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# QUALITY CHANGES DURING POSTHARVEST LIFE IN WHITE FLESHED PEACH (*PRUNUS PERSICA* L. BATSCH) FRUITS: PRELIMINARY OBSERVATIONS

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## Abstract

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Sicilian white flesh peach fruits ecotypes are characterized by a persistent aroma and excellent flavor that is highly appreciated by consumers. Nevertheless, they reach only regional markets, because of fruit sensitivity to decay and the poor information about their postharvest physiology and shelf-life. In this trial, we studied quality changes during postharvest life of non-melting white-flesh peach ecotypes 'Tudia', 'Bella di Bivona' and the cultivar 'Daniela'. Fruits were collected at commercial ripening: a first group was submitted to analytical evaluations and another one was stored (2°C, 90% RH) for 32 days. During this storage period, fruits were submitted to four shelf-life periods at ambient temperature (22°C) for 6 days and analyzed every 3$^{th}$ and 6$^{th}$ day. In the period of shelf-life, during storage of fruit at 2°C, we ascertained that Bella di Bivona and Daniela have a shelf-life of 12–14 days while 'Tudia' could reach up to 25–32 days. Flesh firmness and chilling injuries trends, during shelf-life, allowed to discover 'Tudia' as the variety which presents the best performance after storage at low temperatures for long periods.

*Key words:* ripening, cold storage, shelf-life, chilling injuries

## Introduction

Peach fruit ripens and deteriorates quickly at ambient temperatures whilst low temperature storage is an effective technology to delay ripening and to slow down fruit decay after harvest. Low temperatures reduce fruit respiration, inhibit microbiological development and delay metabolic activities, ripening and senescence (Wang, 1999). Fruits should be stored at a relative humidity greater than 90% and at a temperature between 0 and 2°C to minimize water loss and prolong shelf-life that, in the conditions above, varies from 2 to 6 weeks depending on the variety (Larrigaudiere et al., 1997; Paull, 1999). Low temperatures of around 2.5°C (Von Mollendorff and De Villiers, 1988) normally intensify chilling injuries (CI). However, physiological disorders develop faster and more intensely when peach fruit is stored at temperatures ranging from 2.2 to 7.6°C (killing temperature zone) than near or below 0°C (Harding and Haller, 1934; Crisosto et al., 1999). Loss of quality mainly develops during fruit ripening at ambient temperatures after cold storage and the problem is, usually, not noticed until the fruit reaches customers (Bruhn et al., 1991; Crisosto et al., 1995). CI manifests itself as dry, mealy, woolly (lack of juice) or hard textured fruit with no juice (leatheriness), flesh or pit cavity browning, flesh bleeding (internal reddening) and, in the more advanced stages, flesh tissue separation and cavity formation (Lurie and Crisosto, 2005). Flesh bleeding, expressed as an intense red color development of the flesh, usually radiating from the pit, may be a problem only in some peach cultivars (Lurie and Crisosto, 2005; Liguori et al., 2004 ). It depends on cells near the stone, which contain anthocyanin and it appears as a reddish area around the pit and through-

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out the flesh, when the storage time is extended (Lurie and Crisosto, 2005). The appearance of internal browning in the fruit flesh, or flesh browning, occurs early at temperatures of 2–5°C in respect to the optimal storage temperature of 0°C and it depends on enzymatic activities related to the level of polyphenols of fruits (Laveda et al., 2000; Laveda et al., 2001). CI is genetically influenced and triggered by a combination of storage temperature and storage period (Mitchell, 1987; Crisosto et al., 1999). Flesh reddening and browning may be considered, in white-flesh cultivars, as a severe injury because it affects fruit appearance and limits its commercial appeal. Reddening does not affect fruit taste whilst the presence of browning may alter organoleptic and nutritional properties. Studies have underlined the grade of susceptibility among yellow-fleshed cultivars and nectarines (Crisosto et al., 1999), but there is very little information in literature on white-flesh ecotypes. Many of the late maturation Sicilian peaches are local ecotypes still cultivated in internal areas (Caruso e Sottile, 1999; Sottile et al., 2003; Marchese et al., 2005; Barone et al., 2003) and they are usually characterized by a clingstone, non-melting white flesh and a limited extension of red peel cover color. These ecotypes need a high amount of GDH (600-800 CU and 60-80,000 GDH) (Caruso et al., 2006) and they are characterized by a late ripening time from late August to early October (Sortino et al., 2015). Local consumers greatly appreciate these white-flesh ecotypes because they have a balanced taste, persistent aroma and excellent flavor (Allegra et al., 2015; Marchese et al., 2005). Nevertheless, they reach only regional markets, because of fruit sensitivity to decay and the poor information about postharvest physiology and shelf-life of the different white-flesh peach ecotypes. The aim of this work was to assess the persistence of their quality after storage at 2°C and 90% RH and during the shelf-life.

## Materials and Methods

Fruit of *Daniela*, *Tudia* and *Bella di Bivona* peach genotypes were collected in Riesi (Cl; 37° 17′ N, 14° 04′ E) in the South of Italy. *Tudia* and *Bella di Bivona* are two local ecotypes whereas *Daniela* is a cv obtained by breeding programs in the 1980s (Okie 1998) and largely diffused in Italy. All varieties are characterized by white flesh and a late harvesting time. Trees were trained to a delayed vase shape and grafted on GF677 (*Prunus persica x Prunus amigdalus*). Fruit were harvested in September at commercial ripening using ground color as maturity index. A sample of 90 fruits per cv were collected from five trees. A group of 30 fruits was submitted to analytical evaluations and the other 60 fruits were stored at a temperature of 2°C and 90% of RH. Four subsample of 15 fruits leaving the cold room after 7, 14, 25 and 32 days of storage respectively and were stored at ambient temperature (22° C) for 6 days, simulating the commercial life of the fruit in a point of sale. During each period of 6 days fruit were submitted to chemical-physical analyses immediately after taking out of storage and every 3$^{th}$ and 6$^{th}$ day. Biometrical and physical-chemical characteristics were also observed: fruit weight (FW), flesh firmness (FF), total soluble solid content (TSS), tritatable acidity (TA) and the ratio between total soluble solid content and tritatable acidity (TSS/TA). Fruit weight was determined by a digital scale. Fruit flesh firmness was measured at the equator of the fruit using a digital penetrometer TR5325 fitted with a 7.9 mm diameter head (Turoni, Forlì, Italy): two measurements were made on opposite sides of each fruit after the removal of a 1 mm thick slice of skin and expressed in $kg·cm^{-2}$. Total soluble solid was measured by digital refractometer Atago Palette PR-32 (Atago Co., Ltd, Tokyo, Japan) and expressed in Brix°. Titratable acidity was determined by titration with 0.1 N NaOH and calculated as the malic acid equivalent. The results were expressed as malic acid $g\ l^{-1}$of juice using a CrisonS compact tritator (Crison Instruments, SA, Barcelona, Spain).

After each measurement of firmness and sampling for TSS and TA, fruits were halved and examined visually for flesh disorders and browning. The chilling injuries were evaluated as percentage of fruit affected by internal browning (IB) and reddening (RE). Each sample was considered unsuitable for the consumer when the percentage of affected fruit was more than 50%.

A regression analysis was used to determine the association between time (days) and weight, solid soluble content, flesh firmness and titratable acidity. An Anova analysis was performed on each variety during the four shelf-life.

## Results and Discussion

FW decreased in the three cultivars during cold storage (Figure 1): *Bella di Bivona* had a very fast weight loss of 3.57% in 32 days according to a linear trend; *Daniela* lost 18.42% in fresh weight in the first 15 days after storage according to a polynomial trend; *Tudia* lost less than 1% of fresh weight in 15 days but had a sharp reduction in fresh weight in the next ten days. Its fruit fall in about 10 g in 15 days (8% of the total weight). During the same period, FF (Figure 2) sharply reduced in *Bella di Bivona* and *Tudia* fruits, while *Daniela* had a reduction in firmness in 25 days of its storage. In terms of marketability, *Tudia* had the longest storage life among the three observed cultivars whereas *Bella di Bivona* and the cv *Daniela* reached a very high de-

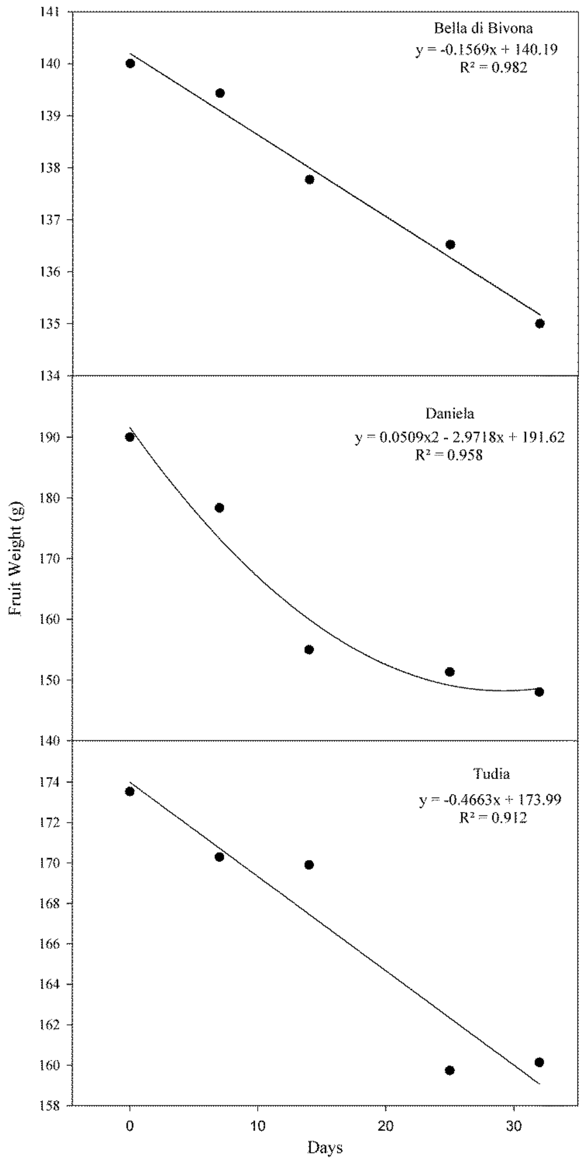


**Fig. 1. FW (Fruit Weight) evolution of *Bella di Bivona*, *Daniela* and *Tudia* white-flesh peach fruit during 32 days of storage at 2°C and 90% RH**

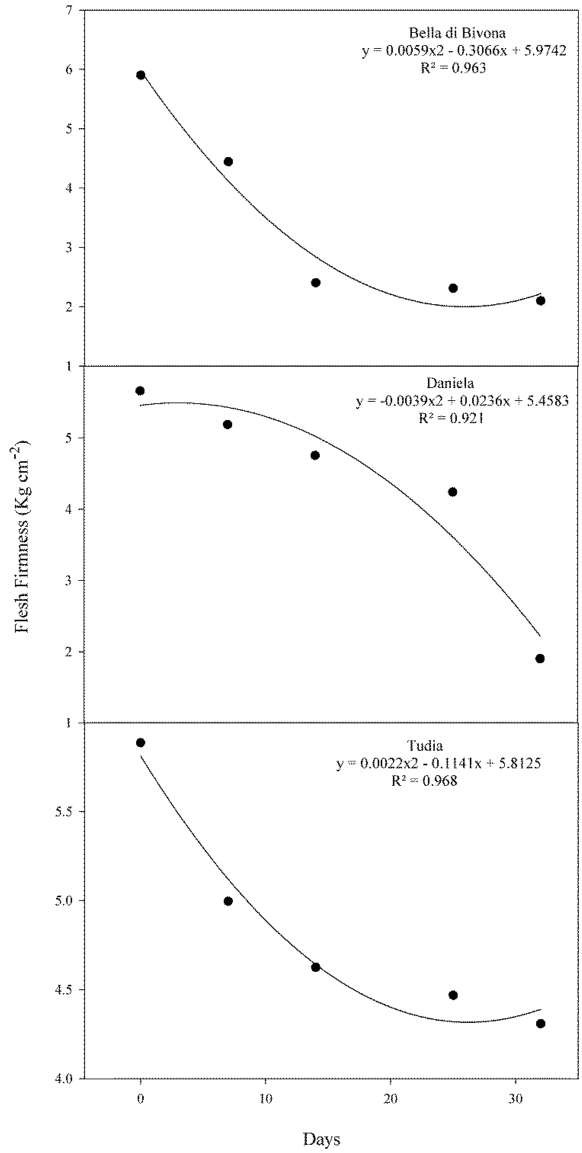


**Fig. 2. FF (Flesh Firmness) evolution of *Bella di Bivona*, *Daniela* and *Tudia* white-flesh peach fruit during 32 days of storage at 2°C and 90% RH**

gree of softening in 15 days.

The evolution of TSS (Figure 3) was not related either to fruit weight or to flesh firmness. *Bella di Bivona* and *Tudia* fruit showed a gradual increase in TSS during the first two weeks of storage, followed by a sharp decrease in the following 15 days. *Bella di Bivona* and *Tudia* showed a progressive loss from the $15^{th}$ day until the last days. These data are in accordance with the research of Togrul and Arlsan (2004) on non-melting. The cv *Daniela* had a different trend with a rapid decrement of TSS during and soon after storage. These data are similar to the studies by Rizzente (2008). A higher concentration of TSS can be explained by the loss of water of the fruit and consequently as weight loss. In the second part of cold storage the respiration rate is probably more active and a part of sugars might be consumed or transformed in other compounds. At the end of the trial *Tudia* showed a higher value of TSS in respect to the first day of storage. This could be due to a weaker respiration rate in the final stage in *Tudia*.

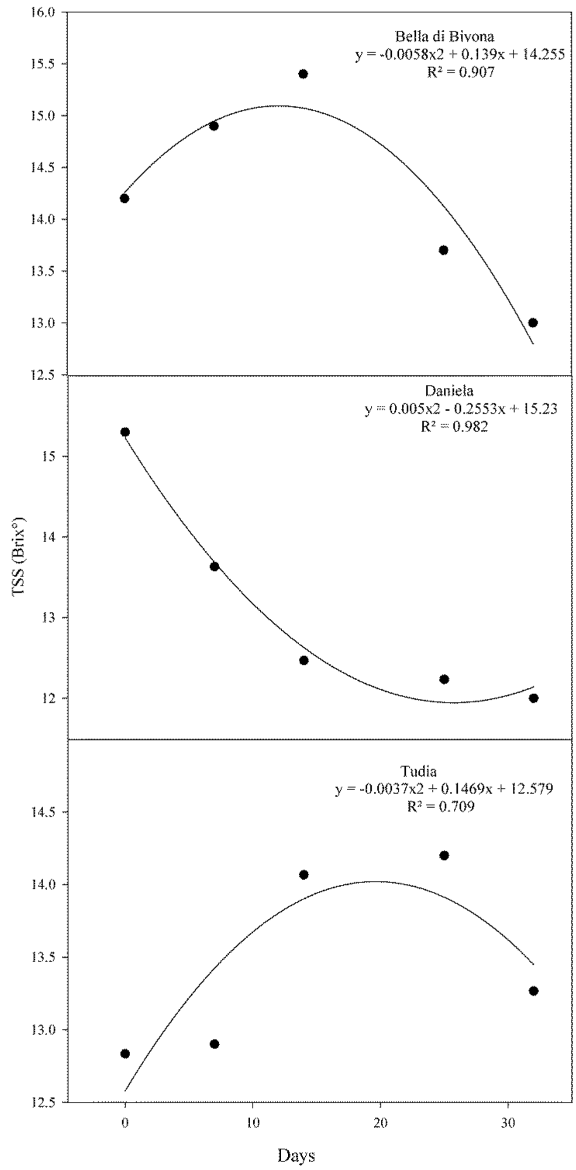


**Fig. 3 TSS (Total Soluble Solid content) of *Bella di Bivona*, *Daniela* and *Tudia* white-flesh peach fruit during 32 days of storage at 2°C and 90% RH**

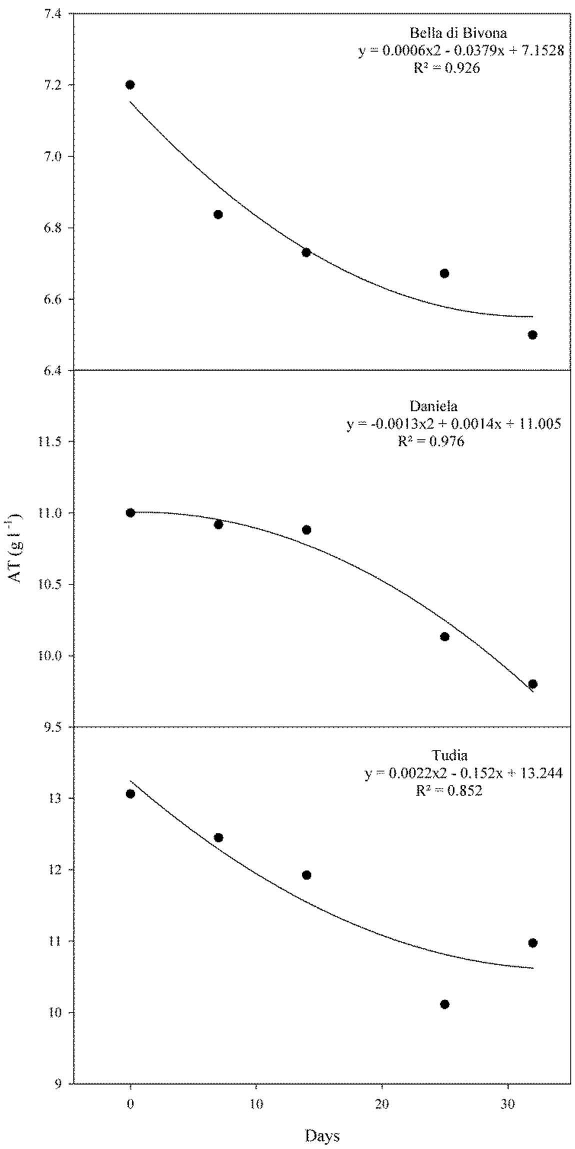


**Fig. 4. AT (Tritatable Acidity) evolution of AT of *Bella di Bivona*, *Daniela* and *Tudia* white-flesh peach fruit during 32 days of storage at 2°C and 90% RH**

TA decreased during storage according to a different trend with a reduction in the first two weeks in *Bella di Bivona* and *Tudia* and with a decrease occurring only after 15 days of storage for *Daniela* (Figure 4).

During the first shelf-life *Daniela* (Table 1) lost much more FW than the two ecotypes. During the second shelf-life, the two ecotypes and the cultivar have a similar behavior with a progressive weight loss. In particular, *Daniela* has a more stable behavior, slightly decreasing its FW whereas in *Bella di Bivona* and *Tudia* the loss of FW is much more rapid. During the third shelf-life, the two ecotypes and the cultivar follow a similar trend decreasing in FW. During the fourth shelf-life the only cv that has a commercial life is *Tudia* even though it has a continuous decrease of FW. The other two reached non-commercial compatible values of flesh firmness (data not shown) and were not examined.

**Table 1**

**FW (Fresh Weight) evolution of *Bella di Bivona*, *Daniela* and *Tudia* white-flesh peach fruit at 0, 3rd and 6th day of shelf life after 7, 14, 25 and 32 days of cold storage at 2°C and 90% RH (mean ± standard deviation)**

| | *CV* | | *Bella di Bivona* | *Daniela* | *Tudia* |
|---|---|---|---|---|---|
| | Shelf life | Days | g. SD | g. SD | g. SD |
| FW (g) | I (7th day) | 0 | 139.43 ± 9.07 | 190.00 ± 6.45 | 170.29 ± 5.82 |
| | | 3 | 134.65 ± 9.49 | 161.93 ± 9.02 | 164.33 ± 8.28 |
| | | 6 | 128.00 ± 9.02 | 154.33 ± 10.23 | 161.68 ± 8.57 |
| | II (14th day) | 0 | 137.77 ± 9.47 | 154.98 ± 8.87 | 169.90 ± 7.20 |
| | | 3 | 130.02 ± 7.10 | 154.00 ± 9.02 | 160.02 ± 8.45 |
| | | 6 | 122.75 ± 10.79 | 153.54 ± 10.23 | 154.27 ± 8.33 |
| | III (25th day) | 0 | 138.52 ± 8.26 | 151.30 ± 4.88 | 169.74 ± 9.14 |
| | | 3 | 128.50 ± 10.25 | 147.00 ± 6.76 | 163.17 ± 8.68 |
| | | 6 | 125.00 ± 9.60 | 141.53 ± 8.46 | 154.45 ± 4.00 |
| | IV (32th day) | 0 | - - | - - | 160.13 ± 10.47 |
| | | 3 | - - | - - | 152.98 ± 10.57 |
| | | 6 | - - | - - | 143.06 ± 10.35 |

**Table 2**

**FF (Flesh Firmness) evolution of *Bella di Bivona*, *Daniela* and *Tudia* white-flesh peach fruit at 0, 3rd and 6th day of shelf life after 7, 14, 25 and 32 days of cold storage at 2°C and 90% RH (mean ± standard deviation)**

| | *CV* | | *Bella di Bivona* | *Daniela* | *Tudia* |
|---|---|---|---|---|---|
| | Shelf life | Days | Kg·cm$^{-2}$ SD | Kg·cm$^{-2}$ SD | Kg·cm$^{-2}$ SD |
| FF (kg/cm) | I (7th day) | 0 | 4.44 ± 0.6 | 5.19 ± 1.00 | 5.00 ± 0.53 |
| | | 3 | 2.60 ± 0.79 | 2.00 ± 0.66 | 4.13 ± 0.96 |
| | | 6 | 2.30 ± 0.82 | 1.61 ± 0.96 | 2.50 ± 0.48 |
| | II (14th day) | 0 | 2.40 ± 0.56 | 4.76 ± 0.64 | 4.63 ± 0.92 |
| | | 3 | 2.32 ± 0.31 | 3.37 ± 0.45 | 3.20 ± 0.59 |
| | | 6 | 1.58 ± 1.58 | 1.50 ± 0.43 | 2.23 ± 0.3 |
| | III (25th day) | 0 | 2.31 ± 0.78 | 2.31 ± 0.58 | 4.47 ± 0.68 |
| | | 3 | 1.96 ± 0.52 | 1.96 ± 1.03 | 3.20 ± 0.98 |
| | | 6 | 1.60 ± 0.62 | 1.60 ± 0.45 | 2.62 ± 0.46 |
| | IV (32th day) | 0 | - - | - - | 4.31 ± 0.64 |
| | | 3 | - - | - - | 4.27 ± 0.65 |
| | | 6 | - - | - - | 2.95 ± 0.56 |

FF loss (Table 2) during the first shelf-life is faster in *Daniela*; moreover, it presented a FF level too low for a valuable commercialization already at day 3 of shelf-life (from 5 kg cm$^{-2}$ to 2 kg cm$^{-2}$ in the first three days).The ecotypes *Tudia* and *Bella di Bivona*, instead, present a decrease of consistency much slower than *Daniela* and reach values that are still tradable at day 3 of shelf-life. In particular, *Tudia* at day 3 loses only 1 kg cm$^{-2}$ of consistency. This indicates its good attitude to cold storage and shelf-life confirming the informations of Caruso et al. (1995). During the second shelf-life, *Bella di Bivona* appears more stable though flesh firmness values are already low for the market needs. *Daniela* and *Tudia* show acceptable consistency values until the third day: both reached a FF of about 3.2 kg cm$^{-2}$ circa whereas, at day 6, they reached values of kg cm$^{-2}$ and 2.2 kg cm$^{-2}$ respectively. During the third shelf-life, *Bella di Bivona* starts from low values reaching 1.6 kg cm$^{-2}$ at day 6 and it is not marketable during its third shelf-life. Both *Daniela* and *Tudia* start from values of above 4 kg cm$^{-2}$, at day 3 reach 3.2 kg cm$^{-2}$ and 3.6 kg cm$^{-2}$ respectively, and arrive at values above 2 kg cm$^{-2}$ for both cvs on the last day. During the fourth shelf-life, only *Tudia* have a commercial life and reaches 2.8 kg cm$^{-2}$ on day 6.

**Table 3**
**TSS (Total Soluble Solide content) evolution of *Bella di Bivona*, *Daniela* and *Tudia* white-flesh peach fruit at 0, 3rd and 6th day of shelf life after 7, 14, 25 and 32 days of cold storage at 2°C and 90% RH (mean ± standard deviation)**

| | *CV* | | *Bella di Bivona* | *Daniela* | *Tudia* |
|---|---|---|---|---|---|
| | Shelf life | Days | Brix° SD | Brix° SD | Brix° SD |
| TSSC (Brix°) | I (7th day) | 0 | 14.90 ± 0.26 | 13.63 ± 0.41 | 12.90 ± 0.88 |
| | | 3 | 14.37 ± 0.45 | 13.67 ± 0.3 | 13.00 ± 1.13 |
| | | 6 | 14.00 ± 0.63 | 13.20 ± 0.6 | 12.80 ± 1.77 |
| | II (14th day) | 0 | 15.40 ± 0.9 | 12.47 ± 0.2 | 14.07 ± 1.30 |
| | | 3 | 15.40 ± 0.69 | 12.13 ± 0.57 | 13.63 ± 1.07 |
| | | 6 | 15.33 ± 1.07 | 12.00 ± 0.47 | 13.30 ± 0.88 |
| | III (25th day) | 0 | 16.20 ± 0.79 | 12.23 ± 0.55 | 14.20 ± 0.91 |
| | | 3 | 16.13 ± 0.56 | 12.17 ± 1.07 | 14.07 ± 0.32 |
| | | 6 | 15.00 ± 0.65 | 12.00 ± 1.32 | 13.07 ± 0.60 |
| | IV (32th day) | 0 | - - | - - | 13.27 ± 0.32 |
| | | 3 | - - | - - | 13.00 ± 0.9 |
| | | 6 | - - | - - | 12.73 ± 0.8 |

**Table 4**
**TA (Titratable Acidity) evolution of *Bella di Bivona*, *Daniela* and *Tudia* white flesh peach fruit at 0, 3rd and 6th day of shelf life after 7, 14, 25 and 32 days of cold storage at 2°C and 90% RH (mean ± standard deviation)**

| | *CV* | | *Bella di Bivona* | *Daniela* | *Tudia* |
|---|---|---|---|---|---|
| | Shelf life | Days | $g \cdot l^{-1}$ SD | $g \cdot l^{-1}$ SD | $g \cdot l^{-1}$ SD |
| TA ($g\ l^{-1}$ malic acid) | I (7th day) | 0 | 6.84 ± 0.7 | 10.92 ± 0.44 | 12.45 ± 1.15 |
| | | 3 | 4.82 ± 0.43 | 8.22 ± 0.35 | 11.24 ± 1.20 |
| | | 6 | 4.00 ± 0.65 | 6.23 ± 0.58 | 7.85 ± 0.98 |
| | II (14th day) | 0 | 6.73 ± 0.74 | 10.88 ± 0.45 | 11.92 ± 1.06 |
| | | 3 | 5.80 ± 0.90 | 8.38 ± 0.35 | 10.15 ± 0.72 |
| | | 6 | 4.05 ± 2.11 | 6.98 ± 0.56 | 9.32 ± 0.63 |
| | III (25th day) | 0 | 6.67 ± 0.78 | 10.13 ± 0.39 | 10.11 ± 0.21 |
| | | 3 | 5.43 ± 0.21 | 7.36 ± 0.8 | 9.39 ± 0.03 |
| | | 6 | 4.52 ± 0.35 | 7.17 ± 0.44 | 8.19 ± 0.37 |
| | IV (32th day) | 0 | - - | - - | 10.97 ± 0.56 |
| | | 3 | - - | - - | 8.51 ± 0.31 |
| | | 6 | - - | - - | 6.70 ± 0.69 |

During the first three shelf-life, all the observed fruits show a similar behavior with a progressive loss of TSS (Tab. 3); this is more evident in the first period than in the second and in the third. In particular, *Tudia* shows a little more loss of TSS indicating, thus, that water loss is very slow. During the fourth shelf-life, *Tudia* is the only cv to have a commercial life: at this point it has an expected further loss of TSS from 13.2 to 12.6° brix on the sixth day.

As for the TA (Table 4) it has a strong tendency to decrease in three different cultivars. During the first shelf-life, the values of *Tudia* start at 12.5 g $l^{-1}$, after 3 days reach 11.2 g $l^{-1}$ and 7.5 g $l^{-1}$. *Daniela* at first control has lower values than *Tudia* (11.0 g $l^{-1}$), 8.5 g $l^{-1}$ after 3 days and 6.5 g $l^{-1}$ on the sixth day. *Bella di Bivona* showed 7 g $l^{-1}$ on the first day, 5.0 g $l^{-1}$ the day 3 and 4 g $l^{-1}$ at day 6. During the second shelf-life, AT continues, as expected, to fall in all cvs; during the third shelf-life, AT reduction is more gradual. During the last shelf-life, *Tudia* is the only variety that maintains the requirements for manipulation with a progressive but slow decline of AT.

The amount of IB and RE changes according to the cultivar (Tables 5, 6) and increases in time. *Daniela* has a prevalently higher extent of IB and RE after 14 and 25 days of storage. This was not the case of *Tudia* and *Bella di Bivona* but for IB, which was higher in *Bella di Bivona* after 25 days of storage. However, *Daniela* showed the highest extent of IB and RE.

**Table 5**

**IB (Internal Browning percentage of affected fruits) evolution of *Bella di Bivona*, *Daniela* and *Tudia* white-flesh peach fruit at 0, 3rd and 6th day of shelf life after 7, 14, 25 and 32 days of cold storage at 2°c and 90% RH**

| | *CV* | | *Bella di Bivona* | *Daniela* | *Tudia* |
|---|---|---|---|---|---|
| | Shelf life | Days | (%) | (%) | (%) |
| IB (%) | I (7th day) | 0 | 0.00 | 0.00 | 0.00 |
| | | 3 | 7.83 | 6.90 | 0.00 |
| | | 6 | 11.25 | 90.00 | 20.00 |
| | II (14th day) | 0 | 0.00 | 0.00 | 0.00 |
| | | 3 | 0.00 | 39.50 | 3.60 |
| | | 6 | 11.74 | 41.10 | 6.90 |
| | III (25th day) | 0 | 0.00 | 22.50 | 0.00 |
| | | 3 | 23.68 | 53.60 | 9.60 |
| | | 6 | 43.85 | 90.00 | 17.50 |
| | IV (32th day) | 0 | - | - | - |
| | | 3 | - | - | - |
| | | 6 | - | - | - |

**Table 6**

**RE (Reddening percentage of affected fruits) evolution of *Bella di Bivona*, *Daniela* and *Tudia* white-flesh peach fruit at 0, 3rd and 6th day of shelf life after 7, 14, 25 and 32 days of cold storage at 2°C and 90% RH**

| | *CV* | | *Bella di Bivona* | *Daniela* | *Tudia* |
|---|---|---|---|---|---|
| | Shelf life | Days | (%) | (%) | (%) |
| RE (%) | I (7th day) | 0 | 0.00 | 0.00 | 3.75 |
| | | 3 | 8.50 | 7.20 | 20.00 |
| | | 6 | 10.35 | 35.00 | 33.75 |
| | II (14th day) | 0 | 0.00 | 0.00 | 0.00 |
| | | 3 | 7.50 | 35.80 | 12.00 |
| | | 6 | 14.35 | 57.80 | 20.77 |
| | III (25th day) | 0 | 0.00 | 25.50 | 0.00 |
| | | 3 | 4.74 | 37.50 | 24.00 |
| | | 6 | 37.00 | 90.00 | 26.88 |
| | IV (32th day) | 0 | - | - | - |
| | | 3 | - | - | - |
| | | 6 | - | - | - |

In conclusion, these preliminary data about white-fleshed peach fruit postharvest attitude and the evolution of chilling injuries has shown the differences of behavior among the observed genotypes underlining the specific response to the cold storage and the shelf life for each of these. During the period of shelf-life, with cold storage of fruit at 2°C and 90% of RH, *Bella di Bivona* and *Daniela* have a shelf life of 12–14 days while *Tudia* could reach up to 25–32 days. The variations of content in TSS and AT are not equally valid indicators but define better the intrinsic characteristics of the white-flesh peaches whereas FF is the most important and limiting parameter for the quality of the white-flesh peach fruit being extremely sensitive to the evolution of post-harvest ripening. FF trends during shelf-life allowed to discover *Tudia* as the variety which presents the best performance after storage at low temperatures for long periods. Moreover, the percentage of deteriorated fruits indicates a high susceptibility in *Bella di Bivona* and *Daniela* while *Tudia* highlights greater resistance to cold storage.

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