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The appraisal of qualitative parameters and antioxidant contents during postharvest peach fruit ripening underlines the genotype significance

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ABSTRACT

Several studies document that peach and nectarine ripening related parameters can be efficiently predicted in a non-destructive manner; however, such studies are being restricted in a relatively limited number of cultivars and parameters measured. In addition, the combined effect of genotype and postharvest ripening on phytochemical content of peach and nectarines has not been elucidated. In the present study, the I_{AD} maturity index, ripening-related parameters, phenolic and flavonoid contents and *in vitro* antioxidant capacity were determined in fruit from 26 commercially important peach and nectarine cultivars, grown in Greece. Analyses were carried out at harvest and after additional ripening at room temperature (~23 ± 2 °C) for 1, 3 and 5 days, to simulate shelf life conditions. Results indicated great variation in the I_{AD} index (variation coefficient = 32%); this index can be used as reference in future studies on a cultivar basis. Flesh firmness was the strongest predicted parameter from the I_{AD} index during off-tree ripening. Segregation of peach and nectarine cultivars revealed great differences on quality parameters and on their ripening behavior. Varietal differences were more pronounced regarding the polyphenolic content; indicatively, total phenol (TP) content ranged from 11.7 to 90.1 mg gallic acid equivalents (GAE) 100^{-1} g fresh weight (FW) at harvest. 'Sun Cloud' and 'Gladys' fruits among peach cultivars and 'Tasty Free' fruits among nectarine cultivars demonstrated high antioxidant contents. Interestingly, postharvest ripening of peach and nectarine cultivars did not seem to affect polyphenolic content and antioxidant capacity in a constant mode. Hence I_{AD} was not correlated with antioxidant contents and to our knowledge this is the first work examining this correlation. Furthermore, data underlines that peach cultivars in general were characterized by higher antioxidant contents compared to nectarine cultivars; this was also the case for late-harvested cultivars *versus* the early-harvested ones.

1. Introduction

Peach and nectarine have a relatively large variation in the on-tree maturity; due to this variability it is essential to apply successive harvests. Maturity at harvest is usually determined based on commercial size and diameter, background color and flesh firmness (Crisosto and Valero, 2008). However, color can be hardly distinguished in some cultivars as an intense blush is developed before the fruit is ripe for harvest, while firmness determination is carried out in a destructive manner, and may vary for a given cultivar in relation to fruit size, climatic conditions, and agronomical practices (Iglesias and Echeverria, 2009).

Nowadays, non-destructive techniques have been developed to precisely evaluate ripening stage and assess fruit internal quality attributes. Among these non-destructive approaches, visible/near infrared (vis/NIR) spectroscopy seems particularly promising since it provides fast and reliable information on internal characteristics of many fruit species (Nicolaï et al., 2007; Vanoli and Buccheri, 2012; Farneti et al., 2015). A vis/NIR device is the DA-meter, which measures the I_{AD} index which is the absorbance difference between 670 nm (the absorbance peak for chlorophyll in stone-fruit) and 720 nm (the minimum absorbance which does not change as chlorophyll is degraded in the peel) (Ziosi et al., 2008). The measurement of the fruit's chlorophyll index gives an

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indication of the ripening stage. The I_{AD} index has allowed to assess peach ripening stage in the field and during storage (Herrero-Langreo et al., 2011; Bonora et al., 2013; Shinya et al., 2013). Nevertheless, reports document the relationships among I_{AD} and specific ripening-related changes in a relatively small number of peach and nectarine cultivars. Therefore, it is an emerging need to set non-destructive index thresholds on a cultivar basis.

Apart from ripening stage and qualitative properties, peach should be additionally evaluated in terms of phytochemical content (Cevallos-Casals et al., 2006; Vicente et al., 2011). Differences are mostly affected by the genotype; this issue is particularly important provided the fact that numerous cultivars exist, while new cultivars are being launched into the market on a yearly basis. Peach is widely consumed, being the second most important temperate fruit crop worldwide. Thus, due to its significant impact on human nutrition, it is important to define cultivars with the highest polyphenolic content (Tomas-Barberán et al., 2001; Gil et al., 2002; Di Vaio et al., 2008; Tavarini et al., 2008; Cantín et al., 2009). This initiative will additionally assist to consider particular genotypes for breeding purposes in order to select and promote cultivars with higher antioxidant content (Cevallos-Casals et al., 2006; Vizzotto et al., 2007; Drogoudi et al., 2008; Cantin et al., 2010; Reig et al., 2013).

Peach fruit physiology has been extensively studied both during on-tree maturation and postharvest ripening after harvest or after cold storage. Nevertheless, little is known on the combined effects of postharvest ripening and genotype on the fruit qualitative and antioxidant potency. The objectives of the current study were initially to evaluate the usefulness of non-destructive assessment of ripening related changes on an array of peach and nectarine cultivars and further to determine the genetic variation in antioxidant phenols and dissect potential correlations among the examined parameters.

2. Materials and methods

2.1. Fruit material and experimental design

Seventeen peach ('May Crest', 'Spring Belle', 'Royal Jem', 'June Gold', 'Royal Glory', 'Rich Lady', 'Maria Bianca', 'Red Haven', 'Sun Cloud', 'Kori', 'Sun Crest', 'Elegant lady', 'Symphonie', 'Fayette', 'Roubidoux', 'Gladys' and 'Opsimo Naoussas') and nine nectarine ('Andrianna', 'Big Bang', 'Rose Diamond', 'Rita Star', 'Big Top', 'Caldesi 2000', 'Red Gold', 'Venus' and 'Tasty Free') cultivars were used in the present study, evenly distributed during the harvest period [June 6–September 10] (Supplementary Fig. 1). Cultivar selection was carried out, mainly based on their commercial importance for Greece, a top-producing country for peaches and nectarines. In particular, the examined cultivars corresponded the 80.1% of peaches and 69.1% of nectarines distributed by the one of the biggest cooperatives in Greece (Agricultural Cooperative of Naoussa) (Supplementary Table 1).

For each cultivar, fruit at commercial maturity stage and of premium quality standards (relatively large size, without defects and on the basis of background skin color that is characteristic for each cultivar) were selected the day of harvest upon arrival to the Agricultural Cooperative of Naoussa. Subsequently, fruit were divided into four homogeneous 24-fruit lots, each analyzed at harvest and after 1, 3 and 5 days maintenance at room temperature ($23 \pm 2\,^{\circ}C$) respectively, to simulate shelf life conditions. Each lot was divided to three eight-fruit sub-lots, corresponding to the three biological replications, unless otherwise stated. The lots used for analysis after 5 days of shelf life were initially used for non-destructive measurements (I_{AD} index, weight loss, respiration rate, ethylene production) throughout the shelf life period.

2.2. Quality attributes

The I_{AD} index was measured with a DA-meter (TR, Sinteleia, Bologna, Italy) on the center of each fruit cheek taking the computer average value displayed on the instrument screen. Weight loss (WL)% was determined by following the formula: $100 \times (A–B)/A$, where A was the fruit weight at harvest and B was the fruit weight after the shelf life period. The color parameters CIE L* (brightness or lightness; 0 = black, 100 = white), a* (−a* = greenness, +a* = redness), b* (−b* = blueness, +b* = yellowness), hue angle (h°) (calculated as $\tan^{-1}b^*/a^*$; 0° = red-purple, 90° = yellow, 180° = bluish-green, 270° = blue) and Chroma (calculated as $(a^{*2} + b^{*2})^{1}/_{2}$; degree of departure from grey to pure chromatic color) were measured in the exocarp at both sides of each fruit, using a Minolta chromatometer (Minolta CR-300, Ramsey, NJ). Flesh firmness (FF) was determined on opposite sides of the equator of each fruit with a penetometer (Effegi, Ravenna, Italy) fitted with an 8 mm plunger; the two readings were averaged for each fruit, and results expressed in Newtons. The soluble solid content (SSC) of the juice was measured with a digital refractometer (model PR-1, Atago, Japan) and data were expressed as %. Titratable acidity (TA) was measured in juices using an automatic titrator (Titrometic 25, Crison Instruments S.A., Barcelona, Spain) and determined by titrating 5 mL of juice with 0.1 N NaOH to a pH end point of 8.2. Results were expressed as g malic acid per 100 g FW. Ripening index (RI) was calculated as the SSC/TA ratio.

2.3. Ethylene and CO_2 production rate

Five two-fruit lots per cultivar were enclosed in 2 L airtight jars and left at room temperature for 2 h. An 1 mL gas sample was taken from the exit air flow of the jars and injected into a gas chromatograph (model Varian 3300, Varian Instruments, Walnut Cree, CA) equipped with a flame ionization detector and a stainless column to determine ethylene. Another 1 mL gas sample was directed to an infrared CO_2 analyzer (model Combo 280, David Bishop Instruments, UK) for the CO_2 measurement. Results were converted into μL $C_2H_4\,kg^{-1}\,h^{-1}$ and mL $CO_2\,kg^{-1}\,h^{-1}$ for the ethylene production and respiration rates, respectively.

2.4. Extraction for polyphenol determinations and antioxidant capacities

Sampling for the antioxidant measurements was carried out after the firmness measurements. Two wedged-shaped slices from the intact peach fruit were dissected, exocarp was removed, immediately frozen into liquid nitrogen and stored at −20 °C until needed.

Five grams of frozen flesh tissue was homogenized in a Polytron with 10 mL extraction buffer comprising water-methanol (2:8, v/v) and 2 mM NaF to inactivate polyphenol oxidases and prevent phenolic degradation due to browning. Homogenates were kept on ice until centrifuged at 11,500 rpm for 15 min at 4 °C. The supernatant was carefully recovered to prevent contamination from the pellet, as elsewhere described (Tomas-Barberán et al., 2001).

2.5. Total phenolics (TPs)

The TPs content was measured using a modified Folin–Ciocalteu colorimetric method (Singleton and Rossi, 1965). The reaction mixture consisted of 0.5 mL of diluted extract, 5 mL of distilled water and 0.5 mL of the Folin-Ciocalteu reagent. The tube was vortexed and then allowed to stand at room temperature for 3 min when one mL of saturated sodium carbonate solution was added.