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An innovative use of DA-meter for peach fruit postharvest management

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ABSTRACT

The DA-meter is a hand-held instrument developed from vis/NIR spectroscopy that measures the index of absorbance difference (I_{AD}) correlated with the flesh chlorophyll-α content of fruit. It was used to divide in two different ripening classes, class I (climacteric peak) and class II (onset of climacteric), harvested fruit belonging to three peach cultivars. At harvest and after 6 days of storage at 20 °C, quality parameters such as flesh firmness (FF), soluble solid contents (SSC), ethylene emission and brown rot incidence were evaluated. Data on ethylene production reported a different emission of phytormone at harvest relating to peach variety and among the two I_{AD} classes. In addition, the I_{AD} values showed a high correlation with FF, while SSC being ethylene-independent did not show marked differences between ripening stages. With respect to brown rot, after 3 days of shelf-life, data from artificial infections, revealed a lesion diameter significantly larger on fruits of class I (10 and 13 mm) than those on class II (8 and 9 mm) for 'Springbelle' and 'Redhaven', respectively. Similarly, in all trials, the incidence of Monilinia rots in fruit natural infected was significantly higher within class I compare to class II. The present work showed the possibility of sorting asymptomatic fruit, harvested at a commercial maturity, by DA-meter, into two I_{AD} classes that will show different brown rot incidence during storage.

1. Introduction

During the last few years, the interest for the development of non-destructive techniques to accurately evaluate the ripening and internal quality of fruit has been increasing. Among these non-destructive approaches, visible/near infrared (vis/NIR) spectroscopy seems particularly promising, since it provides fast and reliable information on the internal characteristics of many fruit species, including stone fruit (Vanoli and Buccheri, 2012). The DA-meter, a hand-held instrument developed from vis/NIR spectroscopy, measures the index of absorbance difference (I_{AD}), and correlates the actual flesh chlorophyll-α content and fruit ethylene production (Ziosi et al., 2008). This relationship is variety specific, associated with consumer acceptability and highly reliable (Ziosi et al., 2008). Moreover, the I_{AD} is more correlated with fruit ripeness than the physico-chemical variables commonly used to describe the maturation process (Costa et al., 2009). The pre-harvest use of the DA-meter has been firstly reported by Ziosi et al. (2008) that confirmed, also with molecular approaches, how the I_{AD} is able to detect both early (transition from pre-climacteric to onset of climacteric stage) and late (transition from onset of climacteric to climacteric stage) physiological changes occurring during on-tree peach fruit ripening. Its application has been extended to other fruit such as plums "Angeleno" and "Autumn Beaut" (Infante et al., 2011), apricots "OrangeRed" and "Bergarouge" (Costa et al., 2010) and apple (Nyasordzi et al., 2013) for planning the best harvest time of each fruit specie and cultivar. The post-harvest use of the DA-meter has been reported for a non-destructive evaluation/prediction of internal quality attributes of peaches (Ziosi et al., 2008) and apples (Nyasordzi et al., 2013; Toivonen and Hampson, 2014) at harvest and during storage.

It is known how an inappropriate time of harvest could affect the organoleptic quality of fruit (Piers et al., 2001) and their susceptibility to disorders, evident as chilling injury (Lurie and Watkins, 2012) or fungal diseases. In fact, a common storage disorder of apples is the scald that usually appears more prevalent on earlier than later harvested fruit (Wilkinson and Fidler, 1973). On the contrary the susceptibility of nectarines and peaches to brown rot, caused by *Monilinia* spp., increases when harvested at optimal commercial maturity. The brown rot represents the most important postharvest disease for stone fruit. The pathogen infects fruit in the field and may remain quiescent until microclimatic

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conditions are favourable and fruit become mature enough for disease appearance (Byrde and Willetts, 1977; Fourie and Holz, 2003). Fruit ripening stage influences thus both, physiological disorders and disease incidence. Specifically, Monilinia rot occurring during storage and transport can be more serious than in the pre-harvest phase, reaching high values of losses (59%) (Larena et al., 2005). In addition to these direct losses, indirect losses, deriving from the appearance of disease after fruit purchase, at consumer level, can negatively affect consumer satisfaction and propensity to consumption. Currently the public demands to reduce pesticide use and improve environmental and human health limit also the pre-harvest application of traditional fungicides and require safer alternatives for fruit disease control.

The main aim of present work was to evaluate the shelf-life of peach fruit harvested at the same date and selected in two different classes of ripening with DA-meter. Particularly the correlations between I_{AD} with (i) quality parameters and ethylene emission, and (ii) brown rot incidence in naturally and artificially infected peaches belonging to three cultivars were investigated.

2. Materials and methods

2.1. Fruit materials and experimental conditions

Peach [*Prunus persica* (L.) Batsh] fruit were obtained from the experimental orchard of the Department of Agricultural Science, located in Bologna, (Italy) (coordinates 44.55–11.41°). The orchard was under conventional management but no fungicide treatments against *Monilinia* spp. were carried out. Fruit of "Springbelle", and "Redhaven" were harvested for two consecutive years and a third variety, "RoyalSummer", was introduced in the second year. All fruit, homogeneous in size, free of visible wounds and rots, were harvested at commercial maturity and were immediately processed for I_{AD} classification.

2.2. I_{AD} classification and fruit analysis

Peach fruit of each variety were initially classified by using a portable DA-meter (TR-Turoni, Forlì, Italy), for single I_{AD} value. The ripening classes for each variety were defined after the ethylene emission analysis of five to ten fruit per I_{AD} class, assessed before storage, as described by Ziosi et al. (2008). The ethylene production was measured by placing a fruit in a 1 L jar sealed with an air-tight lid equipped with a rubber stopper, and left at room temperature for 1 h. A 10 mL gas sample was taken from the jar and injected into a Dani HT 86.01 (Dani, Milan, Italy) packed-gas chromatograph as described previously by Bregoli et al. (2002). After ethylene measurement, each variety was divided in two I_{AD} classes as reported in Table 1. In addition, flesh firmness (FF), soluble solid content (SSC) and titrable acidity (TA) were measured on a sample of 20 fruits for each variety and I_{AD} class. The FF was evaluated on the two opposite sides of each fruit, after eliminating a thin layer of the pericarp, using an automatic pressure tester (FTA-GUSS, South Africa) fitted with an 8 mm plunger. The SSC was determined with an Atago digital refractometer (Optolab, Modena, Italy) by squeezing a part of the mesocarp. The TA was determined on 20 mL of flesh juice (titration with 0.25 N NaOH) using a semiautomatic instrument (Compact-S Titrator, Crison, Modena, Italy). The same measurements were also performed during shelf-life (20 °C) at three and six days after harvest.

2.3. Pathogen inoculum

Monilinia fructicola isolate was obtained from our collection, previously identified by sequencing of ribosomal DNA ITS regions (Mari et al., 2012) and maintained on potato dextrose agar (PDA) at 4 °C until use. In order to obtain a good sporulation, the pathogen was inoculated on V-8 agar (V8A: 250 mL of pure V8 juice and 40 g of agar in 1 L of distilled water) and incubated at 25 °C with 12 h dark, 12 h light cycles for 10 days. Conidia suspensions were prepared by washing the colonies with sterile distilled water containing 0.05% (v/v) of Tween 80, quantified with a haemocytometer and diluted to the concentration of 10^3 conidia per ml.

2.4. Effect of I_{AD} classification on Monilinia rots incidence

2.4.1. Artificially infected fruit

Fruits of each variety, divided in two I_{AD} classes, as reported above, were subdivided in two other lots each. Peaches of the first lot, were wounded with a sterile nail (2 × 2 × 2 mm) and inoculated with 20 μL of a *M. fructicola* conidia suspension (10^3 mL^{-1}), stored at 20 °C for 3 days and evaluated for lesion diameter. The sample unit was represented by 4 replicates of 20 fruits each, for each class and variety.

2.4.2. Naturally infected fruit

Fruit of the second lot, classified by I_{AD} as described above, were stored at 20 °C for 6 days and the natural brown rot incidence was recorded. The sample unit was represented by 4 replicates of 20 fruits for each I_{AD} and variety.

2.5. Data analysis

Data were subjected to one-way analysis of variance (ANOVA) using the statistical package Statistica for windows (Statsoft Inc.). Separation of means was performed using the least significance difference (LSD) test at $P < 0.05$. All experiments were performed for two consecutive years, except for 'Royal Summer' variety and they were carried out in a completely randomized block design.

3. Results

3.1. I_{AD} classification and ethylene emission

On the basis of fruit ethylene emission at harvest, two ripening classes were considered for each variety. For both years, the concentration of ethylene emitted by the two I_{AD} classes was different at harvest as reported on Table 1. Fruit of class I (climacteric peak) showed a significant higher emission of ethylene than fruit of class II (onset of climacteric); the difference in phytormone production between two classes was more than 65% for 'Springbelle' and 'Redhaven' in both years; while for 'Royal Summer' was of 99.7%. In general, these differences were maintained from harvest up to 3 days of shelf life (data not reported).

3.2. I_{AD} classification and fruit quality parameters

The values relating to SSC and TA are reported in Table 2 and in Table 3 are reported the data of FF. At harvest, significant differences were observed comparing the SSC values of 'Springbelle', 'Redhaven', 'Royal Summer' peaches of two I_{AD} classes; generally, fruit of class I showed SSC values significantly higher than fruit of class II, except for 'Springbelle' peach in the second year of experiment. These differences were kept during shelf-life in the first year, while in the second year a great variability was observed. With respect to TA, a significant difference between fruit of two I_{AD} classes was observed only in 'Springbelle' peach in both years: fruits of class I showed always lower values than those of class II. Moreover this difference was also kept after 6 days at 20 °C. Considering FF, a significant difference between the fruit values of the two I_{AD} classes was observed in all cultivars tested and in all trials. The FF values were higher in fruit of class II than those in fruit of