal, ácido decanoico y algunas lactonas como la γ-octalactona, δ-decalactona y and γ-dodecalactona. La importancia de algunos de estos compuestos también ha sido expuesta por Rizzolo et al. (2006) y Ortiz et al. (2009).

5.4 Estudio 4: Efecto del sistema de pre-acondicionado previo a la conservación frigorífica.

En el momento de la cosecha, frecuentemente los frutos no poseen el grado de madurez adecuado para el desarrollo de una calidad sensorial que proporcione en el momento de su consumo plena satisfacción al consumidor. Esto es debido a que son recolectados en un menor grado de madurez para poder ser conservados en frío. El pre-acondicionado es una alternativa para conseguir que dichos frutos alcancen una mayor madurez de consumo. Sus efectos en los parámetros de madurez, la composición volátil y los atributos sensoriales del melocotón 'Early Rich®' y nectarina 'Big Top®' fueron evaluados.Los resultados indican un aumento en la concentración de los principales compuestos que contribuyen al sabor de melocotón y nectarina. La eficacia del tratamiento depende de la variedad y del periodo de conservación. Respecto a la producción de compuestos volátiles 36 horas de pre-acondicionado seguido de 20 días de almacenamiento en frío, proporcionaron frutos de ambas variedades con las mayores concentraciones totales en compuestos volátiles con olor activo. En este notable incremento, fueron fundamentales los aportes de la familia de los ésteres volátiles, siendo en general la familia predominante en ambas variedades. El efecto favorable del pre-acondicionado también ha sido indicado en melocotón con respecto a su grado de aceptación por los consumidores (Infante y col., 2009). No hay precedentes de estudios que relacionen los efectos sobre los parámetros de madurez, composición volátil y atributos sensoriales de melocotón y nectarina.

5.5 Bibliografía

Aubert, C., Gunata, Z., Ambid, C., Baumes, R. Changes in physicochemical characteristics and volatile constituents of yellow-and white-fleshed nectarines during maturation and artificial ripening. *Journal of Agricultural and Food Chemistry.* **2003.** 51, 3083–3091.

Crisosto, C.H., Johnson, R.S., DeJong, T., Day, K.R. Orchard factors affecting postharvest stone fruit quality. *HortScience*. **1997.** 32, 820–823.

Crisosto, C.H., Mitchell, F.G., Ju, Z.,. Susceptibility to chilling injury of peach, nectarine, and plum cultivars grownin California. *HortScience.* **1999a** *34*, 1116–1118.

Crisosto, C.H., Garner, D., Cid, L., Day, K.R., Peach size affects storage, market life. *California Agric*. **1999b.** 53, 33–36.

Crisosto, C.H., Crisosto, G.M. Relationship between ripe soluble solids concentration (RSSC) and consumer acceptance of high and low acid melting flesh peach and nectarine (Prunus persica (L.) Batsch) cultivars. *Postharvest Biology and Technology*. **2005.** 38, 239–246.

Dong, L., Zhou, H.W., Sonego, L., Lers, A., Lurie, S. Ethylene involvement in the cold storage disorder of 'Flavortop' nectarine. *Postharvest Biol. Technol*. **2001.** 23:105-115.

Ghiani, A., Negrini, N., Morgutti, S., Baldin, F., Nocito, F., Spinardi, A., Mignani, L., Bassi, D., Cocucci, M. Melting of `Big Top´ nectarine fruit: some physiologycal, biochemical, and molecular aspects. *Journal of American Society. Horticultual. Science.***2011.***136,* 61–68.

Giehl, R.F.H. et al.. CA affects juiciness in peaches due to an earlier post-storage ethylene production. *Acta Horticulturae*. **2008.** 796, 185-189.

Girardi, C.L., Corrent, A.R., Lucchetta, L., Zanuzo, M.R., Costa, T.S., Brackmann, A., Twyman, R.M., Nora, L., Silva, J.A., Rombaldi, C.V. Effect of ethylene, intermittent warming and controlled atmosphere on postharvest quality and the occurrence of woolliness in peach (Prunus persica cv. Chiripá) during cold storage. *Postharvest Biology and Technology*. **2005**. 38, 25-33.

Horvat, R.J., Chapman, G.W. Comparison of volatile compounds from peach fruit and leaves (Cv. Monroe) during maturation. *Journal of Agriculture and FoodChemistry*.**1990.** 38, 1442–1444.

Horvat, R.J., Chapman, G.W. Jr., Robertson, J.A., Meredith, FL, Scorza, R., Callahan, A.M., Morgens, P. Comparison of the volatile compounds from several commercial peach cultivars. *Journal of Agriculture and Food Chemistry.***1990.** 38, 234–237.

Infante, R., Meneses, Cl., Crisosto, C.H. Preconditioning treatment maintains taste characteristic perception of ripe 'Setember Sun' peach following cold storage. *Int. Journal of Food Science Technology.***2009.** 44, 1011-1016.

Kader, A.A. *Postharvest Technology of Horticultural Crops*. University of California Division of Agri. and Natural Resources, 2nd ed, **1992.**

Kader, A.A., Perspective flavor quality of fruits and vegetables. *Journal of Science Food Agriculture*. **2008.** 88:1863-1868.

Lavilla, T., Recasens, I., López, M.L., Puy, J. Multivariate analysis of maturity stages, including quality and aroma, in 'Royal Glory' peaches and 'Big Top' nectarines. *Journal of the Science of Food and Agriculture.***2002.** 82 (15), 1842–1849.

Luchsinger, L.E., Reginato, G. Changes in quality and maturity of late season nectarines (cvs. July Red and August Red) during maturation and ripening. *Acta Hort*. **2001.** 553:111-115.

Lurie, S., Crisosto, C. Chilling injury in peach and nectarine. *Postharvest Biology and Technology.***2005.** 37:195–208.

Murray, R., Lucangeli, C., Polenta, G., Budde, C. Combined pre-storage heat treatment and controlled atmosphere storage reduced internal breakdown of 'Flavorcrest' peach. *Postharvest Biology and Technology*. **2007.** 44:116 – 121.

Ortiz, A., Echeverria, G., Graell, J., López, L., Lara, l. Overall quality of 'Rich Lady' peach fruit after air- or CA storage. The importance of volatile emission. *LWT-Food Science and Technology*. **2009.** 42(9): 1520-1529.

Raffo, A., Nardo, N., Tabilio, M.R., Paoletti, F. Effects of cold storage on aroma compounds on white- and yellow-fleshed peaches. *Europe Food Research Technology.* **2008.** 226, 1503–1512.

Retamales, J., Cooper, T., Streif, J., Kama, J.C. Preventing cold storage disorders in nectarines. *Journal of Horticultural Science.***1992.** 67:619–626.

Rizzolo, A., Eccher Zerbini, P., Grassi, M., Cambiaghi, P., Bianchi, G. Effect of 1-Methylcyclopropene on Aroma Compounds in "Big Top" Nectarines After Shelf Life.*Journal of Food Quality.***2006.** *29***,** 184–202.

Streif, J., Retamales, J., Cooper, T., Kania, J.C.. Storage of nectarines in CA and high CO_2 concentrations to reduce physiological disorders. *Gartenbauwissenschaft.***1992.** 57:166–172.

Wang, Y., Yang, C., Li, S., Yang, L., Wang, Y., Zhao, J., Jiang, Q. Volatile characteristics of 50 peaches and nectarines evaluated by HP-SPME with GC-MS. *Food Chemistry.* **2009.**116, nº 1, 356–364.

Zhang, B., Shen, J. Y., Wei, W. W., Xi, W. P., Xu, C. J., Ferguson, I., Chen, K. Expression of Genes Associated with Aroma Formation Derived from the Fatty Acid Pathway during Peach Fruit Ripening. *Journal of Agricultural and Food Chemistry.***2010.** 58, 6157–6165.

Zhou, H.W., Lurie, S., Lers, A., Khatchitski, A., Sonego, L., Ben Arie, R. Delayed storage and controlled atmosphere storage of nectarines: two strategies to prevent woolliness. *Postharvest Bioogy and Technology*. **2000.** 18, 133–141.

6. Conclusiones

A continuación se recogen las conclusiones que se pueden deducir de los resultados obtenidos en los diversos estudios llevados a cabo en la presente Tesis:

- En el momento de las recolección, las variedades de melocotón y nectarina más aceptadas por el panel de consumidores presentarón elevados contenido en solidos solubles y altas emisiones de δ-decalactona, γ-dodecalactona, 1-pentanol, octanoato de butilo, acetato de pentilo, hexanoato de 2-metilpropilo y octanoato de etilo.

- El potencial de conservación frigorífica de las 4 variedades de melocotón y 6 de nectarina estudiadas es dependiente de la variedad. Así, las variedades 'Elegant Lady', 'Sweet Dream'y 'Nectagala' fueron más aceptadas por los consumidores tras 10 días a -0,5 ºC. Las variedades 'Early Rich' y 'Big Top' resultaron más aceptadas después de 20 días y las variedades 'Royal Glory' y 'Honey Blaze' a los 40 días.

- En las cuatro variedades de melocotón conservadas a -0,5 ºC la mayor aceptación por parte de los consumidores estuvo asociada con una mayor concentración en sólidos solubles y mayores emisiones en γ-hexalactona y (Z)-3-hexen-1-ol.

- En las variedades de nectarina la mayor aceptación estuvo relacionada con mayores valores de firmeza y con los siguientes compuestos volátiles: octanoato de etilo, hexanoato de hexilo, γ-hexalactona, 2-metilbutanoato de hexilo, 2-metilpropanoato de 2-metilbutilo, acetato de 2-metilbutilo, 1-hexanol, alcohol benzílico y 2-etil-1-hexanol.

- En los frutos conservados en las distintas atmósferas controladas, la percepción de sabor estuvo principalmente relacionada con la percepción de dulzor y jugosidad, así como con la emisión de 2-metilbutanoato de etilo, acetato de 2-metilbutilo, acetato de

hexilo, acetoto de pentilo, 2-etil-1-hexanal, ácido decanoico, γ-octalactona, δ-decalactonay γ-dodecalactona.

- La atmósfera controlada definida con una concentración de oxígeno del 3 % y de dióxido de carbono del 10 % fue la que proporcionó un mejor equilibrio entre los parámetros de calidad estándar, la emisión de compuestos volátiles y los atributos sensoriales principalmente el sabor en las variedades 'Big Top', 'Venus', 'August Red', 'Nectagala', 'Honey Royale' y 'Honey Blaze'.

- Las nectarinas 'Big Top' nectarines pre-acondicionadas 10 horas a 20 ºC seguidas de 20 días de conservación frigorífica a -0,5 ºC estuvieron asociadas con mayor percepción del sabor, jugosidad y dulzor, alto contenido en sólidos solubles y mayores concentraciones de propanoato de butilo, 2-metilpropanoato de 2-metilbutilo y 2-metil-1-butanol que los frutos control. Los melocotones 'Early Rich' pre-acondicionados 36 horas a 20 ºC seguidos de 20 días de conservación frigorífica a -0,5 ºC estuvieron asociados con mayor percepción del dulzor y mayores concentraciones de acetato de propilo, acetato de pentilo y 2-metil-1-butanol que los frutos control.