Changes in biochemical compounds in flesh and peel from Prunus persica fruits grown in Tunisia during two maturation stages.

Changes in biochemical compounds in Flesh and Peel from *Prunus persica* Fruits grown in Tunisia during two Maturation Stages

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Abstract

Plants can synthesize tens to hundreds of thousands of primary and secondary metabolites with diverse biological properties and functions. Fatty acids (FA), phenolic compounds (PC) and volatile compounds (VC) of flesh and peel from three *Prunus persica* cultivars were evaluated at the Regional Centre of Agricultural Research - Experimental Farm (Sidi Bouzid, Tunisia) during two maturation stages. Palmitic, oleic and linoleic acids are the most abundant FA in *Prunus persica* cultivars. A genetic effect on FA composition was observed throughout the two sampling periods. Peel was rich in oleic acid with the highest content (31.3% on total FA) in 'O'Henry' cultivar at the commercial ripening date; flesh was rich in linoleic acid with the highest content (44.7% on total FA) in 'Sweet Cap' cultivar at the full ripening date. The monounsaturated/polyunsaturated fatty acids ratios were higher in the commercial ripe than in the full ripe fruits. The analysis of the composition of the VC led to the characterization of 98 different compounds, showing a very high variability among the cultivars. The full ripe fruit (peel and flesh) exhibited the highest total number of terpenoids. Commercial ripe peels were richest in the percentage of hydrocarbons. Comparing cultivars, 'Sweet Cap' cultivar showed the lowest contents of alcohols in peel and flesh of full ripe fruit but highest in peel of commercial ripe fruit, and lowest content of aldehydes in peel and flesh of commercial ripe fruit but highest in peel of ripe ones and the highest ones of lactones. Among PC, the highest contents were observed for *o*-diphenols and the values showed varietal influence. Total phenols contents decreased in all cultivars studied ($p<0.01$) during ripening process in both peel and flesh tissues. In conclusion, to achieve better FA composition and greater VC and PC production of the peach fruit, *Prunus persica* cultivars should be harvested at the commercial ripening date.

Keywords: *Prunus persica*, flesh, peel, fatty acids, volatile compounds, phenols, maturation.

1. Introduction

Peaches and nectarines [*Prunus persica* (L.) Batsch] belonging to Rosaceae family are tasteful, sweet, and juicy drupe fruits. The genetic diversity of peach is highest in China, with 495 recognized cultivars, indicating that peach has a long history there dating back to 1100 BC (Huang et al., 2008). Peach is grown in all continents except Antarctica, and the world peach production has increased steadily in recent years (Jiang and Song, 2009). It is the fourth more important fruit crop in the world and the second in Europe. The world production of peach and nectarines in 2013 was 21638953.00 tonnes, with 1538174.00 Ha cultivated areas (FAOstat, 2013).

In Tunisia, peaches have an important place in the fruit trees sector; this culture has been expanding since the eighties due to the introduction of new varieties and it has increased in areas equipped with modern irrigation techniques. Therefore, production and exports have significantly increased in recent years. In fact, the evolution of planted areas shows a significant upward trend during the last two decades, where peach and nectarine fruit farming occupies a total area of 1,6 million hectares in Tunisia, with an annual production quantity of 127000.000 tonnes in 2013 (FAOstat, 2013). From the geographical point of view, over 54% of the areas planted with this crop are located in the north of Tunisia, 39% in the center and only 7% in the south (Gifruits, 2015).

Peach cultivars are commonly divided into freestone and clingstone, in reference to the adherence of flesh (mesocarp) to the stone (endocarp or pit). Both free- and clingstone peaches can be either white- or yellow-fleshed, depending on the color of the mesocarp (Scorza, 2004). White-fleshed peaches are mostly very sweet, with low acid content and with distinct flavor because of which are predominantly used as fresh fruits. In contrast, yellow-

84 fleshed cultivars have lower sugars, higher organic acids, and much higher carotenoid
85 content (Davidović et al., 2013).
86 Peach is also the most dynamic fruit species in terms of new cultivars released per year
87 (Byrne, 2002). Sometimes, these cultivars show an uncertain agronomic, and so qualitative,
88 performance when they are grown under climatic conditions that are different from those
89 where they were originally developed (Berra et al., 2011).
90 Peaches are a popular summer fruit and there has been an increasing interest in their
91 nutritional value (Wolfe et al., 2008) due to their antioxidant potential attributed to several
92 compounds, which vary widely in chemical structure and function in plant tissues, grouped
93 in vitamins (C and E), carotenoids, phenolic and volatile compounds (Humphrey and Beale,
94 2006; Jaganath and Crozier, 2009).
95 Lipid composition of peach fruit has also recently received increasing attention in relation
96 to the fatty acid profile (rich in essential fatty acids as linoleic, linolenic, and arachidic acids)
97 because of its role in preventing cardiovascular disease and in the alleviation of other health
98 problems by the reduction of both total and HDL cholesterol (Duan et al., 2013). The fatty
99 acid compositions associate closely with peach fruit developing and ripening (Duan et al.,
100 2013; Wu et al., 2001).
101 Peach fruit volatiles have been extensively studied leading to the identification of more than
102 one hundred compounds (Aubert and Milhet, 2007; Wang et al., 2009). The most abundant
103 components are C6 aldehydes and alcohols (*n*-hexanal, *(E)*-2-hexenal, *n*-hexanol and *(E)*-2-
104 hexenol), together with lactones (mainly γ- and δ-decalactones but also γ-dodecalactone, γ-
105 octalactone and γ-jasmolactone), linalool, benzaldehyde, esters, terpenoids, C13
106 norisoprenoids (β-damascenone, β-ionone and 8,9-dehydrotheaspirone) and ketones (Horvat
107 and Chapman, 1990; Horvat et al., 1990; Jennings and Sevenants, 1964; Kakiuchi and
108 Ohmiya, 1991; Sevenants and Jennings, 1966; Zhang et al., 2011). The esters and lactones

provide fruity notes, and the C6 compounds contribute green sensory notes to the aroma of the ripening fruit (Zhang et al., 2011).

There are several pathways involved in volatile biosynthesis starting from fatty acids, amino acids, carotenoids, phenols and terpenoids. Once the basic skeletons are produced via these pathways, the diversity of volatiles is achieved via additional modification reactions such as acylation, methylation, oxidation/reduction and cyclic ring closure (El Hadi et al., 2013). In fact, the C6 aldehydes and alcohols are generated through the oxidation of linoleic and linolenic acids via the lipoxygenase (LOX) pathway (Bellincontro et al., 2005; Flamini, 2007; Ortiz et al., 2009; Schwab et al., 2008). LOX and hydroperoxide lyase (HPL) convert linoleic and linolenic acids to hexanal and hexenal, respectively, via 9- and 13-hydroperoxide isomers. The aldehydes can then be reduced to the corresponding C6 alcohols by alcohol dehydrogenase (ADH). The aroma esters are produced through alcohol acyltransferase (AAT) catalyzing the final linkage of an acyl moiety and an alcohol. Specific enzymes and genes involved in fatty-acid-derived lactone formation have not been characterized (Schwab et al., 2008).

Aroma and phenolic compounds are essential components of fruit quality (Jaganath and Crozier, 2009; Wang et al., 2009). Many factors affect volatile and phenolic composition of peach fruit, including the degree of maturity and ripening stages (Kakiuchi and Ohmiya, 1991; Lavilla et al., 2002; Scordino et al., 2012), environmental conditions, postharvest handling and storage conditions (Campbell and Padilla-Zakour, 2013; Ortiz et al., 2009; Raffo et al., 2008; Scattino et al., 2014; Tavarini et al., 2011; Yang et al., 2009; Zhang et al., 2011), the genetic makeup (Campbell and Padilla-Zakour, 2013; Horvat and Chapman, 1990; Wang et al., 2009) and the different parts of the fruit (Aubert and Milhet, 2007; Liu et al., 2015; Scordino et al., 2012). 'Early May Crest' is an interesting variety for its earliness. The fruit is average or semi small in size, but large if his strong precocity is considered,

round, resistant to handling and transport. The yellowish skin, is amply covered by red color brilliant and moderated on almost all surface. Flesh is yellow with red veins, closes, of good savor. 'Early May Crest' represents as a whole the best variety with yellow flesh compared to its precocity of maturation (in mid of June).

'O'Henry' variety is characterized by a large fruit, with good firmness and flavor. The freestone peaches have yellow skin highly coloured with red-blushed and yellow flesh streaked red with fine flavor. The tree is a very heavy producer and this high quality variety is late season harvest.

'Sweet Cap' or plate de chine variety is a very oblate to almost flat, small to medium, 25-60% pinkish-red over a cream-green ground color, white-fleshed, freestone peach ripening at the end of July. The flesh is soft, with a mildly sub acid taste. The tree is vigorous, spreading, and very productive, with medium susceptibility to bacterial spot. This freestone peach has an excellent flavor.

Therefore, the aim of this work was to examine the influence of maturing stage on fatty acids, volatile compounds and total phenolic compounds of the flesh and peel from three *Prunus persica* cultivars produced in Tunisia.

2. Experimental Procedures

1.1. Sampling and laboratory analyses

This study was carried out during the two summer seasons 2013-2014 in the Regional Centre of Agricultural Research Farm experimental orchard in the region of Sidi Bouzid, Center-West of Tunisia (35°2′0″N, 9°30′0″E; at 313 m a.s.l.). The peach orchard is located in a semi-arid bioclimatic region, with a mean annual rainfall of 251.8 mm (concentrated mainly from autumn to spring), a mean annual temperature varying from 12.5°C to 25.3°C and an average evapotranspiration (ETc.) of 1634.9 mm. The soil horizons present a silt-clay-loam texture.

Peaches (*Prunus persica* L. [Batsch]) of three different cultivars 'Early May Crest', 'Sweet Cap' and 'O'Henry' were grafted on the ‘Germen’ wild rootstock. Trees were planted in 2005 at a spacing of 4 m x 6 m. The three cultivars are completely different in shape, color, taste, maturation date, etc. 'Early May Crest': yellow melting peach, early maturing cultivar with a harvesting date at the first week of June; 'Sweet Cap': white nectarine, a seasonal variety whose maturity is at the beginning of August; 'O'Henry': yellow very firm melting peach, a late-ripening variety (in the mid of August). Trees were irrigated by a network drop-by-drop with two pipes per row (4 L h^{-1}). During the 2-year experimental period all the three cultivars were similarly fertilized with nitric acid, magnesium and potassium. In order to determine the adequate date of maturity for each variety studied, two harvest date were chosen for each cultivar. The first harvest date or commercial ripening is the date of beginning of ripening favoured by farmers as fruit harvested during this time are very resistant to marketing conditions (refrigeration, export, etc.). It was performed when the fruit was fully developed and almost the full degree of color had been attained but the flesh was firm and the fruit would stand ship- ping. The second harvest date or full ripening is the date of full ripening of fruits (from the point of view taste, color, etc.). Three replicates trees were made for each maturity stage.

Peach Fruit characteristics

Fruit size (fruit diameters) and composition are the most reliable indicators for fruit quality and contribute substantially to their economic value. The width (in mm perpendicular to the fruit suture) of each fruit were measured at harvest time using a caliper (Mitutoyo, UK) and fresh weight was determined using a precision balance. The percentage of moisture content was determined from fresh fruits which were dried in an oven to constant weight. Fruit flesh

184 firmness was measured on a partially peeled fruit, by a penetrometer with an 8-mm probe
185 (Model 327, FT, Italy).
186 To determine total soluble solids content (SSC; °Brix), the pulp from each fruit was crushed
187 and the intact juice was immediately measured by a digital refractometer (Atago-Palette,
188 101, PR,Tokyo, Japan). pH of the juice was measured by a pH meter (MP 220, Mettler
189 Toledo, Switzerland). Titratable acidity (TA) was determined by titration of 10 mL of juice
190 with 0.1 M NaOH to an endpoint of pH 8.2, and expressed as g malic acid 100 mL^{-1}. To
191 characterize the cultivars, two groups were established according to the TA value: (Iglesias
192 and Echeverría, 2009) sweet (<6 g of malic acid L^{-1}); nonsweet (>6 g of malic acid L^{-1}).
193 Conductivity was detrmined by a conductometer and expressed as mS/cm.
194
195 *1.2. Peach fatty acid composition.*
196 Once fruits were hand harvested, peel and flesh were separated within 24 h, lyophilised and
197 stored at -20°C until analysis. Lipids from lyophilized peels and fleshes were extracted as
198 reported previously (Folch et al., 1957). Glycerides were saponified with a solution of NaOH
199 in methanol and the methylation of free fatty acids was achieved using BF_3 (14%, w/v). After
200 addition of NaCl in water (1.5%, w/v) and heptane, samples were centrifuged and 1 mL of
201 supernate was added to 5 mL of heptane. Fatty acid methyl esters (FAME) were quantified
202 by gas chromatography (Shimadzu GC 2010 Plus; Shimadzu, Kyoto, Japan) equipped with
203 a flame-ionization detector, and a CP-Sil 88 capillary column (100 m × 0.25 mm ID, 0.20
204 μm film thickness; Varian Inc., Palo Alto, CA, USA). Injections were made in on-column
205 mode and the injection volume was 0.5 μL. The temperatures of the injector and the flame-
206 ionization detector were maintained at 250 and 280°C, respectively. The column temperature
207 was held at 45°C for 5 min, then raised 20°C/min up to 195°C and maintained for 65 min.
208 Peaks were identified by comparing retention times to pure standards. Quantification was

assessed using heptadecanoic acid (C17:0) as internal standard. The results are expressed and reported as percentages of total detected FA.

1.3. Volatile compound analyses

Solid Phase Micro-extraction (SPME) devices coated with polydimethylsiloxane (PDMS, 100 µm) were used to sampling the headspace of the different plant parts inserted into a 5ml glass septum vial and allowed to equilibrate for 30 min.

SPME sampling was performed using the same new fibre, preconditioned according to the manufacturer instructions, for all the analyses. Sampling was accomplished in an air-conditioned room (22±1°C) to guarantee a stable temperature. After the equilibration time, the fibre was exposed to the headspace for 30 min. Once sampling was finished, the fibre was withdrawn into the needle and transferred to the injection port of the GC and GC-MS system. All the SPME sampling and desorption conditions were identical for all the samples. Furthermore, blanks were performed before each first SPME extraction and randomly repeated during each series. Quantitative comparisons of relative peaks areas were performed between the same chemicals in the different samples and percentages were obtained by peak-area normalisation, without correction factors. GC–EIMS analyses were performed with a Varian (Palo Alto, CA) CP3800 gas chromatograph equipped with a DB-5 capillary column (30 m x 0.25 mm x 0.25 µm; Agilent, Santa Clara, CA) and a Varian Saturn 2000 ion trap mass detector. Analytical conditions were as follows: injector and transfer line temperatures were 250 and 240°C, respectively; oven temperature was programmed from 60 to 240°C at 3°C/min; carrier gas was

helium at 1 ml/min; splitless injector. The identification of the constituents was based on a comparison of the retention times with those of pure standards, comparing their linear retention indices (LRI) relative to a series of *n*-hydrocarbons, and on computer matching against commercial (NIST 98 and Adams) and homemade library mass spectra, built from pure substances, components of known peaches, and MS literature data (Adams, 1995; Davies, 1990; Jennings and Shibamoto, 1980; Masada, 1976; Stenhagen et al., 1974; Swigar and Silverstein, 1981).

1.4. Total phenols and o-diphenols

Briefly, 5 ml of a methanolic solution [methanol/water (80:20, v/v) were homogenized with 0.5 g of lyophilized sample, using an Ultra-Turrax T25 (IKA Labortechnik, Janke & Kunkel, Staufen, Germany), for 1 min at 15,000 x g and then centrifuged at 5,000 x g for 10 min at 4 °C; the extraction was repeated twice. The obtained supernatant was stored at -20°C for further analysis. Then, total phenols and *o*-diphenols were determined colorimetrically (Montedoro et al., 1992) and the results are expressed as mg hydroxytyrosol equivalents $100g^{-1}$ DW (dry weight).

1.5. Total flavonoids

A volume of 250µl of each methanolic extract or standard solution was added to 1.25 ml of dH_2O and 75µl of 5% $NaNO_2$ solution. After 6 min of incubation, a 150µl aliquot of a 10% $AlCl_3$ solution was added. Five minutes later, 0.5 ml of a 1M NaOH solution was added and then the total volume was made up to 2.5 ml with dH_2O. Following the complete mixing of the solution, the absorbance was recorded at 510 nm against a blank (Zhishen et al., 1999).

The flavonoid contents were calculated using a standard calibration curve prepared from catechin and the results were expressed as mg catechin equivalents $100g^{-1}$ DW.

1.6. Total flavonols

The content of flavonols was determined according to the methods proposed by Romani et al. (1996). In an eppendorff tube, methanolic extracts were diluted 1/10 with 10% ethanol. Then, to the obtained solution were added 250 µL of a solution of 0.1% HCl in 95% ethanol and 1 ml of 2% HCl. The solution was mixed and allowed to sit for approximately 15 min before reading the absorbance at 360 nm. The flavonols content was expressed as mg equivalents of quercetin $100g^{-1}$ DW.

1.7. Statistical analysis

All values are expressed as the means ± SD. Data were analysed using SPSS program, release 17.0 for Windows (SPSS, Chicago, IL, USA). Analysis of Variance (ANOVA) was used to determine differences among means. Duncan multiple comparison test was used to discriminate among mean values of the three *Prunus persica* cultivars. Comparison between any two groups of ripeness indexes or fleshes and peels was evaluated using Student-*t* test. Statistically significant differences between groups were defined at $p<0.05$.

2. Results and discussion

2.1. Fruit quality parameters

The determination of fresh weights of the three *Prunus persica* cultivar studied (Figure 1A) showed that 'O'Henry' cultivar have the highest weight (161.91g for the commercial ripening and 228.34g for the full ripening) whereas 'Early May Crest' have the lowest (106.94g for the commercial ripening and 106.77g for the full ripening). Overall, the fruit weight increased during ripening with no significant variation for 'Early May Crest' cultivar.

283 Considering fruit size, 'Early May Crest' and 'O'Henry' cultivars showed the highest diameter
284 values during the two ripening dates (Figures 1B). These diameter values increased
285 significantly during ripening, while ‘Sweet Cap’ was the lowest diameter in all cases.
286 No significant difference was found in flesh firmness among fruit harvested at two different
287 dates, although moisture content was considerably affected by them (Figures 1C and 1D).
288 Moisture content markedly increased in fruits at full ripening stage, especially for 'Early May
289 Crest' cultivar. Flesh fruit firmness values ranged from 2.02 to 5.23 kg/cm^2, values lower
290 than the maximum level of fruit firmness for marketing fresh peaches and nectarines, set by
291 the EU at a 6.5 kg/cm2 (=63.7 N), using a 8 mm diameter probe (Commission Regulation
292 EC, No.1861/2004 of 28 October 2004). These values varied among cultivars. 'Sweet Cap'
293 and 'O'Henry' cultivars showed firmness values higher than 35 N, which has been defined as
294 the threshold between mature and immature fruit (Valero et al., 2007) whereas 'Early May
295 Crest' had values between 18 and 35N, threshold that considered fruits "ready to buy" (Valero
296 et al., 2007). As shown in Figure 1C, firmness values decreased with respect to harvest date,
297 this result confirm previous findings which showed that the loss of fruit firmness is a
298 physiological process that occurs during fruit maturation/ripening on the tree (Bregoli et al.,
299 2002). Although no statistical differences were observed between the two dates.
300 Fruit maturity is a strong determinate of quality attributes such as total acidity (TA), soluble
301 solids concentration (SSC), firmness and shelf life potential. In general, TA and SSC
302 determine consumer acceptance. In this experiment, SSC values varied from 11.04 to 16
303 °Brix (Figure 1E), which are greater than the minimum (8 °Brix) established by the EU to
304 market peaches and nectarines (R-CE No.1861/2004). Previous work (Kader, 1999)
305 considered mean values of SSC over 10 °Brix as the minimum value for consumer
306 acceptance for yellow-flesh nectarines, which is the case of our cultivars. These values

307 increased during the ripening process (Aubert et al., 2003a) and varied according to the
308 cultivar (Figure 1E).
309 Considering pH (Figure 1F), pH values ranged between 3.15 and 6.45 (Figure 1F), while the
310 TA values were around 0.16–1.04 g/100 g citric acid (Figure 1G). These results showed that
311 the fruits of 'Early May Crest' cultivar can be classified as acid (pH<4) (Dirlewanger et al.,
312 1999) whereas the fruits of 'Sweet Cap' and 'O'Henry' as non acid (pH>4) (Dirlewanger et
313 al., 1999). Furthermore, no statistical significant differences for pH and TA values were
314 found among the two ripening dates except for pH values of 'O'Henry'.
315 Electrical conductivity values showed significant variations ($p<0.05$) with respect to
316 ripening among cultivars (Figure 1H). These values decreased drastically at full ripening
317 stage. Furthermore, the highest values were observed for 'Sweet Cap' cultivar at commercial
318 ripening (4.93) whereas the lowest values were observed for 'Early May Crest' cultivar at
319 full ripening (2.55).
320
321 2.2. *Fatty acid composition*
322 The fatty acid composition of peels and fleshes from the three *Prunus persica* cultivars
323 ('Sweet Cap', 'Early May Crest' and 'O'Henry') is reported in Table 1. The fatty acid profiles
324 in the peels and fleshes of the three cultivars were similar, with palmitic acid (45.8% in
325 'O'Henry' at the full ripening; 44.7% in 'Early May Crest' at the full ripening and 44.0 % in
326 'O'Henry' at the commercial ripening), linoleic acid (C18:2n6, 44.7% and 43.8% in 'Sweet
327 Cap', respectively at the second and at the commercial ripening) and oleic acid as the major
328 fatty acids (C18:1c9, 31.3% in 'O'Henry' at the commercial ripening; 21.9% and 17.8% in
329 'Sweet Cap' respectively at the first and at the full ripening). When comparing peels and
330 fleshes from the same cultivar, the majority fatty acids differed significantly ($p<0.05$) except
331 were observed for C12:0 in 'Sweet Cap' fruits at the two harvest dates, C14:0 in 'Early May

Crest' fruits at full ripening and in 'O'Henry' fruits at the two harvest dates, C18:1 c11 in 'Sweet Cap' fruits at commercial ripening, in 'O'Henry' fruits at commercial ripening and in 'Early May Crest' fruits at full ripening, C18:2 n6 in 'Early May Crest' fruits at commercial ripening and finally for C18:3 n3 in 'O'Henry' fruits at commercial ripening. Furthermore, fleshes presented higher contents of C12:0, C14:0, C16:0 and C18:2 n6, whereas peels presented higher contents of C18:0, C18:1 c9, C18:3 n3 and C20:0. The detected profiles are similar to those commonly found in peels and fleshes of other peach cultivars (Jin et al., 2014; Zhu and Zhou, 2006).

Regarding the maturity stages, the majority of fatty acids showed significant differences and FA variation showed the same profile in all cultivars. Saturated fatty acids (SFA), particularly due to palmitic acid (C16:0) contents, predominated over unsaturated ones at all maturity stages, presenting highest values in fleshes from the full ripening. On the contrary, (Aubert and Milhet, 2007) reported a decrease in palmitic acid content over 7 days of ripening. On the other hand, monounsaturated fatty acids (MUFA), mostly due to oleic acid (18:1 *c*9) contribution, had maximum values in peels from the commercial ripening, while polyunsaturated fatty acids (PUFA), with relevance for linoleic acid contents (C18:2n6), gave the highest values in fleshes from the full ripening (Table 1). These results substantially confirmed previous findings (Aubert and Milhet, 2007; Izzo et al., 1995).

The MUFA/PUFA ratio ranged from 0.09, in flesh obtained from trees of 'Early May Crest' harvested lately, to 1.26 in peels of 'O'Henry' harvested early. In addition, peels showed the highest values of MUFA/PUFA ratios independently from the maturity stage. Concerning the ratio UFA/SFA (unsaturated fatty acids/saturated fatty acids), values varied between 1.08 and 1.38 for harvested lately flesh of 'O'Henry' and peel of 'Sweet Cap', respectively.

Few papers on fatty acids from *Prunus persica* fruits can be found in the literature showing different profiles that permitted the authors to distinguish among them.

357

358 *2.3. Volatile compounds*

359 The volatile composition of *Prunus persica* fruits (Table 2) has been thoroughly studied by
360 GC/MS, leading to the identification of approximately one hundred volatile compounds (98
361 compounds). The volatile aroma compounds included alcohols (fifteen), esters (seven),
362 aldehydes (eight), hydrocarbons (thirty three), ketones (three), terpenoids (twenty four),
363 lactones (three), apocarotenes (three) and two others. Among these volatiles, C6 aldehydes
364 and alcohols contribute to the green-note aroma, while lactones and esters are responsible
365 for the fruity aromas (Aubert and Milhet, 2007; Aubert et al., 2003b; Wang et al., 2009).
366 Table 2 shows the percentages and retention indices of the different volatile compounds,
367 found in the fleshes and peels of three *Prunus persica* cultivars. Comparing the three
368 cultivars collected in the same period, some differences in the chemical composition of the
369 volatile compounds may be observed. This composition varies in the different parts of the
370 fruit. In fact, the peels of the three *Prunus persica* L. cultivars 'Sweet Cap', 'Early May Crest',
371 and 'O'Henry', during the commercial ripening gave 95.30, 95.50, and 93.23% total volatiles,
372 respectively. These levels rose slightly during the full ripening to 97.57, 96.0 and 96.43%,
373 respectively for 'Sweet Cap', 'Early May Crest', and 'O'Henry' cultivars. From Table 2, it is
374 apparent that the concentrations of volatile constituents changed with the maturation of
375 peaches, particularly terpenoids (especially camphor, α-terpinene, *p*-cymene, limonene and
376 terpinolene) increased, whereas alcohols (mainly 1-octanol, 1-nonen-3-ol and 3-
377 methylundecanol) and hydrocarbons (especially *n*-nonane, *n*-decane, 2,6-dimethylnonane,
378 2,9-dimethylnonane, 2-methyldecane, 2,6-dimethylundecane, 6-methyldodecane, (*Z*)-3-
379 tridecene, (*E*)-2-tridecene, (*Z*)-2-tridecene, 3-methyltetradecane) decreased. These results
380 are similar to those found previously (Eduardo et al., 2010; Horvat and Chapman, 1990;
381 Visai and Vanoli, 1997; Zhang et al., 2011).

In the case of fleshes, the total volatiles were 92.60, 94.77, and 94.30%, respectively during the commercial ripening and 96.63, 90.93 and 94.13%, respectively during the full ripening. The volatile fraction from the peels of 'Sweet Cap' cultivar, at the commercial ripening, was dominated by 2,6-dimethylnonane (6.53%), 1-octanol (6.03%), 2,4-heptanedione (6.10%), 1-nonen-3-ol (8.57%), 2,9-dimethylnonane (11.07%) and 2,3-butanediol (12.17%). The major constituents of the volatile fraction of the peels of 'Early May Crest' were ethyl acetate (8.23%), limonene (12.10%), 1-nonanol (15.07%) and benzaldehyde (27.17%). Finally, peels of 'O'Henry' were abundant in 1-pentanol (7.73%), (*Z*)-2-hexenal (13.03%), 2,4-heptanedione (6.93%), 2,6-dimethylnonane (7.57%), 2,9-dimethylnonane (13.70%), 1-octanol (5.87%), 1-nonen-3-ol (8.27%). At the full ripening, the peels of 'Sweet Cap' cultivar were characterized by limonene (7.80%), 1-nonanol (8.83%), nonanal (10.83%), myrcene (11.80%) and terpinolene (30.10%) as main constituents, while the volatile fraction from the peels of 'Early May Crest' was found to be rich in nonanal (6.50%), α-pinene (7.13%), terpinolene (7.63%), 1-nonanol (10.57%) and limonene (13.67%). Concerning 'O'Henry' peels, 1-nonanol (7.47%), limonene (8.10%), nonanal (8.63%), myrcene (8.70%) and terpinolene (29.90%). On the other hand, the main constituents of the volatile fraction from the fleshes of 'Sweet Cap' at the commercial ripening were ethyl acetate (5.97%), 2,4-heptanedione (4.01%), 2,9-dimethylnonane (9.23%), 1,8-cineole (7.97%), 1-octanol (5.17%) and 1-nonen-3-ol (8.10%). In the case of 'Early May Crest', the main components of the flesh volatile fraction were ethyl acetate (7.13%), benzaldehyde (27.50%), limonene (7.60%) and 1-nonanol (29.90%). The 'O'Henry', fleshes were rich in 2,4-heptanedione (8.50%), 2,6-dimethylnonane (6.43%), 2,9-dimethylnonane (12.87%), 1-octanol (6.37%), 1-nonen-3-ol (9.07%), 2-methyldodecane (8.27%) and (*Z*)-2-tridecene (5.03%). At the full ripening, fleshes of 'Sweet Cap' cultivar were dominated by benzaldehyde (5.47%), myrcene (14.63%), limonene (8.00%) and terpinolene (31.20%). However, the 'Early May Crest'

fleshes were characterized by 2-pentanol (5.10%), camphor (8.77%) and 1-nonanol (32.07%). Finally, 1-nonanol (22.03%), terpinolene (15.13%), myrcene (7.23%) and benzaldehyde (7.30%) were found in the flesh of 'O'Henry' cultivar.

Esters are considered as key odorants influencing the flavor quality of the peach fruit (Eduardo et al., 2010; Montevecchi et al., 2012). Their concentrations were relatively high in the flesh of the three studied cultivars. Butyl pivalate was only found as a major compound in the commercial ripening fruits of 'Sweet Cap' and 'O'Henry' cultivars (Table 2). The relative concentration of hexyl acetate and (*Z*)-3-hexenyl acetate were low (Table 2) and detected just in the flesh of 'Early May Crest' and 'O'Henry' cultivar at the final point of maturation. Significant values for ethyl acetate were found in the 'Sweet Cap' and 'Early May Crest' cultivars (5.97–7.13%). The chemical composition ultimately depends on the genetic background of the cultivar (Horvat and Chapman, 1990; Montevecchi et al., 2012).

Among terpenoids, linalool has been reported as an important odorous compound in previous studies (Wang et al., 2009), but it was detected only in the flesh of 'Early May Crest' cultivar at the full ripening.

Concerning aldehydes, ketones, lactones and apocarotenes, their contents depended on the type of cultivar. In fact, the presence of aldehydes (others than benzaldehyde and nonanal) in the cultivars was typically low, from 0.23% to 2.37%, except in the case of (*Z*)-2-hexenal, with a relative concentration of 13.03% and 4.83%, respectively for the peel and flesh of 'O'Henry' cultivar. Furthermore, the contribution of C6 aldehydes was also low. The highest concentrations of benzaldehyde were found to be mainly located close to the stone (in the flesh) suggesting that in peach this compound could be derived from enzymatic hydrolysis of amygdalin (Aubert and Milhet, 2007).

Lactones, particularly γ-decalactone and δ-decalactone, provide the characteristic flavor of peach (Maga, 1976). These compounds were only present in the flesh of 'Sweet Cap' cultivar and 'O'Henry'. This findings is inconsistent with previous studies (Engel et al., 1988).

Among ketones, the major compound detected was 2,4-heptanedione during the commercial ripening of fruits of 'Sweet Cap' and 'O'Henry' cultivars (Table 2). The other ketones (4-methyl-2-heptanone and 6-methyl-5-hepten-2-one) were low in concentration.

In addition, also apocarotenes were present in very low percentages (0.17%-1.60%). The presence of other unclassified compounds was relatively minor in importance, from 0.43% to 4.53%. Major compound was cyclohexyl isothiocyanate in the flesh of 'Early May Crest' (3.03% and 4.53%, respectively in the first and full ripening).

Finally, levels of aldehydes were found to be higher in peel than in flesh whereas the levels of the other compounds depend on cultivar and the period of harvest.

2.4. Phenolic compounds

The changes in concentration of *o*-diphenols, flavonols, flavonoids, and total phenolics in 'Sweet Cap', 'Early May Crest' and 'O'Henry' peels and fleshes from the two harvest periods are presented in Table 3. In the peach fruit extracts, *o*-diphenols were the major class of phenolics present, and their contents showed varietal influence, followed by flavonoids and flavonols. Total phenols contents decreased in all the cultivars ($p<0.01$) during the ripening process in both peel and flesh tissues, which confirm previous studies (Andreotti et al., 2008; Liu et al., 2015; Scordino et al., 2012). This decrease was more observed for 'Early May Crest' (from 984.99 to 402.84mg /100g and from 367.96 to 280.86 mg/100g respectively in peels and fleshes, respectively) and 'O'Henry' cultivars (from 1632.81 to 1091.17mg /100g and from 735.15 to 617.00 mg/100g, respectively in peels and fleshes, respectively).

454 The content of *o*-diphenols in peach peels were 1022.26-1028.50 mg/100g for 'Sweet Cap',
455 290.53-135.49 mg/100g for 'Early May Crest', and 597.78-420.25 mg/100g for 'O'Henry'.
456 These values in peach fleshes were 835.83- 865.80 mg/100g for 'Sweet Cap', 135.48-104.46
457 mg/100g for 'Early May Crest', and 299.51-254.65 mg/100g for 'O'Henry'. Ripening
458 differences in *o*-diphenols content were minimal for 'Sweet Cap' peach peels and for all
459 cultivars studied fleshes. Similar results were observed for flavonoids and flavonols contents
460 (Table 3).
461 During the commercial ripening, significant differences were observed for flavonols content
462 ($p<0.01$) in 'Sweet Cap' cultivar whereas these differences were observed for all classes of
463 phenolics in 'O'Henry' cultivar. However, during the full ripening, all the classes of phenolics
464 were higher in peels than fleshes. These results are in good agreement with those reported
465 for other peach cultivars (Andreotti et al., 2008; Legua et al., 2011; Scordino et al., 2012).
466 In addition, when comparing the fruits from the cultivars, 'Sweet Cap' fruits contain the
467 highest amount of phenolic compounds, whereas 'Early May Crest' showed the lowest levels
468 (Table 3). Therefore, the pattern of accumulation of all classes of phenols were cultivar-
469 dependent in a wide range of both peach and nectarine round cultivars (Andreotti et al., 2008;
470 Legua et al., 2011; Scordino et al., 2012). This reflects the difference in maturity time for
471 these three peach cultivars in the centre of Tunisia, where 'Early May Crest' is an earlier
472 cultivar than 'Sweet Cap' and 'O'Henry'.
473

474 **3. Conclusion**

475 From the above observations, it can be concluded that peaches contain high percentages of
476 FA, VC and PC. These different parameters seem to be affected by the cultivar, the ripening
477 stage and the part of the fruit (peel or flesh). The concentrations of volatile constituents
478 changed with the maturation of peaches; in particular an increase in terpenoids can be

observed in peel and flesh peaches, whereas alcohols and hydrocarbons decreased in peel. Concerning aldehydes, ketones, esters, lactones and apocarotenes, their contents were strongly cultivar-depended. A wide variation of the phenolics content in 'Early May Crest', 'Sweet Cap' and 'O'Henry' peaches fruits was apparent, which generally decreased with ripening. The peach fleshes showed in general lower phenolics amounts than peels. To the best of our knowledge, this is the first study reporting chemical composition of peach fruits from cultivars grown in Tunisia. Therefore, further studies of peach cultivars grown outside their traditional growing regions will permit to better determine their best date of harvest that is the commercial ripening stage in the current study.

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Figure Legends

Figure 1. Quality traits evaluated in three *Prunus pursica* cultivars during two harvested dates

(A) Fresh weight, (B) Fruit diameter, (C) Firmness, (D) Moisture content, (E) Soluble Solid content, (F) pH, (G) Titrable acidity and (H) Conductivity.

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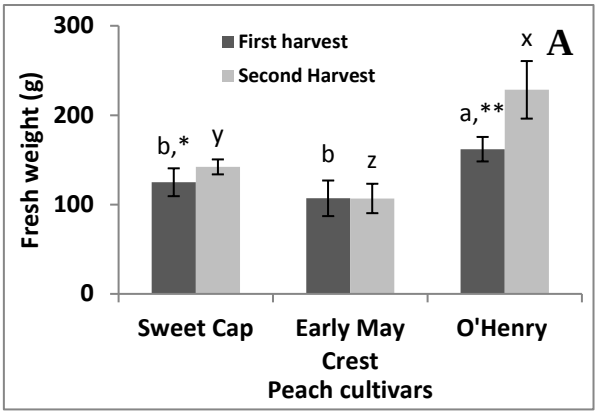

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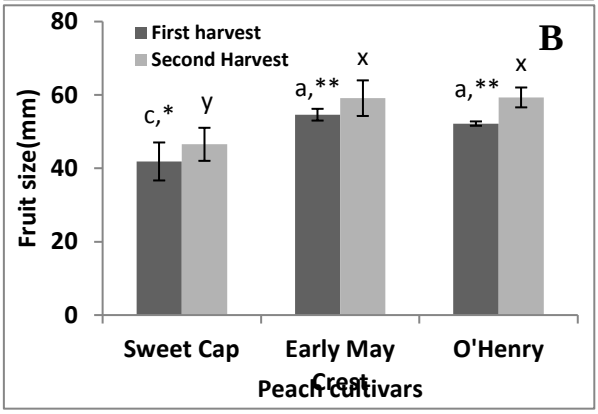

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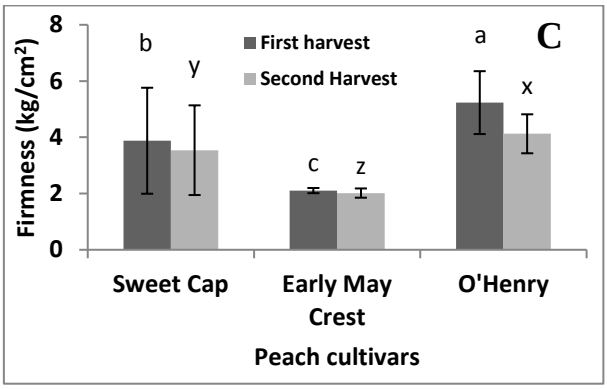

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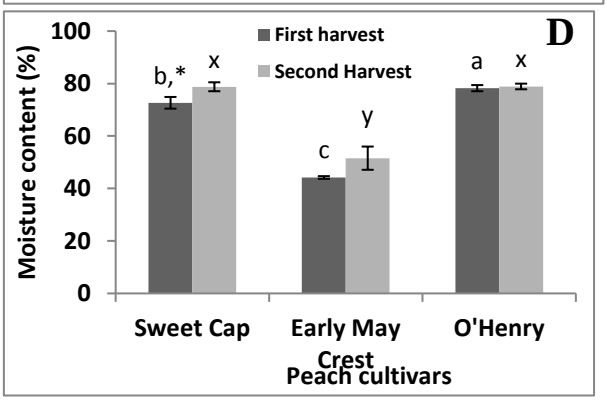

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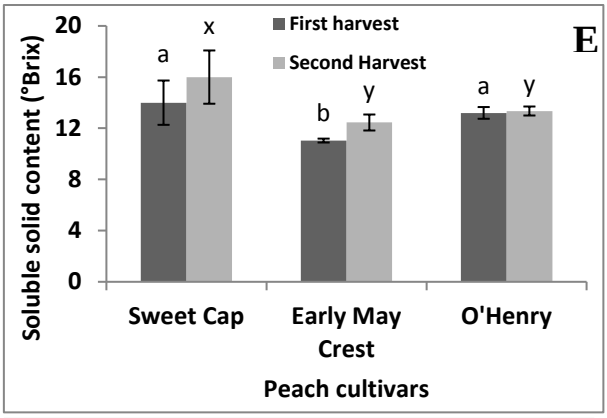

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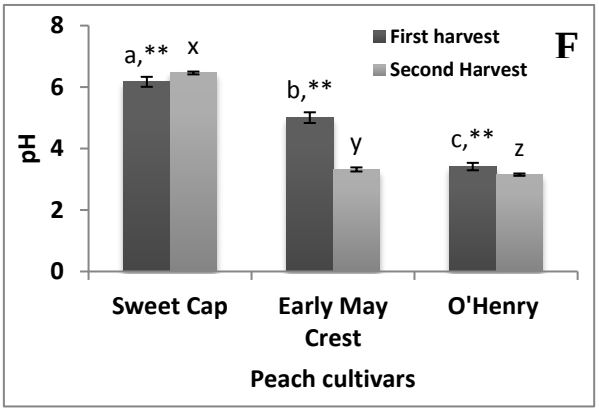

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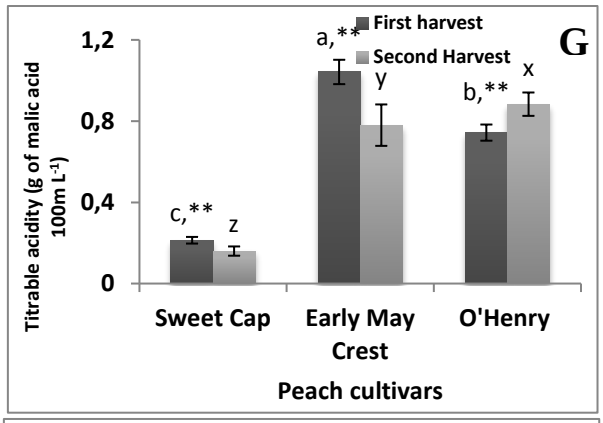

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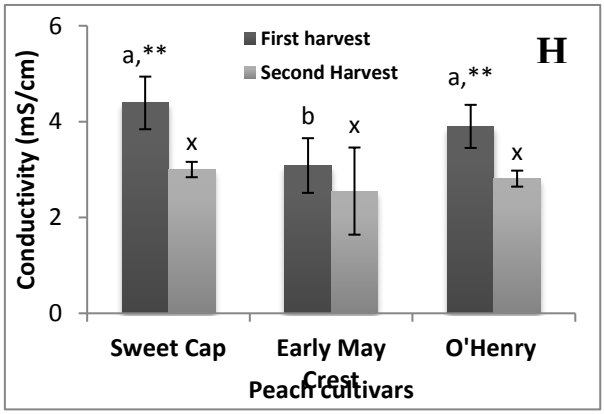

681 **Figure 1**

682 **Dabbou et al. 2015**

683 Table 1. *Main fatty acid composition (% on total fatty acids) evaluated in peel and flesh from Prunus persica cultivars harvested at two different dates.*

	Commercial ripening						*Full ripening*					
	Sweet Cap		*Early May Crest*		*O'Henry*		*Sweet Cap*		*Early May Crest*		*O'Henry*	
	Peel	*Flesh*	*Peel*	*Flesh*	*Peel*	*Flesh*	*Peel*	*Flesh*	*Peel*	*Flesh*	*Peel*	*Flesh*
C12:0	0.27 ± 0.02^{g}	0.50 ± 0.17^{c}	$0.59\pm0.05^{f,\S,++}$	1.08 ± 0.12^{b}	$1.02\pm0.05^{e,++}$	1.85 ± 0.23^{a}	0.27 ± 0.07^{r}	0.25 ± 0.05^{z}	$0.51\pm0.01^{q,++}$	0.91 ± 0.10^{y}	$1.06\pm0.01^{p,++}$	1.60 ± 0.09^{x}
C14:0	$0.60\pm0.05^{g,++}$	$0.87\pm0.08^{a,**}$	$0.85\pm0.09^{f,\S,+}$	$1.44\pm0.21^{a,*}$	1.00 ± 0.01^{e}	1.24 ± 0.43^{a}	$0.57\pm0.05^{r,++}$	0.32 ± 0.02^{y}	0.65 ± 0.03^{q}	0.87 ± 0.15^{x}	1.01 ± 0.04^{p}	1.01 ± 0.27^{x}
C16:0	$29.75\pm1.32^{e,\S,++}$	41.43 ± 1.74^{a}	$29.66\pm0.32^{e,++}$	42.58 ± 0.95^{a}	$29.21\pm0.60^{e,++}$	44.03 ± 1.05^{a}	$26.58\pm0.25^{q,++}$	41.63 ± 1.52^{y}	$29.18\pm0.81^{p,++}$	$44.73\pm2.47^{x,y}$	$29.82\pm0.15^{p,++}$	45.78 ± 1.67^{x}
C18:0	$6.98\pm0.04^{f,\S\S,++}$	2.98 ± 0.61^{b}	$7.63\pm0.28^{e,\S,++}$	$4.30\pm0.16^{a,**}$	$7.11\pm0.04^{f,\S,++}$	3.19 ± 0.52^{b}	$6.68\pm0.03^{q,++}$	2.17 ± 0.30^{x}	$6.81\pm0.13^{q,++}$	2.77 ± 0.27^{x}	$9.32\pm0.82^{p,++}$	2.28 ± 0.30^{x}
C18:1 c9	$21.97\pm2.47^{f,\S,++}$	5.47 ± 1.75^{b}	$10.00\pm0.51^{g,\S,++}$	$4.98\pm1.48^{b,*}$	$31.33\pm1.42^{e,\S\S,++}$	$13.49\pm2.79^{a,*}$	$17.77\pm0.75^{p,++}$	4.87 ± 0.41^{x}	$11.32\pm0.04^{q,++}$	2.23 ± 0.56^{x}	$17.67\pm0.89^{p,++}$	5.86 ± 3.23^{x}
C18:1 c11	1.64 ± 0.13^{e}	2.13 ± 0.50^{a}	$1.57\pm0.01^{e,\S\S}$	1.68 ± 0.42^{a}	1.29 ± 0.16^{f}	$1.29\pm0.41^{a,**}$	$1.75\pm0.01^{p,++}$	$2.31\pm0.04^{x,y}$	1.65 ± 0.02^{q}	1.98 ± 0.29^{y}	$1.47\pm0.03^{r,++}$	2.51 ± 0.28^{x}
C18:2 n6	$32.95\pm3.82^{f,+}$	43.76 ± 4.46^{a}	37.86 ± 0.04^{e}	$38.47\pm5.04^{a,b}$	$19.32\pm0.98^{g,\S\S,+}$	29.91 ± 4.79^{b}	$38.70\pm1.68^{p,+}$	44.69 ± 1.94^{x}	37.89 ± 0.43^{p}	39.18 ± 2.53^{y}	$32.02\pm0.26^{q,+}$	36.28 ± 1.89^{y}
C18:3 n3	$3.84\pm0.13^{g,\S,++}$	$2.85\pm0.12^{b,*}$	$10.14\pm1.24^{e,+}$	5.47 ± 2.03^{a}	$6.65\pm1.32^{f,\S}$	$5.00\pm0.18^{a,b,*}$	$4.88\pm0.55^{q,+}$	3.76 ± 0.30^{y}	$9.32\pm0.14^{p,+}$	7.34 ± 0.93^{x}	$3.95\pm0.18^{r,++}$	4.68 ± 0.05^{y}
C20:0	$2.00\pm0.03^{f,\S\S,++}$	nd	$1.71\pm0.05^{g,\S\S,++}$	nd	$3.08\pm0.13^{e,\S\S,++}$	nd	$2.80\pm0.29^{q,++}$	nd	$2.67\pm0.29^{q,++}$	nd	$3.69\pm0.17^{p,++}$	nd
MUFA/ PUFA	$0.64\pm0.14^{f,++}$	0.16 ± 0.06^{b}	0.24 ± 0.02^{g}	0.15 ± 0.05^{b}	$1.26\pm0.17^{e,\S\S,++}$	0.42 ± 0.13^{a}	$0.45\pm0.03^{q,++}$	$0.14\pm0.02^{x,y}$	$0.27\pm0.01^{r,++}$	0.09 ± 0.01^{y}	$0.53\pm0.03^{p,++}$	0.20 ± 0.08^{x}
UFA/SFA	1.53 ± 0.15^{e}	1.18 ± 0.10^{a}	$1.47\pm0.11^{e,++}$	1.02 ± 0.06^{a}	$1.41\pm0.09^{e,++}$	0.99 ± 0.10^{a}	$1.71\pm0.19^{p,+}$	1.25 ± 0.09^{x}	$1.51\pm0.11^{p,q,+}$	$1.03\pm0.11^{x,y}$	$1.23\pm0.04^{q,++}$	0.97 ± 0.07^{y}

684

685 Values are the means of three different fruit samples (n=3) ± standard deviations. Different superscripts for the same quality parameter mean significant differences among
686 cultivars $p<0.05$. Different letters a–c, e-g, p-r and x-z, for the same parameter, within columns indicate significant differences $p < 0.05$ with respect to harvest date for peel or
687 flesh. Different symbols *, **, for the same parameter, within columns indicate significant differences $p < 0.05$ with respect to harvest date for flesh at each harvest $p < 0.05$.
688 Different symbols §, §§, for the same parameter, within columns indicate significant differences $p < 0.05$ with respect to harvest date for peel at each harvest $p < 0.05$. Different
689 symbols +,++, for the same parameter, within columns indicate significant differences between peel and flesh with respect to cultivar. C12:0, lauric acid; C14:0, myristic acid;
690 C16:0, palmitic acid; C18:0, stearic acid; C18:1 *c*9, oleic acid; C18:1 *c*11, vaccenic acid; C18:2 n6, linoleic acid; C18:3 n3, α-linolenic acid; C20:0, eicosanoic acid;
691 MUFA/PUFA, monounsaturated / polyunsaturated fatty acids ratio; UFA/SFA, unsaturated /saturated fatty acids ratio.

692 Table 2. *Volatile compounds (% on total volatile compounds) evaluated in peel and flesh from Prunus persica cultivars harvested at two different dates.*

		Commercial ripening						*Full ripening*					
		Sweet Cap		*Early May Crest*		*O'Henry*		*Sweet Cap*		*Early May Crest*		*O'Henry*	
Volatiles	*LRI*	*Peel*	*Flesh*	*Peel*	*Flesh*	*Peel*	*Flesh*	*Peel*	*Flesh*	*Peel*	*Flesh*	*Peel*	*Flesh*
2-butanol	603	nd	nd	nd	nd	0.37±0.06	nd	nd	nd	nd	nd	nd	nd
2-pentanol	704	1.47±0.50§§	1.63±0.35*	nd	nd	nd	nd	3.07±0.25^{p}	2.73±0.50^{y}	4.57±2.64^{p}	5.10±1.31^{x}	4.10±3.08^{p}	2.27±0.38^{y}
1-pentanol	768	nd	nd	nd	nd	7.73±1.19^{++}	2.03±0.40	nd	nd	nd	nd	nd	nd
1,3-butanediol	788	1.10±0.36^{+}	0.33±0.06	nd	nd	nd	nd	0.60±0.26^{p,q}	0.37±0.06	nd	nd	1.13±0.58^{p}	nd
2,3-butanediol	789	12.17±6.12§§	3.37±1.05^{a,**}	nd	nd	nd	0.83±0.25^{b}	0.93±0.32^{p,q}	0.77±0.21^{x}	0.40±0.10$^{q,++}$	0.97±0.15^{x}	2.03±1.14^{p}	0.80±0.26^{x}
1-hexanol	869	nd	nd	nd	nd	nd	nd	nd	0.23±0.06^{z}	0.43±0.06$^{p,++}$	2.47±0.15^{x}	0.53±0.11^{p}	1.03±0.35^{y}
2-methyl-1-heptanol	1034	nd	nd	nd	nd	0.73±0.32	0.93±0.30	nd	nd	nd	nd	nd	nd
5-methyl-1-heptanol	1046	nd	nd	nd	nd	0.47±0.11	nd	nd	nd	nd	nd	nd	nd
1-octanol	1073	6.03±1.26^{e}	5.17±0.85^{b}	nd	nd	5.87±0.42^{e}	6.37±0.58^{a}	nd	nd	nd	nd	nd	nd
1-nonen-3-ol	1088	8.57±1.70^{e}	8.10±0.26^{b}	nd	nd	8.27±0.65^{e}	9.07±0.65^{a}	nd	nd	nd	nd	nd	nd
1-nonanol	1172	nd	nd	15.07±3.03$^{e,++}$	29.90±0.56^{a}	0.30±0.10$^{f\S\S,+}$	1.03±0.30^{b**}	8.83±0.68$^{q,++}$	12.00±0.56^{z}	10.57±0.93$^{p,++}$	32.07±2.40^{x}	7.47±0.93$^{q,++}$	22.03±1.34^{y}
(E)-2-decen-1-ol	1242	nd	nd	nd	nd	nd	1.33±0.15	nd	nd	nd	nd	nd	nd
7-methylnonanol	1250	nd	nd	nd	nd	0.47±0.06	0.60±0.20	nd	nd	nd	nd	nd	nd
3-methylundecanol	1326	2.47±0.68^{e}	2.83±0.42^{b}	nd	nd	1.97±0.66$^{e,+}$	3.57±0.06^{a}	nd	nd	nd	nd	nd	nd

693 Table 2. *to be continued.*

		Commercial ripening						*Full ripening*					
		Sweet Cap		*Early May Crest*		*O'Henry*		*Sweet Cap*		*Early May Crest*		*O'Henry*	
Volatiles	*LRI*	*Peel*	*Flesh*	*Peel*	*Flesh*	*Peel*	*Flesh*	*Peel*	*Flesh*	*Peel*	*Flesh*	*Peel*	*Flesh*
1-tetradecanol	1676	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.67±0.15
Alcohols		**31.80±3.02$^{e\S\S,++}$**	**21.43±1.43^{c**}**	**15.07±3.03$^{g,++}$**	**29.90±0.56^{a**}**	**26.17±1.04^{f§§}**	**25.77±1.90^{b}**	**13.43±1.27$^{p,+}$**	**16.07±0.66^{z}**	**15.97±3.19$^{p,++}$**	**40.60±0.95^{x}**	**15.27±1.15$^{p,++}$**	**26.80±2.01^{y}**
Ethyl acetate	614	nd	5.97±1.17^{a**}	8.23±3.91	7.13±0.30^{a}	nd	nd	nd	0.23±0.06	nd	nd	nd	nd
Butyl pivalate	1005	1.53±0.32^{e}	1.30±0.43^{a}	nd	nd	1.80±0.17^{e}	1.60±0.62^{a}	nd	nd	nd	nd	nd	nd
(Z)-3-hexenyl acetate	1008	nd	nd	nd	nd	nd	nd	nd	nd	nd	1.77±0.42^{x}	nd	1.40±0.36^{x}
1-hexyl acetate	1010	nd	nd	nd	nd	nd	nd	nd	nd	nd	2.80±0.36^{x}	nd	1.33±0.35^{y}
(E)-2-hexenyl acetate	1017	nd	nd	nd	nd	nd	nd	nd	nd	nd	2.20±0.30^{x}	nd	1.70±0.36^{x}
Methyl octanoate	1128	0.77±0.15	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
Ethyl octanoate	1197	1.00±0.17^{e}	nd	1.17±0.23^{e}	nd	nd	nd	0.63±0.23^{p,q}	nd	nd	nd	1.30±0.96^{p}	nd
Esters		**3.30±0.53$^{f\S\S,++}$**	**7.27±1.22^{a,**}**	**9.40±4.06^{e}**	**7.13±0.30^{a}**	**1.80±0.17^{f}**	**1.60±0.62^{b,*}**	**0.63±0.23^{p,q}**	**0.23±0.06^{z}**	**nd**	**6.77±0.94^{x}**	**1.30±0.96$^{p,++}$**	**4.43±0.58^{y}**
hexanal	802	nd	nd	1.97±0.90^{e}	nd	1.43±0.06$^{e,++}$	0.40±0.17	2.03±0.15^{p}	nd	1.60±0.53^{p}	1.33±0.21	1.63±0.65^{p}	nd
(Z)-2-hexenal	842	2.13±0.42^{f}	2.23±1.34^{b}	nd	nd	13.03±0.90^{e}	4.83±0.30^{a}	nd	nd	nd	nd	nd	nd
(E)-2- hexenal	856	2.07±0.93^{e§}	nd	1.27±0.15$^{e,++}$	0.60±0.10	nd	nd	0.90±0.10^{p}	nd	nd	nd	0.87±0.21^{p}	nd
heptanal	901	nd	nd	1.60± 0.36	1.43±0.51	nd	nd	0.67±0.38^{p,q}	0.17±0.06^{y}	1.03±0.23^{p}	1.77±0.58^{x}	0.20±0.01^{q}	nd

octanal	1002	nd	nd	nd	nd	nd	nd	2.37±0.30^{p}	nd	nd	nd	1.87±1.10^{p}	nd

694 Table 2**.** *to be continued.*

		Commercial ripening						*Full ripening*					
		Sweet Cap		*Early May Crest*		*O'Henry*		*Sweet Cap*		*Early May Crest*		*O'Henry*	
Volatiles	*LRI*	*Peel*	*Flesh*	*Peel*	*Flesh*	*Peel*	*Flesh*	*Peel*	*Flesh*	*Peel*	*Flesh*	*Peel*	*Flesh*
nonanal	1104	4.37±1.26$^{e§§,++}$	0.77±0.38^{a}	4.13±1.82$^{e,+}$	0.67±0.40^{a*}	0.80±0.10^{f§§}	nd	10.83±1.04$^{p,++}$	1.07±0.29^{x,y}	6.50±1.15$^{q,+}$	1.37±0.15^{x}	8.63±1.10$^{q,++}$	0.67±0.32^{y}
decanal	1204	nd	nd	1.63±0.66	0.60±0.35	nd	nd	nd	nd	1.03±0.23^{p}	0.87±0.06^{x}	0.60±0.10$^{q,++}$	0.23±0.06^{y}
benzaldehyde	962	2.83±0.94^{f}	1.97±0.30^{b*}	27.17±2.95^{e}	27.50±2.96^{a**}	2.50±0.10^{f}	3.63±0.80^{b**}	4.33±1.53^{p,q}	5.47±1.27^{y}	nd	1.47±0.35^{z}	5.73±3.62^{p}	7.30±0.20^{x}
Aldehydes		**11.40±1.11$^{e§§,++}$**	**4.97±0.71^{c}**	**37.77±1.97$^{e§§,+}$**	**30.80±2.09^{a**}**	**17.77±1.10^{f}**	**8.87±0.49^{b}**	**21.13±3.01$^{p,++}$**	**6.70±1.04^{x}**	**10.17±1.46$^{q,+}$**	**6.80±1.01^{x}**	**19.53±4.47$^{p,+}$**	**8.20±0.30^{x}**
toluene	773	nd	1.37±0.29	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
n-octane	800	nd	nd	nd	nd	1.27±0.30	0.47±0.11	nd	0.23±0.06	nd	nd	nd	nd
p-xylene	867	nd	nd	nd	nd	nd	nd	0.63±0.06	nd	nd	1.20±0.30	nd	nd
n-nonane	900	0.73±0.11^{e}	0.60±0.01^{b**}	nd	nd	0.97±0.38^{e}	1.20±0.36^{a}	nd	0.27±0.06	nd	nd	nd	nd
n-decane	1000	1.10±0.17^{e}	0.60±0.30^{a,b}	nd	nd	0.73±0.25^{f}	0.90±0.56^{a}	nd	nd	nd	nd	nd	nd
2,6-dimethylnonane	1012	6.53±1.43^{e}	4.40±0.56^{b}	nd	nd	7.57±0.68^{e}	6.43±0.61^{a}	nd	nd	nd	nd	nd	nd
2,9-dimethylnonane	1024	11.07±2.33^{e}	9.23±0.49^{b}	nd	nd	13.70±1.57^{e}	12.87±1.52^{a}	nd	nd	nd	nd	nd	nd
4-methyldecane	1059	1.27±0.25^{e,f}	1.47±0.23^{a}	1.37±0.30^{e§}	nd	0.83±0.06^{f}	1.27±0.30^{a}	nd	nd	0.60±0.26$^{,++}$	2.97±0.21	nd	nd
2-methyldecane	1063	1.47±0.66^{e}	nd	nd	nd	0.63±0.06^{f}	0.67±0.25	nd	nd	nd	nd	nd	nd
1-undecene	1093	nd	nd	nd	nd	nd	nd	nd	nd	nd	2.00±0.36	nd	nd

n-dodecane	1200	1.40±0.56^{e}	0.90±0.17^{b*}	1.17±0.25^{e}	2.83±1.55^{a}	0.83±0.06^{e}	1.27±0.35^{a,b}	1.07±0.06$^{p,+}$	1.57±0.25^{x}	1.07±0.21$^{p,+}$	2.53±0.60^{x}	1.10±0.61^{p}	2.00±0.65^{x}

695 Table 2**.** *to be continued.*

		Commercial ripening						*Full ripening*					
		Sweet Cap		*Early May Crest*		*O'Henry*		*Sweet Cap*		*Early May Crest*		*O'Henry*	
Volatiles	*LRI*	*Peel*	*Flesh*	*Peel*	*Flesh*	*Peel*	*Flesh*	*Peel*	*Flesh*	*Peel*	*Flesh*	*Peel*	*Flesh*
2,6-dimethylundecane	1212	0.93±0.21^{e}	1.00±0.10^{a}	nd	nd	0.53±0.11^{f}	0.53±0.21^{b}	nd	nd	nd	nd	nd	nd
6-methyldodecane	1245	2.27±0.58^{e}	2.30±0.30^{a}	nd	nd	1.97±0.35^{e}	2.73±0.30^{a}	nd	nd	nd	nd	nd	nd
4-methyldodecane	1255	nd	nd	nd	nd	0.83±0.11	1.07±0.15	nd	nd	nd	nd	nd	nd
2-methyldodecane	1262	nd	nd	nd	nd	4.70±1.04	8.27±0.90	nd	nd	nd	nd	nd	nd
1-cyclohexyl hexane	1237	nd	nd	nd	1.37±0.35	nd	nd	0.73±0.21	0.90±0.01^{y}	nd	2.13±0.55^{x}	nd	0.97±0.45^{y}
(Z)-3-tridecene	1282	0.83±0.06^{e}	nd	nd	nd	0.73±0.11^{e}	0.97±0.06	nd	nd	nd	nd	nd	nd
n-tridecane	1300	nd	0.63±0.06	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
(E)-2-tridecene	1305	2.37±0.68^{e}	2.60±0.36^{b}	nd	nd	1.87±0.50^{e}	3.23±0.15^{a}	nd	nd	nd	nd	nd	nd
(Z)-2-tridecene	1315	3.33±0.61^{e}	4.00±0.56^{b}	nd	nd	2.97±0.90^{e}	5.03±0.15^{a}	nd	nd	nd	nd	nd	nd
4-methyltridecane	1354	nd	nd	nd	nd	nd	nd	nd	nd	nd	1.10±0.17^{x}	nd	0.53±0.30^{y}
1-tetradecene	1393	nd	nd	nd	nd	nd	nd	0.37±0.15	0.13±0.06^{z}	nd	0.43±0.15^{y}	nd	0.80±0.20^{x}
n-tetradecane	1400	nd	nd	1.30±0.10^{e}	1.63±0.64^{a}	0.13±0.06^{f§§}	0.63±0.23^{b**}	0.53±0.06$^{p,+}$	0.67±0.06^{z}	1.93±1.54^{p}	1.17±0.15^{y}	0.77±0.15$^{p,++}$	3.80±0.36^{x}
1-cyclohexyloctane	1442	nd	nd	0.76±0.21	0.83±0.38	nd	nd	0.50±0.01^{++}	0.17±0.06^{y}	nd	0.40±0.10^{x}	nd	0.40±0.10^{x}
5-methyltetradecane	1452	nd	0.53±0.06	nd	nd	nd	0.13±0.06	nd	nd	nd	nd	nd	nd

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697 Table 2. *to be continued.*

		Commercial ripening						*Full ripening*					
		Sweet Cap		*Early May Crest*		*O'Henry*		*Sweet Cap*		*Early May Crest*		*O'Henry*	
Volatiles	*LRI*	*Peel*	*Flesh*	*Peel*	*Flesh*	*Peel*	*Flesh*	*Peel*	*Flesh*	*Peel*	*Flesh*	*Peel*	*Flesh*
4-methyltetradecane	1456	nd	nd	nd	nd	nd	0.73±0.23	nd	nd	nd	nd	nd	nd
2-methyltetradecane	1462	nd	0.60±0.10	nd	nd	0.23±0.15	nd	nd	nd	nd	nd	nd	nd
3-methyltetradecane	1473	nd	0.80±0.26^{a}	nd	nd	0.30±0.20	0.80±0.10^{a}	nd	nd	nd	nd	nd	nd
n-pentadecane	1500	nd	0.90±0.30	2.07±0.90	nd	nd	nd	nd	nd	nd	nd	nd	1.13±0.25
n-hexadecane	1600	nd	nd	nd	0.67±0.30	nd	nd	nd	nd	0.83±0.06	nd	nd	nd
(E)-2-hexadecene	1606	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.60±0.20
5-methylhexadecane	1652	nd	nd	nd	nd	0.17±0.11	nd	nd	nd	nd	nd	nd	nd
3-methylhexadecane	1674	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.43±0.15
Hydrocarbons		**33.30±5.13^{f,§§}**	**30.57±2.01^{b,**}**	**6.67±0.97^{g}**	**7.33±2.47^{c,*}**	**39.70±0.95^{e,§§}**	**48.73±1.66^{a,**}**	**3.20±0.01^{p,q}**	**3.70±0.40^{z}**	**4.43±1.71$^{p,++}$**	**12.70±1.47^{x}**	**1.87±0.74$^{q,++}$**	**10.63±0.35^{y}**
4-methyl-2-heptanone	942	nd	nd	nd	nd	0.87±0.11	0.83±0.11	nd	nd	nd	nd	nd	nd
6-methyl-5-hepten-2-one	987	nd	0.20±0.01**	nd	nd	nd	nd	0.40±0.17^{q}	0.63±0.06^{z}	0.87±0.11$^{p,++}$	2.13±0.25^{x}	0.77±0.15$^{p,+}$	1.13±0.11^{y}
2,4-heptanedione	975	6.10±0.10$^{e,++}$	4.01±0.40^{b}	nd	nd	6.93±0.78^{e}	8.50±2.11^{a}	nd	nd	nd	nd	nd	nd
Ketones		**6.10±0.10$^{f,§§,++}$**	**4.20±0.40^{b,**}**	**nd**	**nd**	**7.80±0.89^{e,§§}**	**9.33±2.12^{a,**}**	**0.40±0.17^{q}**	**0.63±0.06^{z}**	**0.87±0.11$^{p,++}$**	**2.13±0.25^{x}**	**0.77±0.15$^{p,+}$**	**1.13±0.11^{y}**

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699 Table 2. *to be continued.*

		Commercial ripening						*Full ripening*					
		Sweet Cap		*Early May Crest*		*O'Henry*		*Sweet Cap*		*Early May Crest*		*O'Henry*	
Volatiles	*LRI*	*Peel*	*Flesh*	*Peel*	*Flesh*	*Peel*	*Flesh*	*Peel*	*Flesh*	*Peel*	*Flesh*	*Peel*	*Flesh*
α-pinene	941	2.50±0.36$^{§,+}$	5.53±1.33*	nd	nd	nd	nd	1.47±0.32^{q}	1.90±1.13^{x}	7.13±1.44^{p}	nd	2.20±0.10$^{q,++}$	1.43±0.25^{x}
Camphene	955	0.90±0.36^{+}	2.47±0.49	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.87±0.21
sabinene	977	nd	1.37±0.32	nd	nd	nd	nd	0.53±0.06^{p}	0.83±0.23^{x}	nd	nd	0.67±0.11$^{p,+}$	0.33±0.15^{y}
β-pinene	982	0.70±0.10$^{§§,++}$	2.33±0.42	nd	nd	nd	nd	1.23±0.15^{q}	1.67±0.81^{x}	nd	nd	1.60±0.17$^{p,++}$	0.57±0.30^{y}
Myrcene	993	0.97±0.21^{f§§}	1.00±0.20*	3.30±0.53^{e}	nd	nd	nd	11.80±0.56^{p}	14.63±2.95^{x}	4.00±1.21^{r}	nd	8.70±2.08^{q}	7.23±1.38^{y}
α-phellandrene	1006	nd	nd	nd	nd	nd	nd	nd	nd	2.70±0.36	nd	nd	nd
δ-3-carene	1013	nd	nd	nd	nd	nd	nd	nd	nd	2.37±0.11	nd	nd	nd
α-terpinene	1020	nd	nd	nd	nd	nd	nd	0.60±0.10^{p}	0.67±0.11	nd	nd	0.80±0.20^{p}	nd
p-cymene	1028	nd	nd	nd	nd	nd	nd	1.27±0.49^{p}	1.23±0.50^{x}	0.30±0.01^{q}	nd	1.50±0.46$^{p,++}$	1.13±0.32^{x}
limonene	1032	nd	nd	12.10±3.72	7.60±2.47*	nd	nd	7.80±0.46^{q}	8.00±0.62^{x}	13.67±0.50$^{p,++}$	2.20±0.78^{z}	8.10±1.55^{q}	4.60±0.36^{y}
1,8-cineole	1034	4.33±0.74	7.97±3.48	nd	nd	nd	nd	nd	nd	nd	nd	nd	2.67±0.40
(E)-β-ocimene	1052	nd	nd	nd	nd	nd	nd	0.17±0.06	nd	nd	nd	nd	nd
Dihydrotagetone	1054	nd	nd	nd	2.17±0.81	nd	nd	nd	nd	nd	nd	nd	nd
γ-terpinene	1063	nd	nd	nd	nd	nd	nd	3.10±0.10$^{p,+}$	3.67±0.32^{x}	0.77±0.15^{q}	nd	3.03±0.67^{p}	2.10±0.30^{y}
Artemisia ketone	1064	nd	2.60±0.56	3.07±1.40	nd	nd	nd	nd	nd	nd	nd	nd	0.70±0.10

Terpinolene	1090	nd	nd	1.73±0.60§§	2.47±0.75	nd	nd	30.10±3.26^{p}	31.20±1.11^{x}	7.63±0.15^{q}	nd	29.90±1.78$^{p,++}$	15.13±2.58^{y}

700 Table 2**.** *to be continued.*

		Commercial ripening						*Full ripening*					
		Sweet Cap		*Early May Crest*		*O'Henry*		*Sweet Cap*		*Early May Crest*		*O'Henry*	
Volatiles	*LRI*	*Peel*	*Flesh*	*Peel*	*Flesh*	*Peel*	*Flesh*	*Peel*	*Flesh*	*Peel*	*Flesh*	*Peel*	*Flesh*
Linalool	1101	nd	nd	nd	nd	nd	nd	nd	nd	nd	3.07±1.42	nd	nd
(E)-tagetone	1141	nd	nd	nd	1.23±0.40	nd	nd	nd	0.63±0.06^{y}	nd	1.33±0.38^{x}	nd	1.03±0.06^{x,y}
(E)-myroxide	1144	nd	nd	nd	nd	nd	nd	nd	0.50±0.10	nd	nd	nd	nd
Camphor	1145	nd	nd	2.87±1.10§§	2.00±0.61**	nd	nd	nd	nd	12.87±3.61	8.77±1.30^{x}	nd	0.23±0.06^{y}
Dill ether	1189	nd	nd	nd	nd	nd	nd	nd	nd	9.73±2.19	nd	nd	nd
Carvone	1244	nd	nd	nd	nd	nd	nd	nd	nd	0.77±0.30	nd	nd	nd
Piperitone	1254	nd	nd	nd	nd	nd	nd	nd	nd	0.63±0.23	nd	nd	nd
Isobornyl acetate	1287	nd	nd	nd	nd	nd	nd	nd	nd	1.27±0.29	nd	nd	nd
Terpenoids		**9.40±1.28$^{f§§,++}$**	**23.27±2.60^{a**}**	**23.07±3.36$^{e§§,+}$**	**15.47±3.20^{b}**	**nd**	**nd**	**58.07±2.70$^{p,+}$**	**64.93±1.17^{x}**	**63.83±3.57$^{p,++}$**	**15.37±1.93^{z}**	**56.50±6.69$^{p,+}$**	**38.00±3.67^{y}**
γ-caprolactone	1058	nd	nd	nd	nd	nd	nd	nd	0.97±0.21^{y}	nd	nd	nd	1.47±0.06^{x}
γ-decalactone	1465	nd	0.97±0.25	nd	nd	nd	nd	nd	1.01±0.40	nd	nd	nd	nd
δ-decalactone	1495	nd	nd	nd	nd	nd	nd	nd	0.20±0.01	nd	nd	nd	nd
Lactones		**nd**	**0.97±0.25***	**nd**	**nd**	**nd**	**nd**	**nd**	**2.17±0.60^{x}**	**nd**	**nd**	**nd**	**1.47±0.06^{y}**
cis-α-ambrinol	1437	nd	nd	nd	nd	nd	nd	nd	0.17±0.06	nd	nd	nd	nd

Table 2. *to be continued.*

		Commercial ripening						*Full ripening*					
		Sweet Cap		*Early May Crest*		*O'Henry*		*Sweet Cap*		*Early May Crest*		*O'Henry*	
Volatiles	*LRI*	*Peel*	*Flesh*	*Peel*	*Flesh*	*Peel*	*Flesh*	*Peel*	*Flesh*	*Peel*	*Flesh*	*Peel*	*Flesh*
(E)- geranylacetone	1455	nd	nd	nd	nd	nd	nd	nd	nd	nd	0.90 ± 0.10^{x}	nd	0.37 ± 0.11^{y}
(E)-β-ionone	1487	nd	nd	1.60±0.53	nd	nd	nd	nd	0.17±0.06	nd	nd	nd	nd
Apocarotenes		**nd**	**nd**	**1.60±0.53**	**nd**	**nd**	**nd**	**nd**	**0.33 ± 0.06^{y}**	**nd**	**0.90 ± 0.10^{x}**	**nd**	**0.37 ± 0.11^{y}**
benzothiazole	1226	nd	nd	$0.60\pm0.17^{\S}$	1.10±0.26	nd	nd	nd	0.50 ± 0.01^{y}	nd	1.13 ± 0.23^{x}	$0.43\pm0.11^{+}$	1.07 ± 0.21^{x}
Cyclohexyl isothiocyanate	1236	nd	nd	$1.33\pm 0.35^{\S}$	3.03±1.17	nd	nd	0.73 ± 0.11^{p}	1.40 ± 0.43^{y}	$0.73\pm0.06^{p,++}$	4.53 ± 0.32^{x}	$0.77\pm0.15^{p,++}$	2.07 ± 0.25^{y}
Others		**nd**	**nd**	**$1.93\pm0.21^{\S\S}$**	**4.13±1.40**	**nd**	**nd**	**$0.73\pm0.11^{q,+}$**	**1.90 ± 0.43^{z}**	**$0.73\pm0.06^{q,++}$**	**5.67 ± 0.55^{x}**	**$1.20\pm0.10^{p,++}$**	**3.13 ± 0.06^{y}**
Total identified		**95.30 ± 3.42^{e}**	**$92.60\pm1.70^{a*}$**	**95.50 ± 3.83^{e}**	**94.77 ± 2.21^{a}**	**93.23 ± 1.45^{e}**	**94.30 ± 1.54^{a}**	**97.57 ± 0.51^{p}**	**96.63 ± 1.59^{x}**	**96.00 ± 2.68^{p}**	**90.93 ± 0.32^{z}**	**96.43 ± 1.89^{p}**	**94.13 ± 1.40^{y}**

Values are the means of the three different *Prunus persica* samples (n=3) ± standard deviations. Different superscripts for the same quality parameter mean significant differences among cultivars $p<0.05$. Different superscripts for the same quality parameter mean significant differences among cultivars $p<0.05$. Different letters a–c, e-g, p-r and x-z, for the same parameter, within columns indicate significant differences $p < 0.05$ with respect to harvest date for peel or flesh. Different symbols *, **, for the same parameter, within columns indicate significant differences $p < 0.05$ with respect to harvest date for flesh at each harvest $p < 0.05$. Different symbols §, §§, for the same parameter, within columns indicate significant differences $p < 0.05$ with respect to harvest date for peel at each harvest $p < 0.05$. Different symbols +,++, for the same parameter, within columns indicate significant differences between peel and flesh with respect to cultivar.

Table 3. *Phenolic compounds (mg 100g^{1} DW) evaluated in peel and flesh from Prunus persica cultivars harvested at two different dates.*

	Commercial ripening						*Full ripening*					
	Sweet Cap		*Early May Crest*		*O'Henry*		*Sweet Cap*		*Early May Crest*		*O'Henry*	
	Peel	*Flesh*	*Peel*	*Flesh*	*Peel*	*Flesh*	*Peel*	*Flesh*	*Peel*	*Flesh*	*Peel*	*Flesh*
o-diphenols	1022.26±159.05^{e}	835.83±107.63^{a}	290.53±24.7^{g,§§}	135.48±27.23^{c}	597.78±13.48$^{f,++,§§}$	299.51±10.78^{b}	1028.50±32.34^{p}	865.80±128.52^{x}	135.49±27.07$^{r,++}$	104.46±21.46^{y}	420.25±41.46$^{q,++}$	254.65±35.34^{y}
Flavonols	92.49±6.23$^{e,++,§}$	27.68±6.68^{a,*}	54.10±5.67^{f,§}	36.98±9.07^{a}	107.69±17.51$^{e,++,§}$	25.39±5.69^{a}	71.48±8.88$^{p,++}$	45.27±5.92^{x,*}	95.21±17.27$^{p,++}$	41.27±8.04^{x}	70.94±10.46$^{p,++}$	19.83±4.44^{y}
Flavonoides	406.04±43.54^{e}	337.25±43.27^{a}	125.23±28.74^{g,§}	32.17±10.04^{c}	245.52±19.05$^{f,++}$	106.82±3.15^{b,**}	371.62±12.43$^{p,++}$	290.16±33.36^{x}	48.81±11.05$^{r,++}$	16.80±5.20^{z}	194.81±29.82$^{q,+}$	73.43±4.01^{y}
Total phenols	1926.21±285.84^{e}	1538.72±333.10^{a}	984.99±159.86^{f,§§}	367.96±91.33^{b}	1632.81±172.19$^{e,++,§}$	735.15±9.72^{b,*}	1912.20±159.84^{p}	1517.48±213.35^{x}	402.84±25.46$^{r,++}$	280.86±52.74^{z}	1091.17±148.51$^{q,++}$	617.00±44.78^{y}

Values are the means of the three different *Prunus persica* samples (n=3) ± standard deviations. Different superscripts for the same quality parameter mean significant differences among cultivars $p<0.05$. Different superscripts for the same quality parameter mean significant differences among cultivars $p<0.05$. Different letters a–c, e-g, p-r and x-z, for the same parameter, within columns indicate significant differences $p < 0.05$ with respect to harvest date for peel or flesh. Different symbols *, **, for the same parameter, within columns indicate significant differences $p < 0.05$ with respect to harvest date for flesh at each harvest $p < 0.05$. Different symbols §, §§, for the same parameter, within columns indicate significant differences $p < 0.05$ with respect to harvest date for peel at each harvest $p < 0.05$. Different symbols +,++, for the same parameter, within columns indicate significant differences between peel and flesh with respect to cultivar.

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