Prunus persica by-products: a source of minerals, phenols and volatile compounds

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Abstract

Large amounts of peach (*Prunus persica*) leaves and stems are by-products deriving from peach tree cultivation and canned industries. This work aimed to evaluate mineral nutrients, phenolic and volatile profile and antioxidant activities from the by-products of five peach cultivars (Early Maycrest, Sweet Cap, O'Henry, Flordastar and Rubirich).

Minerals showed significant variations with respect to peach by-product. N showed higher contents in peach leaves among macronutrients, while Mn showed higher contents among micronutrients. Stems had high levels of Ca and traces of micronutrient levels. The HPLC-DAD phenols analysis showed twelve compounds identified (neochlorogenic and chlorogenic acids, catechin and epicatechin, gallic, caffeic, syringic, ferulic and coumaric acids, quercetin-3-rutinoside, quercetin-3-galactoside, cyanidin-3-glucoside, cyanidin-3-galactoside). Flavonols showed the highest values (quercetin-3-galactoside with 70.79 - 232.16 mg $100g^{-1}$ DW, quercetin-3-rutinoside with 63.88 - 206.37 mg $100g^{-1}$ DW), while the least content was observed for anthocyanins. Cultivar had a significantly ($P < 0.05$) impact on phenolic compounds. Comparing by-products, stems showed higher levels of phenols. The GC-MS volatile compounds analysis revealed 43 compounds in different percentages and occurrences, depending on the cultivar and the by-product. Benzaldehyde was detected as the major volatile leaf component (70-95%), whereas myrcene (18-21%) and terpinolene (18-26%) were found to be the most important compounds in stems. Methanolic extracts of mature leaves were characterized by lower antioxidant capacity. Finally, peach by-products could represent a natural source of minerals, volatiles and phenolic compounds with high antioxidant activities having a great potential use in food products as natural flavouring agents and as nutraceutical supplements and pharmaceutical and cosmetic molecules.

Keywords: *Prunus persica*, Agricultural by-products, Mineral nutrients, Phenol profile, Volatile compounds, Antioxidant activity.

1. Introduction

Interest for bioactive compounds of natural origin with a high antioxidant capacity has increased considerably in the past two decades, mostly due to their potential for the treatment and prevention of cancer, cardiovascular, chronic and neurodegenerative diseases (Joana Gil-Chávez et al., 2013). Phenolic compounds are ubiquitous in vegetation, constitute an important part of the human diet, pharmaceutical, and cosmetic industry and have aroused much interest due to their antioxidant properties (Kuppusamy et al., 2016) and health-promoting properties (Shashank and Pandey, 2013).

Furthermore, one of the most important and overlooked diet constituents today is represented by minerals (Kuppusamy et al., 2016). People have increased interest to incorporate high nutrient levels with sufficient amounts of essential minerals into the regular diet (Alagić et al., 2018), due to their role as structural components of organs (e.g. bones and teeth) and their involvement in many physiological and metabolic processes (Soetan et al., 2010).

Besides, plants emit into the environment many types of volatile organic compounds (VOC), which behave as info chemicals in biotic communication (Blée, 2002; Niinemets et al., 2013) and in abiotic stress acclimation. VOCs represent also a method for plants to face stress and reduce the negative effects (Loreto and Schnitzler, 2010). Furthermore, many authors have proven the important role of VOC in food industry to improve shelf-life and safety of fresh or minimally processed fruits (Lanciotti et al., 2004) as well as in industrially produced food, which are often subjected to aroma losses during processing and storage (Tylewicz et al., 2017). Indeed, investigating plant by-products, is one of the main topics of research and innovation nowadays, in the hope to reduce environmental damage and provide new extracts of high purity. These enriched fractions and isolated compounds, assessed for their safety and efficacy, should be incorporated in food and pharma formulations and products.

Prunus spp. is a member of the plant family Rosaceae that is widely distributed in most countries of the world. During the last two decades, the Tunisian areas cultivated with *Prunus* showed a significant upward trend, with more than 1.3 million hectares and an annual production of 123000.000 tonnes in 2016 (FAOstat, 2018). In fact, peach cultivation occupies an important place in the sector of fruit trees in Tunisia; 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 (Dabbou et al., 2016). Trees producing nectarines, flat peach, white peach and yellow peach are characterized by different leaf traits (Dai et al., 2017). Leaves and stems are considered as a by-product deriving from peach tree cultivation and canned

89 industries. Large amounts of these by-products are principally generated during harvesting of the peach fruit and
90 following leaf fall in winter. Winter fall is responsible for the most abundant accumulation of these by-product,
91 though this production has been never statistically quantified. Besides nutritional and nutraceutical value of the fruit,
92 also peach by-products as peel and remnant pulp have a hypoglycemic and hypotriglyceridemic effect (Rodríguez-
93 González et al., 2018) whereas leaves showed pharmaceutical potential and are traditionally used as antihelmentic,
94 laxative and sedative (Kazan et al., 2014). A decoction of the leaves is used as a bath to treat heat rash, skin disease
95 and circulatory troubles (Perry and Metzger, 1980).
96 The full characterization of bioactive compounds obtained from natural matrices is a major challenge for researchers
97 in the food, pharmaceutical, and cosmetic industry (Karabegovic et al., 2014). The huge amount of food related
98 materials represents a potential reservoir of functional substances, whose recovery can create additional income and
99 contribute to reduce waste.
100 However, data on mineral, volatiles and nutraceutical composition of agricultural by-products of *P. persica* crops
101 are scarce. Therefore, the present investigation is aimed to evaluate phenolic profile and mineral and volatile
102 composition of leaves and stems from five peach cultivars grown in Tunisia under the same agricultural,
103 geographical and climatic conditions.

104

105 ## 2. Material and methods

106 ### *2.1. Plant material*

107 Peach agricultural by-products (young and mature leaves and stems) were collected during the two summer seasons
108 2013-2014 from the experimental orchard of the Regional Centre of Agricultural Research Farm in the region of
109 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-
110 arid bioclimatic region, with a mean annual rainfall of 251.8 mm (concentrated mainly from autumn to spring), a
111 mean annual temperature varying from 12.5°C to 25.3°C and an average evapotranspiration (ETc.) of 1634.9 mm.
112 The soil horizons present a silt-clay-loam texture. Peach agricultural by-products of five different cultivars of
113 *Prunus persica* L. [Batsch], Early Maycrest, Sweet Cap, O'Henry, Flordastar and Rubirich grafted on the Germen
114 wild rootstock, were studied. Trees were planted in 2005 at a spacing of 4 m x 6 m. Trees were irrigated by a
115 network drop-by-drop with two pipes per row (4 L h^{-1}). During the 2-year experimental period the three cultivars
116 were similarly fertilized with nitric acid, magnesium and potassium. Young leaves were a few days old and mature
117 leaves were >1-year-old. Three replicates were made for each peach by-products. Plant materials were hand
118 harvested, washed with tap water, lyophilised and stored at -20°C until analysis.

2.2. Analytical methods

2.2.1. Macro and microelements quantification

Cations was determined by atomic absorption spectrophotometry (PerkineElmer Analyst 100, Waltham, MA, USA) as reported previously (Ranieri et al., 2005) with slight modifications. Briefly, the acidic digestion of dried samples was carried out by dissolving 500 mg of dry matter in 9 mL flame-heated concentrated HNO_3. H_2O_2 drops were added until complete clarification of samples, and final volumes were adjusted to 25 mL by milliQ water. The concentrations of Ca, Mn, Na, Cu, K, Mg and Zn were successively measured using PerkineElmer INTENSITRON lamps. Nitrogen was measured by Kjeldahl procedure after acidic digestion in H_2SO_4. Results were expressed as mg g^{-1} DW.

2.2.2. Spectrophotometric analysis

The phenolic extract was obtained from the homogenation of 0.5 g of lyophilised peach leaves and methanol (80%) and their centrifugation at 5,000 x g for 10 min at 4 °C (Dabbou et al., 2016); these steps was repeated twice. The collected extracts were stored at -20°C until analysis.

2.2.2.1. Total phenols and o-diphenols

The total phenols and *o*-diphenols content of peach leaves were determined calorimetrically using the Folin–Ciocalteu method (Montedoro et al., 1992). The results were expressed as mg hydroxytyrosol 100 g^{-1} DW.

2.2.2.2. Total flavonoids

To determine the total flavonoid content of leaf extract, the aluminum chloride colorimetry method was used (Zhishen et al., 1999). In brief, the methanolic extract sample was diluted with dH_2O. Then, the diluted extract was mixed with $NaNO_2$ (5%), $AlCl_3$ (10%) and NaOH (1M) solutions and dH_2O and the absorbance of the obtained solution was measured at 510 nm. The results were expressed as mg catechin 100 g^{-1}DW.

2.2.2.3. Total flavonols

Total flavonols was analyzed spectrophotometrically at 360 nm using the colorimetric method described previously (Romani et al., 1996). Diluted leaf extracts were added to ethanol (10%), 0.1% HCl in 95% ethanol and 2% HCl. The mixed solution was allowed to stand for 15 min and the absorbance was read at 360 nm against the blank. The total flavonols content was expressed as mg quercetin 100 g^{-1} DW.

2.2.2.4. In vitro antioxidant analysis

147 Antioxidant potential of the peach leaves extracts was studied using 2,2-azino-bis-3-ethylbenzothiazoline-6-
148 sulfonicacid (ABTS) radical scavenging assay (Re et al., 1999; Rice-Evans et al., 1996) and the reducing power
149 assay (Oyaizu, 1986). The results were expressed as the effective concentration (EC50) value (mg $100g^{-1}$ DW)
150 (Dabbou et al., 2015).

151 **2.2.3. Individual phenolic compounds analyses**

152 Individual phenols were determined from the lyophilised leaves and stems (0.25 g) homogenised, for 2 min on ice,
153 in an Ultra-Turrax T25 (IKA Labortechnik, Janke & Kunkel, Staufen, Germany), with 5 mL of 80% methanol
154 aqueous solution, BHT (0.1% w/v) to prevent oxidation. The homogenates were then centrifuged (16000 rpm, 15
155 min, 4°C). The procedure was repeated twice and the resulted supernatants were evaporated to dryness at 35°C
156 under vacuum through a rotary evaporator. The supernatant was recovered in 1 mL of MilliQ water and filtered
157 through 0.45 µm filter. Analysis of phenolic compounds was performed following the method of Tomás-Barberán et
158 al. (2001) using a Spectra System P4000 HPLC, equipped with a UV 6000 LP photodiode array detector (Thermo
159 Fisher Scientific, Waltham, MA) using a Phenomenex Prodigy LC-18 RP column (5 µm particle size, 250 x 4.6 mm,
160 Phenomenex Italia, Castel Maggiore, Italy). Concentrations were expressed as mg $100g^{-1}$ dry weight (DW).
161
162 **2.2.4. Volatile compound analyses**

163 Supelco (Bellefonte, PA) SPME devices coated with polydimethylsiloxane (PDMS, 100 µm) were used to sample
164 the headspace of dry plant material inserted into a 15 mL glass vial and allowed to equilibrate for 30 min. After the
165 equilibration time, the fiber was exposed to the headspace for 35 min at room temperature. Once sampling was
166 finished, the fiber was withdrawn into the needle and transported to the injection port of the GC–MS system. All the
167 SPME sampling and desorption conditions were identical for all the samples. Moreover, blanks were performed
168 before each first SPME extraction and randomly repeated during each series. Quantitative comparisons of relative
169 peaks areas were carried out between the same chemicals in the different samples.

170 GC-EIMS analyses were executed with a Varian (Palo Alto, CA) CP3800 gas chromatograph equipped with a DB-5
171 capillary column (30 m x 0.25 mm x 0.25 µm; Agilent) and a Varian Saturn 2000 ion trap mass detector. The
172 analytical settings were as follows: injector and transfer line temperatures were 250 and 240°C, respectively; oven
173 temperature was programmed from 60 to 240 °C at 3 °C min^{-1}; carrier gas was helium at 1 mL min^{-1}; splitless
174 injection. Constituents identification was based mainly on a comparison of the retention times with those of
175 authentic samples, comparing their linear retention indices relative to the series of n-hydrocarbons (C7-C28) and on

computer matching against the commercial (NIST 2014 and Adams 2007) and homemade libraries of mass spectra, and MS literature data (Adams, 1995; Davies, 1990; Jennings and Shibamoto, 1980; Stenhagen et al., 1974; Swigar and Silverstein, 1981). Results were expressed as % of total volatile compounds.

2.3. 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 five *P. persica* cultivars. Statistically significant differences between groups were defined at $p<0.05$.

3. Results

3.1. Macro and micronutrients

The mineral composition of agricultural by-products (young, mature leaves and stems) from the five peach cultivars (Sweet Cap, Early Maycrest, O'Henry, Flordastar and Rubirich) is reported in Table 1. Comparing the different minerals, N showed higher contents in peach leaves among macronutrients, while Mn showed higher contents among micronutrients. Stems also recorded high levels of Ca, comparable to those found in young leaves, an exception observed for Rubirich. Traces were recorded for micronutrient levels in the stems. In average, young leaves contained 1.5 to 3-times higher amounts from Ca and Mn than mature leaves, from 14 to 85-times higher amounts from Na, while levels of Zn, Cu, K, and N were approximately identical thought ripening process of peach leaves. Magnesium contents differed between young and mature leaves according to cultivars (Table 1). Mg values for the different cultivars of peach leaves ranged from 5.88 to 24.20 mg g^{-1} DW in young leaves for Rubirich and Early Maycrest cultivars, respectively and from 7.88 to 12.01 mg g^{-1} DW in mature leaves for Flordastar and Rubirich cultivars, respectively. Comparing cultivars, accumulation of leaf and stems nutrients was cultivar-dependent, but inconsistent. In fact, leaf N concentration was not significantly affected by the cultivar.

3.2. Spectrophotometric analysis

Variations in total flavonoids, flavonols, *o*-diphenols and total phenols in the by-products of five peach cultivars (young and mature leaves and stems) are presented in Table 2. Total phenols showed values ranging from 2534.06 to 4593.01 mg 100 g^{-1} MS. Total flavonoids varied from 649.25 to 1011.26 mg 100 µg-1 MS and the lowest values were found in leaves. Early Maycrest, Flordstar and Rubbirich cultivars did not show statistically significant

differences among phenolic compounds (flavonoids, flavonols, *o*-diphenols and total phenols contents). In addition, the stems showed the highest levels of total phenols, total flavonoids and *o*-diphenols among the peach by-products studied but the lowest flavonol contents. These results are cultivar-dependent with the richest Sweet Cap cultivar.

Table 2 showed that among cultivars, no statistical difference (p>0.05) between mature leaves were observed. However, young leaves of Sweet Cap and Rubbirich cultivars showed the highest contents of *o*-diphenols (1534.85 and 1546.97 mg 100 g^{-1} DW, respectively), flavonoids (1011.26 and 869.13 mg 100 g^{-1} DW, respectively) and total phenols (4593.01 and 4326.83 mg 100g^{-1} DW, respectively). O'Henry and Flordstar leaves had the highest contents of flavonols (1309.39 and 1413.05 mg 100 g^{-1} DW, respectively).

The antioxidant and antiradical activity of the agricultural by-products of the five peach cultivars were investigated using two methods, ABTS+•, and reducing power assays (Table 2). All young leaf extracts were more effective at reducing power capacity (82.26 - 177.51 mg 100 g^{-1} MS, respectively for Rubirich and Sweet Cap) than ripe leaf extracts. ABTS values showed no variation between the two types of leaves (p> 0.05), with the exception of Sweet Cap. In addition, the comparison with the stem extracts, potent activities were observed for both tests evaluated among the peach by-products studied. Comparing the cultivars, O'Henry showed the highest ABTS value, while no significant difference was shown between the other cultivars. For stem extracts, the highest activity was observed in Early Maycrest ; This result can be explained by its high content of phenolic compounds.

3.3. Individual phenolic compounds

Table 3 illustrates the quantity of individual phenolic compounds detected in the methanol extract of peach leaves and stems. Thirteen compounds were identified and quantified including hydroxycinnamic acid derivatives (neochlorogenic acid, chlorogenic acid, caffeic acid, coumaric acid and ferulic acid), flavan-3-ols (catechin and epicatechin), hydroxybenzoic acids (gallic acid), flavonols (quercetin-3-rutinoside and quercetin-3-galactoside) and anthocyanins (cyanidin-3-glucoside and cyanidin-3-galactoside).

Quantitatively, among the individual compounds identified, in addition to chlorogenic acid (127.34-178.25 mg 100g^{-1} DW), flavonols were the most concentrated compounds in the leaves, with quercetin-3-galactoside contents ranging between 73.43 mg 100g^{-1} DW and 106.09 mg 100g^{-1} DW, followed by quercetin-3-rutinoside (73.85-115.84 mg 100 g^{-1} DW) whereas flavan-3-ol were the most abundant compounds in the stems, with catechin (170.09-199.98 mg 100g^{-1} DW) being the most concentrated, but no statistical differences were observed between cultivar (Table 3). Quercetin-3-galactoside, also known as hyperoside, was statistically ($P < 0.01$) higher concentrated in young leaves of O'Henry and Early Maycrest cultivars than in the other cultivars (Table 3).

Anthocyanins showed the least contents among the peach agricultural by-products. As shown in Table 3, the cultivar ($P < 0.05$) had a significantly remarkable impact on individual phenolic compounds of peach by-products. Cyanidin-3-rutinoside was not detected in the two types of leaves of the Flordastar and Rubirich cultivars as well as in Early Maycrest young leaves, and cyanidin-3-glucoside was undetectable in Flordastar mature leaves.

3.4. Volatile compounds

The study allowed the characterization of 59 volatile compounds at different percentages and occurrences in the peach by-products (Table 4), of which 43 were present in the leaf. GC-MS analysis revealed that benzaldehyde was detected as the major volatile leaf component (70-95%), whereas myrcene (18-21%) and terpinolene (18-26%) were found to be the most important compounds in stems. The other major compounds of leaves were 1-pentanol (2.4-4.2%), (*Z*)-2-hexenal (3.3-5.3%), (*E*)-2-hexenal (0.6-4.1%), 2,6-dimethylnonane (1.6-2.7%) and 2,9-dimethylnonane (2.3-4.5%). The levels of these compounds varied according to the cultivar and the maturity of the leaves (Table 4). The compounds *α*-pinene, 1-pentanol, (*Z*)-2-hexenal, 2,6-dimethylnonane, 2,9-dimethylnonane, 1-octanol, 1-nonen-3-ol, 6-methyldodecane, (*E*)-2-tridecane, (*Z*)-2-tridecane and 3-methyldecanol were found only in mature peach leaves. On the contrary, myrcene, limonene, (*E*)-*β*-ocimene, *γ*-terpinene, *β*-bourbonene, *β*-caryophyllene, (*Z*)-3-hexenyl acetate, benzyl alcohol, 1-nonanol, *n*-tetradecane, 1-cyclohexyloctant and *n*-hexadecane were exclusive of young peach leaves. Apocarotenoids (theaspirane I and theaspirane II) were detected only at the stems (Table 4).

4. Discussion

4.1. Macro and micronutrients

The mineral composition of agricultural by-products (young, mature leaves and stems) from the five peach cultivars (Sweet Cap, Early Maycrest, O'Henry, Flordastar and Rubirich) showed significant variations in the levels of Mg, Ca, Mn, K and Na with respect to harvests, which confirms that the uptake of mineral elements by peach trees varies with the plant physiological stages over the production cycle (Leonel et al., 2011). Abadia et al. (1985) found different results of the mineral composition in peach leaves which are the following : Ca (1.37 mg $100g^{-1}$ DW), Mg (0.48 mg $100g^{-1}$ DW), K (2.09 mg $100g^{-1}$ DW), Na (0.06 mg $100g^{-1}$ DW), Mn (28 mg $100g^{-1}$ DW), Cu (10 mg $100g^{-1}$ DW), and Zn (34 mg $100g^{-1}$ DW). In addition, our results are higher than those found in *Prunus cerasifera* leaves (C 448.6; N 14.7; P 1.5; K 24.8; Ca 15.7; Mg 2.4; Na 1.2 ; Mn 44.4; Cu 7.7 ; Zn 10.2 mg g^{-1} DW) (Kuppusamy et al., 2016) but lower than those found in plums (Mg 0.35%; Ca 2.24%; K 2.59%; Zn 23.6 mg kg^{-1} DW; Mn 31.6 mg kg^{-1} DW; Cu 5.27 mg kg^{-1} DW) (Reig et al., 2018). Comparing cultivars, accumulation of leaf and stems nutrients

was cultivar- dependent, but inconsistent, and resulted in nutrient deviations from normal values which confirm previous findings on *Prunus avium* (Milošević et al., 2015). In fact, leaf N concentration was not significantly affected by the cultivar. These results are consistent with previous works (Balal et al., 2011; El-Jendoubi et al., 2014).

4.2. Spectrophotometric analysis

Total phenols and total flavonoids values of the *P. persica* leaves found in our study are higher than those of the leaves of *Prunus cerasifera* and *Prunus laurocerasus* reported by other works (Karabegovic et al., 2014; Kuppusamy et al., 2016). Early Maycrest, Flordstar and Rubbirich cultivars did not show statistically significant differences among phenolic compounds (flavonoids, flavonols, *o*-diphenols and total phenols contents). In addition, the stems showed the highest levels of total phenols, total flavonoids and *o*-diphenols among the peach by-products studied but the lowest flavonol contents. These results are cultivar-dependent where Sweet Cap cultivar was found to be the richest. These findings confirmed the work of Eftekhari et al. (2017) on leaves and stems of *Vitis vinifera*.

Our findings of the by-product in the five peach cultivars indicate that peach leaves had important contents of polyphenol compounds, which could have potential biological importance. Similar results were observed in apricot leaves (Vieira et al., 2016; Zeb et al., 2017), where the total phenolic content increased with maturation. The increase was highly correlated with the variation in the polyphenols profile of the leaves. According to these authors (Vieira et al., 2016; Zeb et al., 2017), variations in the polyphenol compounds of the leaves during maturation may be correlated with fruit development. Furthermore, these variations may be affected by the variety, climate, soil and environmental conditions.

Quantitatively proved, stems showed higher levels of phenols than young and mature leaves. However, differences between cultivars in phenol levels of mature leaves were almost inexistent.

According to our results, Sweet cap showed an important antioxidant and antiradical activity mainly in young leaves comparing to the other peach cultivars. These results can be explained by the higher phenol contents of Sweet Cap; this confirms previous work (Dabbou et al., 2015). For stems extracts, the highest activity was observed in Early Maycrest, consistent with the high content of phenolic compounds.

4.3. Individual phenolic compounds

According to the HPLC analysis, chlorogenic acid was the major phenolic compound found in peach leaves, that contained also other hydroxycinnamic acid derivatives, flavan-3-ols acids, hydroxybenzoic acids, flavonols and anthocyanins. This phenolic profile was proved by previous works on leaves extracts from *Prunus* genus and

especially *Prunus dulci*s Mill. (Bottone et al., 2018) and *Prunus avium* (Dziadek et al., 2019). However, in other leaves from the same genus *Prunus* the major compound found was the neochlorogenic acid (Jesus et al., 2019). Karabegović et al. (2014) also identified luteolin-7-glucoside, apigenin-7-glucoside, kaempferol-3-glucoside and naringin in leaf extracts of *Prunus laurocerasus* L.. Furthermore, Dziadek et al. (2019) found myricetin compound in addition to caffeic, cholorogenic, *p*-coumaric and ferulic acids in *Prunus avium* L. leaves, while 36 compounds were identified in leaves of *Prunus cerasus* L. and 26 compounds in stem extracts of *Prunus avium* L. (Bastos et al., 2015; Oszmianski and Wojdylo, 2014).

Quantitatively, the O'Henry cultivar seemed to be the richest one for young leaves and stems compared to the other cultivars, indicating a genotype-depending variability in the phenolic content of the different plant organs.

Anthocyanins, the most important group of water-soluble vacuolar pigments, appear as red, blue, or purple and occur in all plant tissues, including flowers, stems, leaves, roots, and fruits (Xu et al., 2017). These substances showed the least contents among the peach agricultural by-products. Conversely, flavonols were the most concentrated compounds in the leaves of the five cultivars studied.

According to our results, phenolic compounds vary depending on cultivar ($P< 0.05$). Early Maycrest had the highest catechin content among the analysed peach cultivars in mature leaves, though no statistical differences were observed for young leaves (Table 3).

The analysis of stems methanolic extract showed the abundance of catechin. These results confirm those found previously in the stems of *Prunus avium* L. (Aires et al., 2017; Bastos et al., 2015; Jesus et al., 2019). However, values were higher than those of *P. persica* stems studied. It was shown that catechin is one of the flavan-3-ol acids compounds with the highest antioxidant activity (Frankel et al., 1997).

4.4. Volatile compounds

GC-MS analysis of the volatile compounds from leaves and stems of *P. persica* revealed that benzaldehyde was detected as the major volatile leaf component, whereas myrcene and terpinolene were found to be the most important compounds in stems. Benzaldehyde levels were higher than those reported by other studies (Horvat and Chapman, 1990; Verma et al., 2017). Benzaldehyde probably arises from the cyanogenic glycoside amygdalin, a typical constituent of many *Prunus* species (Takeoka et al., 1990). Based on market demand, it represent the second most important molecule in the industry as ingredient for flavouring foods and beverages; it is also requested by fragrance industries (Verma et al., 2017). Furthermore, Farré-armengol et al. (2016) showed a physiological

importance of benzaldehyde from green leaf in plant protection against microbe infection or predators, constituting a relevant role in ecological signalling.

Comparing young to mature leaves, *α*-pinene, 1-pentanol, (*Z*)-2-hexenal, 2,6-dimethylnonane, 2,9-dimethylnonane, 1-octanol, 1-nonen-3-ol, 6-methyldodecane, (*E*)-2-tridecane, (*Z*)-2-tridecane and 3-methyldecanol were found in mature peach leaves only and myrcene, limonene, (*E*)-*β*-ocimene, *γ*-terpinene, *β*-bourbonene, *β*-caryophyllene, (*Z*)-3-hexenyl acetate, benzyl alcohol, 1-nonanol, *n*-tetradecane, 1-cyclohexyloctant and *n*-hexadecane were detected exclusively in young peach leaves. These results confirm previous works indicating that developmental stages and phenological processes affects the emission of VOCs (Bracho-Nunez et al., 2011). The profiles of the emitted VOCs is strongly specie-specific, so their accumulation in plants may results constitutively different (Vieira et al., 2016). Concerning terpinolene, 1,8-cineole, (*E*)-2-hexenal and benzaldehyde, their levels remained approximately the same during leaf maturation, which confirm previous studies (Horvat and Chapman, 1990). Biosynthesis of mono- and sesquiterpenes in plants is often related to the presence of specialized secretory structures (e.g. glandular trichomes, oil and resin ducts and glandular epidermis); consequently, each part of the plant may have typical aroma compounds composition (Lewinsohn et al., 1998).

Takahashi et al. (2006), when analysing volatiles from leaves of the subgenera (*Cerasus*, *Padus*, *Laurocerasus*, and *Prunus*) in the genus *Prunus* found linalool, phenethyl alcohol, and coumarin compounds. These compounds were not found in *P*. *persica* leaves studied in the present work.

According to our bibliographic researches, there is no previous work published to date on the volatile compounds of *P*. *Persica* stems.

5. Conclusion

Most of the studies on peach are focused on the economic, nutritional and antioxidant importance of peach fruit. Conversely, very few works focused on the other organs of peach tree, as leaves, branches, stems, etc. This study aims to valorize the peach agricultural by-products (young and mature leaves and stems) characterizing their bioactive and mineral compounds. Decreased Ca and Na levels were observed throughout maturity. However, no statistical difference ($p > 0.05$) for the micronutrients was observed between the leaves. The stems contained only traces. In addition, the mineral and phenol contents were cultivar-dependent. Volatile compounds of leaf and stems from peach trees were dominated by the benzaldehyde compound. The contents of volatile and phenolic compounds were significantly affected by peach by-product as well as the cultivar. Quantitatively, total phenols were the most abundant in the young leaves and stems of the O'Henry cultivar. As well, stems showed the highest levels of total

355 phenols, total flavonoids and *o*-diphenols among the peach by-products studied but the lowest flavonol contents.
356 From HPLC-DAD analysis, chlorogenic acid, quercetin-3-galactoside and quercetin-3-rutinoside were the most
357 concentrated compounds in the leaves whereas catechin was the most abundant in the stems.
358 Furthermore, stem extracts showed higher antioxidant activities for the two tests evaluated. In conclusion, even if an
359 essential oil is not present in peach leaves and stems, these agricultural by-products may be used as flavouring
360 agents to substitute expensive natural pure compounds, i.e. for masking undesirable odors. Furthermore, they may
361 also contain secondary metabolites useful for improving health.
362

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Compliance with Ethical Standards

Conflict of interest

The authors declare that they have no conflict of interest.

519

Tables

Table 1. *Mineral nutrients evaluated in young, mature leaves and stems of five Prunus persica cultivars grown in the center of Tunisia*

	Young leaves					Mature leaves					Stems				
Minerals	**Sweet Cap**	**Early Maycrest**	**O'Henry**	**Flordastar**	**Rubirich**	**Sweet Cap**	**Early Maycrest**	**O'Henry**	**Flordastar**	**Rubirich**	**Sweet Cap**	**Early Maycrest**	**O'Henry**	**Flordastar**	**Rubirich**
Macronutrients (mg g^{-1} MS)															
N	148.13^{b}	$157.79^{a.b}$	143.43^{ab}	158.80^{ab}	167.38^{a}	150.73^{p}	141.49^{pq}	131.80^{q}	139.08^{pq}	133.19^{q}	0.06^{vw}	0.08^{v}	0.05^{v}	0.06^{vw}	0.05^{w}
Na	8.17^{b}	15.55^{a}	5.22^{cd}	7.78^{bc}	3.06^{d}	0.25^{p}	0.19^{p}	0.26^{p}	0.26^{p}	0.23^{p}	8.19^{bc}	12.14^{w}	6.21^{wx}	5.28^{x}	23.83^{v}
Mg	12.88^{b}	24.20^{a}	7.47^{c}	7.72^{c}	5.88^{c}	8.75^{q}	8.98^{q}	7.88^{q}	7.96^{q}	12.01^{p}	12.90^{b}	24.05^{v}	6.95^{x}	5.53^{x}	7.94^{x}
Ca	66.45^{a}	52.21^{b}	30.87^{c}	40.05^{c}	19.02^{d}	23.69^{q}	18.96^{q}	22.37^{q}	24.96^{q}	33.45^{p}	66.59^{a}	60.22^{vw}	41.39^{wx}	30.09^{x}	76.89^{v}
K	18.24^{a}	20.20^{a}	20.16^{a}	20.65^{a}	15.49^{a}	23.36^{q}	21.45^{q}	20.41^{q}	19.41^{q}	30.16^{p}	18.28^{a}	4.01^{w}	3.86^{w}	4.29^{w}	3.6^{w}
Micronutrients (μg g^{-1} MS)															
Zn	14.68^{a}	15.35^{a}	18.22^{a}	14.23^{a}	18.85^{a}	12.38^{p}	14.80^{p}	9.95^{p}	11.28^{p}	11.94^{p}	0.02^{v}	0.02^{v}	0.02^{v}	0.02^{v}	0.02^{v}
Mn	60.83^{a}	46.92^{abc}	43.23^{bc}	54.79^{ab}	39.34^{c}	90.96^{p}	78.50^{p}	74.17^{p}	55.74^{p}	69.80^{p}	0.01^{vw}	0.01^{v}	0.01^{v}	0.01^{w}	0.01^{w}
Cu	4.12^{vw}	2.48^{c}	4.80^{ab}	3.14^{c}	6.61^{a}	6.27^{p}	4.99^{p}	5.64^{p}	4.98^{p}	4.47^{p}	0.01^{v}	tr^{v}	tr^{v}	tr^{v}	0.01^{v}

Values are the means of the five different *Prunus persica* by-products samples (n=3). Different superscripts for the same quality parameter mean significant differences among cultivars $p<0.05$. For any parameter, different letters a – e, p-t and v-z indicate significant differences among young, mature leaves and stems, respectively of the five cultivars.

Table 2. *Total phenolic compounds and antioxidant activities (EC50) expressed as mg 100g^{1} DW and evaluated in young, mature leaves and stems of five Prunus persica cultivars*

		Young leaves					***Mature leaves***					***Stems***				
		Sweet Cap	***Early Maycrest***	***O'Henry***	***Flordastar***	***Rubirich***	***Sweet Cap***	***Early Maycrest***	***O'Henry***	***Flordastar***	***Rubirich***	***Sweet Cap***	***Early Maycrest***	***O'Henry***	***Flordastar***	***Rubirich***
o-diphenols		1534.85^{a}	1285.01^{b}	1522.74^{a}	1177.36^{b}	1546.97^{a}	991.15^{p}	1211.93^{p}	1048.36^{p}	1239.19^{p}	1289.45^{p}	2792.58^{v}	3084.37^{v}	2670.10^{v}	2226.28^{w}	1957.57^{w}
Flavonols		1155.64^{bc}	1169.63^{bc}	1309.39^{ab}	1036.43^{c}	1413.05^{a}	747.72^{q}	935.96^{pq}	872.33^{pq}	982.38^{pq}	1051.71^{p}	234.16^{w}	210.97^{w}	247.22^{w}	328.40^{v}	266.27^{w}
Flavonoides		1011.26^{a}	691.86^{d}	790.36^{c}	689.82^{d}	869.13^{b}	732.29^{p}	809.02^{p}	649.25^{p}	721.74^{p}	778.72^{p}	1038.22^{v}	1057.02^{v}	1071.22^{v}	829.42^{w}	782.76^{w}
Phenols		4593.00^{a}	3656.54^{c}	4120.01^{b}	3226.23^{d}	4326.83^{ab}	2534.06^{q}	3448.68^{p}	3071.47^{pq}	3100.84^{pq}	3564.31^{p}	5145.38^{v}	5249.23^{v}	5206.12^{v}	3976.91^{w}	3952.06^{w}
EC50																
	ABTS	316.74^{a}	350.58^{a}	225.30^{b}	384.88^{a}	337.67^{a}	155.35^{t}	335.07^{q}	300.45^{rs}	347.78^{p}	293.33^{rs}	140.34^{w}	85.86^{x}	104.93^{wx}	101.89^{wx}	215.93^{v}
	Reduced power	137.38^{bc}	147.32^{ab}	114.87^{c}	169.45^{a}	82.26^{d}	177.51^{q}	171.54^{q}	272.09^{p}	145.0^{q}	166.92^{q**}	62.48^{vw}	64.07^{vw}	72.71^{v}	60.63^{w}	45.54^{x}

Values are the means of the five different *Prunus persica* by-products samples (n=3). Different superscripts for the same quality parameter mean significant differences among cultivars $p<0.05$. For any parameter, different letters a – e, p-t and v-z indicate significant differences among young, mature leaves and stems, respectively of the five cultivars.

Table 3. *Individual phenolic compounds (mg 100g^{-1} DW) identified in young, mature leaves and stems of five Prunus persica cultivars grown in the center of Tunisia*

	Young leaves					Mature leaves					Stems				
Phenolic compounds	**Sweet Cap**	**Early Maycrest**	**O'Henry**	**Flordastar**	**Rubirich**	**Sweet Cap**	**Early Maycrest**	**O'Henry**	**Flordastar**	**Rubirich**	**Sweet Cap**	**Early Maycrest**	**O'Henry**	**Flordastar**	**Rubirich**
Hydroxycinnamic acid derivatives															
Neochlorogenic acid	45.55^{a}	42.82^{ab}	40.06^{ab}	31.97^{b}	51.41^{a}	38.73^{p}	17.29^{q}	14.09^{q}	17.53^{q}	15.13^{q}	17.16^{v}	14.82^{vw}	15.93^{vw}	9.00^{x}	11.82^{wx}
Chlorogenic acid	178.17^{a}	161.37^{ab}	166.48^{a}	142.69^{b}	178.25^{a}	139.10^{p}	129.21^{p}	128.80^{p}	127.34^{p}	135.13^{p}	8.01^{x}	59.27^{w}	66.59^{v}	10.42^{x}	9.71^{x}
Caffeic acid	18.40^{a}	13.33^{b}	13.71^{b}	14.76^{b}	16.36^{ab}	22.28^{p}	17.11^{q}	12.85^{r}	15.20^{qr}	14.74^{qr}	5.49^{v}	3.33^{wx}	4.12^{w}	2.56^{x}	2.75^{x}
Coumaric acid	12.59^{b}	13.16^{b}	10.14^{b}	9.80^{b}	19.10^{a}	11.90^{q}	9.02^{q}	34.17^{p}	7.34^{q}	10.28^{q}	12.79^{v}	8.07^{w}	11.30^{vw}	7.68^{w}	7.91^{w}
Ferulic acid	1.70^{d}	2.60^{bc}	3.06^{ab}	2.28^{cd}	3.30^{a}	2.21^{r}	2.95^{pq}	3.00^{pq}	2.38^{qr}	3.58^{p}	3.59^{v}	3.04^{v}	4.06^{v}	3.39^{v}	3.50^{v}
Flavan-3-ols acids															
Catechin	24.61^{a}	31.29^{a}	36.33^{a}	31.98^{a}	30.66^{a}	46.59^{pq}	51.63^{p}	39.98^{pq}	44.33^{pq}	36.05^{q}	177.00^{v}	187.47^{v}	199.98^{v}	170.09^{v}	172.67^{v}
Epicatechin	31.82^{a}	40.46^{a}	46.98^{a}	41.35^{a}	39.65^{a}	60.24^{pq}	66.77^{p}	51.70^{pq}	57.33^{pq}	46.62^{q}	42.26^{v}	33.80^{w}	37.43^{vw}	33.51^{w}	37.13^{vw}
Hydroxybenzoic acids															
Gallic acid	24.17^{a}	23.52^{ab}	18.20^{b}	19.60^{ab}	21.72^{ab}	30.46^{p}	24.47^{q}	17.06^{r}	20.19^{r}	19.57^{r}	7.29^{vw}	4.59^{w}	5.46^{w}	6.45^{vw}	8.83^{v}
Flavonols															
Quercetin-3-rutinoside	170.12^{b}	190.31^{ab}	206.37^{a}	183.49^{b}	179.56^{b}	130.46^{p}	163.49^{p}	153.66^{p}	169.12^{p}	158.16^{p}	63.88^{w}	72.62^{vw}	83.78^{v}	83.15^{v}	71.06^{vw}
Quercetin-3-galactoside	188.55^{c}	214.51^{ab}	232.16^{a}	203.36^{ab}	199.00^{bc}	159.29^{p}	198.91^{p}	168.63^{p}	200.42^{p}	175.20^{p}	70.79^{w}	98.16^{v}	90.92^{v}	89.86^{v}	87.52^{vw}
Anthocyanins															
Cyanidin-3-glucoside	0.19^{a}	0.06^{bc}	0.07^{b}	0.01^{d}	0.03^{cd}	0.44^{q}	0.67^{p}	0.25^{r}	nd	0.04^{s}	0.09^{vw}	0.02^{x}	0.02^{wx}	0.11^{v}	0.08^{vwx}
Cyanidin-3-rutinoside	0.14^{b}	nd	0.22^{a}	nd	nd	1.05^{p}	1.13^{p}	0.13^{q}	nd	nd	0.11^{w}	0.09^{w}	0.08^{w}	0.32^{v}	0.28^{v}

Values are the means of the five different *Prunus persica* by-products samples (n=3). Different superscripts for the same quality parameter mean significant differences among cultivars $p<0.05$. For any parameter, different letters a – e, p-t and v-z indicate significant differences among young, mature leaves and stems, respectively of the five cultivars.

Table 4. *Volatile compounds (% on total volatile compounds) evaluated in young, mature leaves and stems of five Prunus persica cultivars grown in the center of Tunisia.*

Volatiles	LRI	Young leaves					Mature leaves					Stems				
		Sweet Cap	Early Maycrest	O'Henry	Flordastar	Rubirich	Sweet Cap	Early Maycrest	O'Henry	Flordastar	Rubirich	Sweet Cap	Early Maycrest	O'Henry	Flordastar	Rubirich
α-pinene	941	-	-	–	–	–	0.53^{q}	0.67^{q}	0.77^{q}	1.13^{p}	0.57^{q}	3.67^{x}	5.47^{v}	4.53^{w}	5.30^{v}	-
Camphene	955	-	-	-	-	-	-	-	-	-	-	0.20^{w}	0.30^{v}	-	0.27^{w}	-
Sabinene	977	-	-	-	-	-	-	-	-	-	-	0.97^{w}	1.03^{v}	0.93^{x}	1.10^{v}	-
β-pinene	982	-	-	-	-	-	-	-	-	-	-	2.83^{w}	3.27^{v}	2.57^{y}	2.67^{x}	-
myrcene	933	0.27^{ab}	–	0.47^{a}	0.47^{a}	–	-	–	–	–	–	20.87^{w}	23.37^{v}	22.33^{v}	18.67^{x}	-
α-terpinene	1020	-	-	-	-	-	-	-	-	-	-	0.50^{x}	0.57^{v}	0.53^{w}	0.50^{x}	-
p-cymene	1028	-	-	-	-	-	-	-	-	-	-	1.77^{w}	1.80^{w}	2.20^{v}	1.53^{x}	-
limonene	1032	0.60^{a}	–	0.43^{ab}	0.47^{ab}	0.27^{b}	–	–	–	–	–	9.37^{w}	10.20^{v}	10.27^{v}	8.63^{x}	-
(*E*)-*β*-ocimene	1052	–	0.17^{ab}	–	0.13^{ab}	0.33^{a}	–	–	–	–	–	0.77^{w}	0.40^{x}	-	0.27^{y}	2.33^{v}
γ-terpinene	1063	–	–	0.10^{ab}	0.17^{a}	–	–	–	–	–	–	1.77^{y}	2.43^{w}	2.63^{v}	1.93^{x}	-
terpinolene	1090	0.73^{a}	0.30^{a}	1.23^{a}	0.97^{a}	0.43^{a}	0.73^{pq}	0.83^{p}	0.60^{q}	–	–	18.97^{x}	26.20^{v}	25.23^{v}	20.50^{w}	-
Monoterpene hydrocarbones		$\mathbf{1.60^{ab}}$	$\mathbf{0.47^{b}}$	$\mathbf{2.23^{a}}$	$\mathbf{2.20^{a}}$	$\mathbf{1.03^{ab}}$	$\mathbf{1.27^{pq}}$	$\mathbf{1.50^{p}}$	$\mathbf{1.37^{pq}}$	$\mathbf{1.13^{q}}$	$\mathbf{0.57^{r}}$	$\mathbf{61.67^{x}}$	$\mathbf{75.03^{v}}$	$\mathbf{71.23^{w}}$	$\mathbf{61.37^{x}}$	$\mathbf{2.33^{y}}$
1,8-cineole	1034	–	0.43^{ab}	0.60^{a}	–	0.40^{ab}	0.63^{q}	0.70^{q}	1.07^{pq}	1.53^{p}	0.83^{q}	-	-	-	-	-
artemisia ketone	1064	–	–	–	–	–	–	–	–	0.43	–	-	-	-	-	-
(*E*)-tagetone	1141	-	-	-	-	-	-	-	-	-	-	0.67^{w}	0.53^{x}	0.57^{x}	0.33^{y}	1.23^{v}
camphor	1145	–	–	–	–	0.20	–	–	0.50^{x}	–	–	1.17^{w}	-	-	-	1.50^{v}
Oxygenated monoterpenes		**–**	$\mathbf{0.43^{ab}}$	$\mathbf{0.60^{a}}$	**–**	$\mathbf{0.60^{a}}$	$\mathbf{0.63^{q}}$	$\mathbf{0.70^{q}}$	$\mathbf{1.57^{p}}$	$\mathbf{1.97^{p}}$	$\mathbf{0.83^{q}}$	$\mathbf{1.83^{w}}$	$\mathbf{0.53^{x}}$	$\mathbf{0.57^{x}}$	$\mathbf{0.33^{y}}$	$\mathbf{2.73^{v}}$
benzothiazole	1226	–	–	–	0.23	–	–	–	–	–	–	-	-	-	-	-
cyclohexyl isothiocyanate	1236	–	–	–	0.23	–	–	–	–	–	–	0.90^{x}	0.60^{z}	0.77^{y}	1.17^{w}	1.83^{v}
Nitrogen/sulfur derivatives		–	–	–	0.47	–	–	–	–	–	–	0.90^{x}	0.60^{z}	0.77^{y}	1.17^{w}	1.83^{v}
Theaspirane I	1298	-	-	-	-	-	-	-	-	-	-	0.23^{v}	-	-	0.20^{v}	-
Theaspirane II	1315	-	-	-	-	-	-	-	-	-	-	0.23^{v}	-	-	0.23^{v}	-
Apocarotenoides		-	-	-	-	-	-	-	-	-	-	0.47^{v}	-	-	0.43^{w}	-
β-bourbonene	1385	–	–	0.20^{a}	–	0.17^{a}	–	–	–	–	–	-	-	-	-	-
presilphiperfol-7-ene	1346	-	-	-	-	-	-	-	-	-	-	0.67^{w}	-	-	0.30^{x}	1.13^{v}
7-epi-silphiperfol-5-ene	1345	-	-	-	-	-	-	-	-	-	-	0.90^{y}	0.60^{z}	1.17^{w}	1.07^{x}	2.03^{v}
silphiperfol-6-ene	1350	-	-	-	-	-	-	-	-	-	-	0.13^{w}	-	-	0.27^{v}	-
β-caryophyllene	1419	1.20^{a}	0.10^{b}	0.67^{ab}	–	0.37^{ab}	–	–	–	–	–	0.87^{x}	0.57^{z}	1.53^{w}	0.60^{y}	2.17^{v}
trans-*α*- bergamote	1437	–	–	–	–	-	–	–	–	–	–	0.77^{y}	0.53^{z}	1.60^{v}	0.90^{x}	1.07^{w}

Values are the means of the five different *Prunus persica* by-products samples (n=3). LRI: Linear retention indexes. Different superscripts for the same quality parameter mean significant differences among cultivars $p<0.05$. For any parameter, different letters a – e, p-t and v-z indicate significant differences among young, mature leaves and stems, respectively of the five cultivars.

Table 4. *(continued)*

Volatiles	LRI	Young leaves					Mature leaves					Stems				
		Sweet Cap	Early Maycrest	O'Henry	Flordastar	Rubirich	Sweet Cap	Early Maycrest	O'Henry	Flordastar	Rubirich	Sweet Cap	Early Maycrest	O'Henry	Flordastar	Rubirich
α-humulene	1455	-	-	-	-	0.30^{a}	-	-	-	-	-	0.47^{x}	-	0.77^{w}	0.23^{y}	0.83^{v}
(E)-β-farnesene	1458	-	-	-	-	-	-	-	-	-	-	0.60^{x}	0.43^{z}	0.90^{v}	0.53^{y}	0.77^{w}
Sesquiterpenes hydrocarbones		**1.20^{a}**	**0.10^{b}**	**0.87^{a}**	–	**0.83^{a}**	–	–	–	–	–	**4.30^{x}**	**2.13^{z}**	**5.97^{w}**	**3.90^{y}**	**8.00^{v}**
(E)-neroidol	1564	-	-	-	-	-	-	-	-	-	-	0.43^{w}	0.57^{v}	-	-	-
Oxygenated sesquiterpenes		-	-	-	-	-	-	-	-	-	-	**0.43^{w}**	**0.57^{v}**	**-**	**-**	**-**
1-pentanol	768	–	–	–	–	–	3.07^{p}	3.67^{p}	2.40^{p}	3.23^{p}	4.20^{p}	-	-	-	-	-
hexanal	802	1.60^{a}	0.23^{b}	0.23^{b}	0.40^{b}	0.40^{b}	0.60^{p}	–	–	–	–	0.47^{x}	0.50^{x}	0.57^{w}	0.30^{y}	1.67^{v}
(Z)-2-hexenal	842	–	–	–	–	–	3.30^{p}	4.70^{p}	4.10^{p}	4.73^{p}	5.30^{p}	-	-	-	-	-
(E)-2-hexenal	856	4.10^{a}	0.60^{c}	1.53^{bc}	1.70^{b}	1.00^{bc}	1.60^{p}	–	–	1.67^{p}	2.17^{p}	0.70^{w}	0.37^{z}	0.63^{x}	0.47^{y}	1.97^{v}
1-hexanol	869	–	–	–	–	–	0.67^{p}	0.73^{p}	–	–	–	-	-	-	-	-
n-nonane	900	–	–	–	–	–	–	0.60^{p}	–	–	–	-	-	-	-	-
heptanal	901	–	–	–	0.27	–	–	–	–	–	–	0.63^{w}	-	-	0.60^{w}	0.80^{v}
benzaldehyde	962	85.40^{b}	95.13^{a}	86.33^{b}	88.73^{b}	91.30^{ab}	77.57^{pq}	76.23^{pq}	81.33^{p}	70.07^{q}	73.53^{pq}	12.70^{x}	3.70^{y}	2.33^{z}	17.00^{w}	48.70^{v}
(Z)-3-hexenyl acetate	1008	0.37^{b}	0.10^{c}	0.63^{a}	–	0.20^{bc}	–	–	–	–	–	-	-	-	-	-
2,6-dimethylnonane	1012	–	–	–	–	–	1.63^{q}	1.67^{q}	1.60^{q}	2.67^{p}	2.27^{pq}	-	-	-	-	-
2,9-dimethylnonane	1024	–	–	–	–	–	2.53^{q}	2.93^{q}	2.23^{q}	4.47^{p}	3.47^{pq}	-	-	-	-	-
benzyl alcool	1034	0.57^{a}	0.47^{a}	–	0.57^{a}	0.37^{a}	–	–	–	-	–	-	-	-	-	-
4-methyldecane	1059	–	–	–	–	–	–	–	0.50^{p}	–	–	-	-	-	-	-
1-octanol	1073	–	–	–	–	–	1.30^{q}	1.30^{q}	1.03^{q}	0.20^{p}	1.50^{pq}	-	-	-	-	-
1-nonen-3-ol	1088	–	–	–	–	–	1.57^{qr}	1.63^{qr}	1.33^{r}	2.73^{p}	2.10^{pq}	-	-	-	-	-
nonanal	1104	–	–	0.40^{a}	0.17^{ab}	–	–	–	–	–	–	0.40^{w}	0.53^{v}	0.40^{w}	0.33^{x}	-
1-nonanol	1172	2.10^{a}	0.77^{b}	1.80^{ab}	2.30^{a}	0.87^{b}	–	–	–	–	–	10.07^{x}	9.90^{y}	11.13^{w}	7.77^{z}	24.90^{v}
(Z)-3-hexenyl butyrate	1188	–	–	0.73^{a}	–	–	-	–	–	–	–	-	-	-	-	-
decanal	1204	–	–	–	0.23^{a}	–	–	–	–	–	–	0.30^{w}	-	-	0.33^{v}	-
1-cyclohexylhexane	1237	-	-	-	-	-	-	-	-	-	-	0.60^{y}	0.53^{x}	0.73^{w}	0.47^{z}	1.30^{v}
6-methyldodecane	1245	–	–	–	–	–	0.47^{pq}	0.43^{q}	0.33^{q}	0.63^{p}	–	-	-	-	-	-
(E)-2-tridecene	1305	–	–	–	–	–	0.47^{pq}	0.30^{q}	–	0.60^{p}	–	-	-	-	-	-
(Z)-2-tridecene	1315	–	–	–	–	–	0.83^{pq}	0.60^{q}	0.53^{q}	0.97^{p}	0.77^{pq}	-	-	-	-	-
3-methylundecanol	1326	–	–	–	–	–	0.53^{q}	0.33^{r}	0.37^{r}	0.83^{p}	–	-	-	-	-	-
1-tetradecene	1393	–	–	–	0.17^{a}	–	–	–	–	–	–	-	-	-	-	-
n-tetradecane	1400	0.53^{a}	$0.20^{a.b}$	0.47^{a}	0.40^{a}	–	–	–	–	–	–	0.70^{y}	0.93^{w}	0.43^{z}	0.77^{x}	1.13^{v}
1-cyclohexyloctane	1442	0.20^{a}	0.10^{a}	–	–	–	–	–	0.23^{a}	–	–	0.40^{w}	0.43^{v}	0.40^{w}	0.43^{v}	-
n-pentadecane	1500	–	–	0.50^{a}	–	–	–	–	–	–	–	0.37^{w}	0.50^{v}	-	0.37^{w}	-
(Z)-3-hexenyl benzoate	1570	–	–	–	–	0.27^{a}	–	–	–	–	–	-	-	-	-	-
n-hexadecane	1600	0.57^{b}	0.17^{c}	1.03^{a}	0.30^{bc}	0.30^{bc}	–	–	–	–	–	0.57^{x}	0.73^{w}	0.53^{y}	0.83^{v}	-
Others		**95.43^{a}**	**97.77^{a}**	**93.67^{a}**	**95.47^{a}**	**94.70^{a}**	**96.13^{p}**	**95.13^{pq}**	**95.77^{pq}**	**94.60^{q}**	**95.30^{pq}**	**27.90^{x}**	**18.13^{y}**	**17.17^{y}**	**29.67^{w}**	**80.47^{v}**
Total volatiles		**98.23^{a}**	**98.77^{a}**	**97.37^{a}**	**98.13^{a}**	**97.17^{a}**	**98.03^{pq}**	**97.33^{q}**	**98.70^{p}**	**97.70^{pq}**	**96.70^{q}**	**97.50^{v}**	**97.00^{v}**	**95.70^{w}**	**96.87^{vw}**	**95.37^{w}**

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