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Quality Attributes and Chilling Injury Susceptibility of New Peach [Prunus Persica (L.) Batsch] Cultivars Grown Under Tunisian Conditions

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***Abstract*—A detailed phenotypic analysis of fruit quality traits and chilling injury symptoms was conducted among ten earlier new peach varieties. Quality attributes such as firmness, soluble solids (ºBrix), pH and titratable acidity (TA) were evaluated. Major symptoms of chilling injury such as mealiness, graininess, leatheriness, flesh browning, flesh bleeding and loss of flavor, were evaluated after storage during 2 or 4 weeks at 5 ºC and 95% RH (relative humidity). Results showed that after 2 weeks of cold storage, mealiness, flesh browning and bleeding were observed but with minor proportions, whereas mealiness was predominant after 4 weeks of storage. The cultivars presented good values of SSC and TA with an intermediate CI susceptibility due to their precocity. This relationship should be considered in the current breeding programs to select cultivars whit enhanced postharvest performance.**

***Keywords*— Peach; fruit quality; firmness; chilling injury**

I. INTRODUCTION

Peach [Prunus persica (L.) Batsch] is one of the most important fruit crops in the world in terms of production (approx. 21 million tons in 2013) with a cultivated area of around 1,538,174 ha [1], and it is the most important species of the genus Prunus. The external quality of fruits is determined by shape, colour and size, while the internal quality is determined by the texture, sugars, organic acids and antioxidant compounds contents, which contribute significantly to the taste and aroma of the fruit [2]. SSC is an important quality trait in peaches and nectarines, since it has been related to the degree of liking and consumer acceptance [3]. Consumer acceptance of high-acid cultivars has been reported to increase as SSC increases, until reaching a plateau (at 11–12 ºBrix) above which it becomes insensitive to any additional increase in SSC. Peach firmness is a significant characteristic in terms of quality; it is important for determining the optimum harvest date [4], and during postharvest, it is useful to follow maturity evolution during storage [5]. In general, fruit quality traits, such as soluble solids concentration (SSC) and titratable acidity (TA) are related to maturation and to the sensory quality of the fruit [6].

Cold storage is used to delay ripening and decay development of many commodities including peaches [7]. If susceptible varieties of peach, nectarine and other stone fruits are held too long at a low temperature, they will not ripen properly when re-warmed and they will suffer physiological disorders collectively known as chilling injury [8]. The chilling injury (CI) manifested as flesh browning, bleeding and mealiness, these symptoms are of commercial importance since shipping of peaches to distant markets and storage before selling requires low temperature [9]. CI develops faster and more intensely when susceptible fruit are stored at temperatures between 2.2 and 7.6°C (killing temperature zone) than when stored at 0°C [10].

Mealiness and leatheriness are fruit flesh textural disorders, where affected ripe fruit has a dry grainy feel when chewed [11]. Browning is often seen in mealy or leathery fruit, although it can occur in the absence of mealiness, when enzymes such as polyphenol oxidase act on phenolic substrates [8; 11]. Peace [11] reported that flesh bleeding results from a spread of red pigment, presumably anthocyanins, through the fruit flesh during cold storage or after subsequent ripening. In simple terms, mealy fruits are dry and soft when ripe, whereas leathery fruits have dry and firm texture when ripe [11; 12]. Leathery fruits show a high degree of cell wall thickening compared with mealy or juicy fruits [13]. Leatheriness has been described as similar but with even less free juice than in mealy fruit, and the texture of the flesh firm rather than grainy [14]. Freestone melting flesh (FMF) and clingstone melting flesh (CMF) cultivars have the potential to develop mealiness in their fruit, depending on whether they carry further genes for susceptibility [11].

The main objectives of this work were (1) to evaluate the quality attributes of peach new cultivars and (2) to quantify the expression of different CI symptoms in the peach varieties after two different periods of cold storage.

II. MATERIALS AND METHODS

A. Plant material

The experiments were carried out with early and mid-season peach [Prunus persica (L.) Batsch] varieties in 2015. Ten commercial peach and nectarine cultivars (Table I) were made in commercial orchards during 2009. The cultivars were budded on the same rootstock (Garnem) and established in a commercial orchard in the zone of Regueb (centre west Tunisia, Sidi Bouzid). Trees were trained to the standard open vase system and planted at a spacing of 6 m × 3 m. Hand-thinning was carried out to reduce fruit load when required. Trees were grown under standard conditions of irrigation, fertilization and pest and disease control.

Table I. Peach and nectarine commercial cultivars fruit type (round or flat, peach or nectarine), flesh colour (yellow or white) and stone adhesion (cling or free) for each variety are shown

Cultivar	Fruit type	Flesh colour	Stone
UFO 2	Round/ peach	white	freestone
UFO 3	Round/ peach	white	freestone
UFO 4	Round/ peach	white	freestone
Viowhite 5	Round/ nectarine	white	freestone
Plawhite 5	Round/ peach	white	clingstone
Plawhite 10	Round/ peach	white	clingstone
Plagold 5	Round/ peach	yellow	clingstone
Plagold 10	Round/ peach	yellow	clingstone
Plagold 15	Round/ peach	yellow	clingstone
Blanvio 10	Flat/ peach	white	freestone

B. Basic biochemical fruit quality traits

Agronomic and fruit quality traits were measured individually in each variety. Harvest date and annual production were also recorded. Harvest date ranged from early-April to mid-July, depending on the variety. Fruits were hand-picked at commercial maturity as assessed by peel fruit colour and flesh firmness. Fruits were considered commercially mature in the tree when their growth had stopped, exhibited yellow ground colour, began softening, and were easily detached. Production (kg/tree) was measured and a representative fruit sample (40 fruits) was taken for fruit quality evaluations as described by [15]. Fruit weight was also scored. Flesh firmness of the fruits was performed by a hand penetrometer in two opposite sides of the fruit that had been previously peeled to remove the epidermis. The SSC (ºBrix), initial pH and titratable acidity (TA) of the juice were measured as described in [15]. The ripening index (RI) was calculated as the ratio between SSC and TA.

C. Chilling injury symptoms

Chilling injury susceptibility was evaluated in the cultivars after storage of samples of 20 fruits per cultivar at 5 ºC and 95% RH (relative humidity) according to [8] during 2 or 4 weeks and subsequent ripening at room temperature during 2 days. Fruits were then evaluated as described in [16] for symptoms of CI such as hard texture with no juice (leatheriness), flesh browning and flesh bleeding (internal reddening). Mealiness was evaluated in all cultivars. Observations were made on the mesocarp and the area around the pit immediately after the fruit were cut into two halves through the suture plane. Fruits which had a dry appearance and little or no juice after hand squeezing were considered leathery. Leatheriness and off-flavor were scored as the proportion of fruit affected with these symptoms in the sample. Internal browning was visually scored on a scale of 1 (no browning) to 6 (severe browning). Bleeding was visually scored on a scale of 1 (no bleeding) to 3 (more than 50% of the flesh with bleeding). Then the percentage of progenies in the population with each proportion/score was calculated for every CI symptom. Eventually, the degree of CI (CI index) was visually assessed according to the global fruit appearance of each genotype, from healthy fruit with no symptoms (1) to severe CI symptoms (6) when the fruit was extremely injured with CI symptoms.

D. Statistical analysis

All traits were measured or scored for each cultivar separately. Mean values and mean standard error (SE), were calculated for each studied trait using SPSS 20.0 (SPSS Inc., Chicago, IL). Data for each cultivar were averaged, and mean values were used as estimated genotypic values. Principal component analysis (PCA) of chilling injury symptoms was carried out using SPSS 20.0. The component matrix (correlated matrix) was evaluated and orthogonal factors were rotated using variance maximizing (Varimax).

III. RESULTS AND DISCUSSION

A. Basic biochemical fruit quality traits

The results for basic biochemical fruit quality traits evaluated among cultivars were summarized in Table 2. Mean values of fruit weight, firmness, soluble solids content (SSC), pH, titratable acidity (TA) and the ripening index ratio (RI = SSC/TA) were determined for each cultivar. Results showed high variability among cultivars for the different fruit quality traits evaluated. These variations supported the quantitative nature of these traits. There was also great genetic diversity in fruit weight: the variety with the largest fruit (124.5 g) was‘Plagold 15’, whereas the one with the smallest (50.2 g) was ‘UFO3’ (Table II). The fruit weight varied greatly among cultivars as a consequence of the variability in tree production and fruits number for each cultivar. Fruit weight is a major quantitative inherited factor determining yield, fruit quality and consumer acceptability [17]. Our analysis revealed a mean firmness of 29 N for ‘UFO 2’ cultivar to 48 N for ‘Plagold 10’ these values are lower than the maximum level of fruit firmness for marketing fresh peaches and nectarines, set by the EU at a 6.5

kg/cm2 (=63.7 N), using a 8 mm diameter probe (Commission Regulation EC, No.1861/2004 of 28 October 2004). The taste of peach fruit is principally governed by the levels of sugars and acids in the juice as well as the fruit ripening ratio. The overall juice SSC levels ranged from 9.2% in 'UFO 2' to 11.5% in 'Plawhite 10'. The pH values varied from 2.08 to 4.09 among cultivars, which are values of normal acidity fruits. We observed remarkable differences among peach cultivars in their juice acidity levels, from 0.51% in 'UFO 4' to 0.76% in 'Viowhite 5'. These observed differences in juice SSC and acidity levels resulted in remarkable variability in fruit ripening ratios, from 13.1 in 'UFO 2' to 22.1 in 'UFO 4'. Crisosto et al. [18] reported that in the case of cultivars with TA > 0.90% and SSC < 12.0%, consumer acceptance was controlled by the interaction between TA and SSC rather than SSC alone. In peaches, the RI is a major organoleptic quality trait of the mature fruit and is commonly used as a quality index [19]. The observed ripeness level of the fruit in this experiment can be considered to be homogeneous among cultivars.

Table II. Mean values and standard error (SE) of the quality attributes in peach and nectarine cultivars.

Cultivar	Firmness	SSC	TA
UFO 2	29 ± 0.1	9.2 ± 0.2	0.70 ± 0.1
UFO 3	34 ± 0.4	9.5 ± 0.1	0.54 ± 0.1
UFO 4	43 ± 0.2	11.3 ± 0.3	0.51 ± 0.1
Viowhite 5	33 ± 0.3	11.5 ± 0.1	0.76 ± 0.1
Plawhite 5	46 ± 0.6	10.5 ± 0.1	0.70 ± 0.1
Plawhite 10	40 ± 0.3	11.5 ± 0.1	0.64 ± 0.1
Plagold 5	31 ± 0.2	10.0 ± 0.2	0.74 ± 0.1
Plagold 10	48 ± 0.8	11.0 ± 0.1	0.60 ± 0.1
Plagold 15	38 ± 0.5	10.5 ± 0.2	0.71 ± 0.1
Blanvio 10	47 ± 0.1	10.0 ± 0.2	0.74 ± 0.1

Units and abbreviations: Firmness (N); N = Newtons; SSC = Soluble solids content (°Brix); TA = Titratable acidity (g malic acid/100 g FW)

B. Chilling injury symptoms

The cultivars showed high variability for all evaluated CI symptoms. As expected, the duration of storage (2 or 4 weeks at 5 ºC) increased the severity of CI symptoms.

After 2 weeks of cold storage, mealiness, bleeding and browning were observed with minor proportion (Fig. 1).

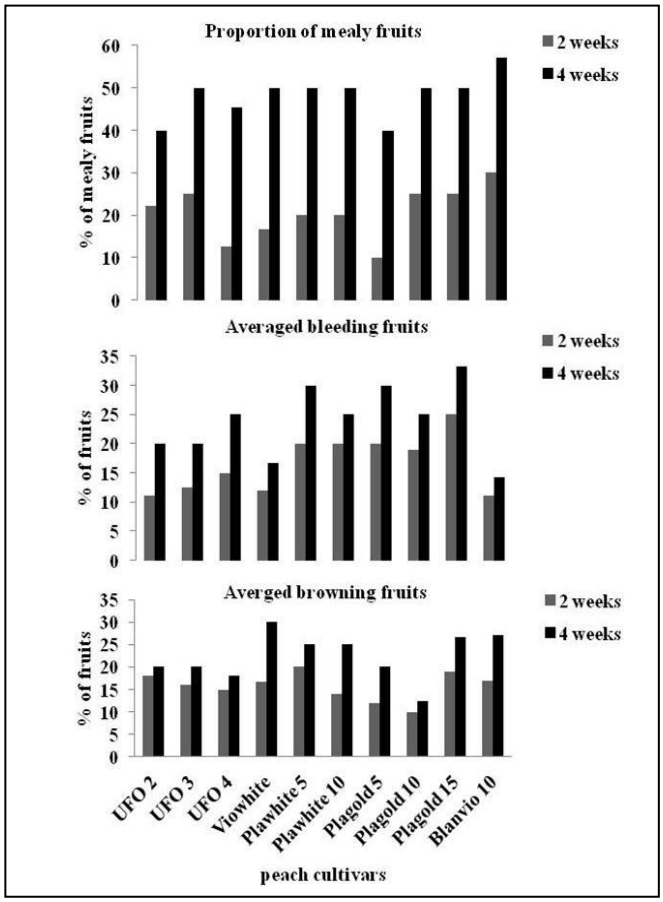

Figure 1. Distribution of internal breakdown symptoms in peach cultivars after storage at 5 ºC for 2 and 4 weeks and then ripening at 20 ºC for 2 days. Mealiness was scored as proportion of mealy fruits in the sample. Bleeding was scored on a scale of 1 (no bleeding) to 3 (more than 50% of the flesh with bleeding). Browning was scored on a scale of 1 (no browning) to 6 (severe browning).

After 4 weeks of cold storage, a considerably higher proportion of fruit was significantly affected by CI symptoms, showing that these disorders are triggered by the cold storage duration. The major CI symptom observed after 4 weeks of storage was mealiness. However, the red flesh color observed could be due to the characteristic pigmentation of fruit flesh. Lurie and Crisosto [20] reported that flesh bleeding could be associated with fruit senescence and not with CI disorders, which could be an explanation of the low impact of storage duration on this CI symptom in this study. Cultivars displayed a great variability (Figure 2a). An examination of PC1 loadings (Figure IIb) suggested that this separation was mainly due to bleeding and mealiness after four weeks of storage.

A PCA of the main CI symptoms was performed to evaluate the susceptibility of cultivars to the physiological disorders during storage (Figure II). Principal components 1 and 2 (PC1 and PC2) accounted for 39.60 and 28.09% of total variance respectively. Cultivars displayed a great variability (Figure IIa). An examination of PC1 loadings (Figure IIb) suggested that this separation was mainly due to

bleeding and mealiness after four weeks of storage. In general, these new peach cultivars have an important SSC/TA report and an intermediate CI susceptibility which could be considered in the current breeding programs to select cultivars whit good nutritional quality and postharvest performance.

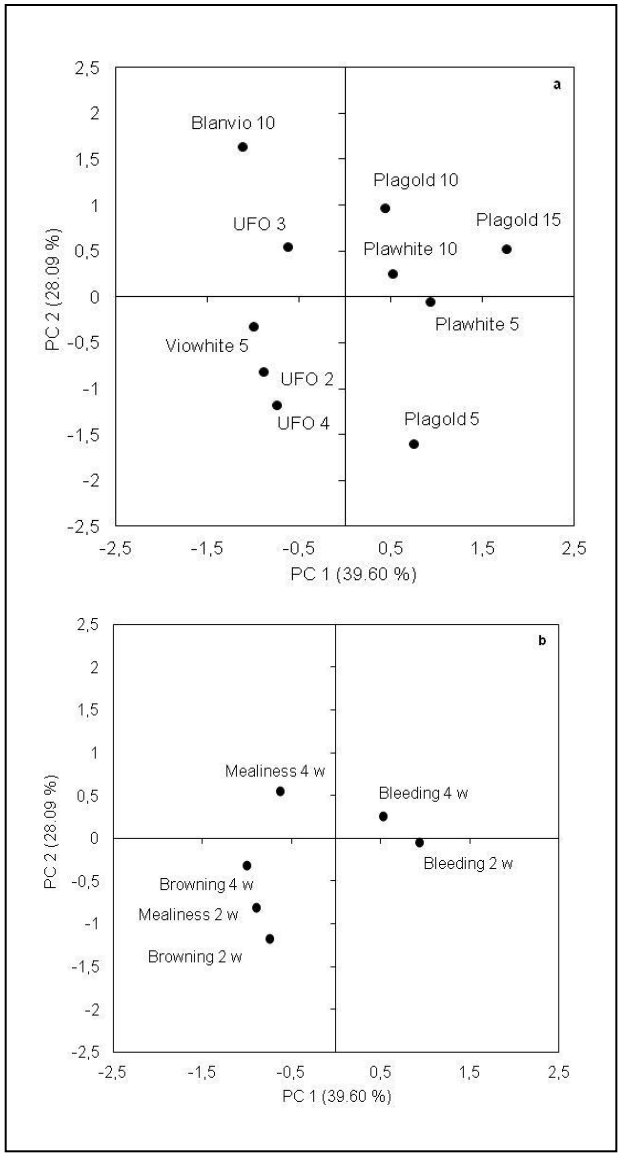

Figure 2. Principal component analysis of main chilling injury symptoms in peach cultivars. Chilling injury symptoms after storage at 5 ºC for 2weeks and then ripening at 20ºC for 2 days.

Conclusions

In general, these new peach cultivars have an important SSC/TA report and an intermediate CI susceptibility which could be considered in the current breeding programs to select cultivars whit good nutritional quality and postharvest performance.

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