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Fruit quality during ripening and cold storage of two Japanese plum varieties cultivated in Tunisia

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Abstract

Fruit Quality attributes of two Japanese plum (*Prunus salicina* L.) varieties 'Black Diamond' and 'Fortune' cultivated in Tunisia were monitored during fruit ripening on the tree and cold storage. A five years old commercial orchard was used for the study. Harvested fruits were stored in cold rooms at temperature less than 2°C and relative humidity around 90%. Beginning at two weeks before harvest, until the end of the cold storage period, samples of 20 fruits were taken at irregular time intervals and used for the determination of soluble solids concentration (SSC), titratable acidity (TA) and fruit firmness. At harvest, values of SSC were similar for both varieties reaching 15 and 14.8%, respectively for 'Black Diamond' and 'Fortune'. During cold storage, the increase in SSC was nil for 'Fortune' and very low (0.2%) for 'Black Diamond'. In contrast, values of TA were different for 'Black Diamond' and 'Fortune', the former was more acidic at harvest and during cold storage. TA values ranged between 0.94 and 1.24 % malic acid at harvest and 0.8 and 1% at the end of storage period. The sugar to acid ratio (SSC/TA) showed a continuous increase during ripening and cold storage for both varieties. Values of SSC/TA, differed largely between the two varieties, at all sampling dates. Fruit Firmness decreased during ripening and cold storage for both cultivars. At harvest 'Fortune' fruits were more firm (28.44 N) than 'Black Diamond' (21.77 N). At the end of cold storage, these values were as low as 10.64 N for 'Black Diamond' and 15.64 N for 'Fortune'. A linear regression analysis showed that the rate of firmness decrease during cold storage was very similar for both cultivar and reached a value of 0.23 N day^{-1}. Thus, fruit firmness could be used to determine harvest time and to predict cold storage duration.

Key words: Japanese plum, *Prunus salicina* L., maturity, fruit quality, cold storage, Tunisia.

Introduction

Most plum cultivars grown in Tunisia belong to the European variety, *i.e., Prunus domestica* (Ben Tamarzizt *et al.,* 2009). However, some Japanese plum varieties (*Prunus salicina* Lindell) were introduced thirty years ago (Mzali *et al.,* 2002). Among these, 'Black Diamond', 'Fortune' and 'Angeleno' are the most cultivated. Unfortunately, no information is available on their fruit quality attributes during maturity and cold storage under Tunisian conditions. The main attributes for monitoring fruit quality during maturity on the tree and cold storage are soluble solids concentration (SSC), titratable acidity (TA), sugar-to-acid ratio (SSC/TA) and fruit firmness (Kader and Gordon Mitchell, 1989). SSC and TA determine consumer acceptance (Crisosto *et al.,* 2004). Fruit firmness is used to determine both harvest date and cold storage duration (Valero *et al.,* 2007). Some additional attributes like skin colour and fruits weight loss (Guerra and Casquero, 2008) or phenolics content (Usenik *et al.,* 2008) have been used as quality attiributes.

Cold storage duration before marketing depends on plum variety (Peirs *et al.,* 2000), fruit maturity stage at harvest (Guerra and Caquesro, 2009) and storage conditions such as temperature and relative humidity (Gordon Mitchell and Kader, 1989). The purpose of this study was to monitor the fruit quality of Japanese plum varieties 'Black Diamond' and 'Fortune', during fruit maturity and cold storage, using measurements of SSC, TA and fruit firmness to establish quality indices that can be used by plum producers to optimize fruit harvest time and storage.

Materials and methods

Site description: The experiment was carried out in summer 2009 in a commercial orchard located in the region of Ben Arous (lat. 36°39'N, long. 10°12'E) and composed mainly of cv. 'Black Diamond' and 'Fortune', along with Black Star and Black Gold as pollinizers, all grafted on Mariana rootstock. The trees were planted in 2004 at a spacing of 5 x 3 m, drip irrigated and fertigated.

Cold storage conditions: The harvested fruits were immediately transported to the cooling room (located 5 km away from the orchard) where they were stored in plastic containers (0.55 x 0.4 x 0.3 m) at temperatures between 0 and 2°C and a relative humidity around 90%.

Fruit sampling and quality measurements: Two weeks before the harvest date, samples consisting of 20 fruits each were taken at irregular intervals, a few days apart and used for quality measurements. Medium sized fruits were hand picked at a height of 1.5 m, in all directions around the tree canopy. During cold storage, additional 20-fruit samples were chosen at random from 10 different plastic containers each time the producer sent fruits to the market. Quality measurements were undertaken at the Laboratoire d'Arboriculture Fruitière at the Institut National Agronomique de Tunisie. For each sample, fruits were first assessed for flesh firmness using a hand penetrometer (FPT mod. FT 011 with a 8 mm tip). Measurements were taken on each fruit at 2 opposite sites on the equatorial plane after removing a disc of peel. Firmness readings on the penetrometer were converted from

kg force (kg f) to Newtons (N) using the formula N = kg f x 9.807. Twenty fruits were pressed, their juices mixed together and used to measure SSC with an automatic temperature compensated hand held refractometer (Reichert mod. 137530L0). TA was determined by titrating 10 mL of juice with 0.1N NaOH up to pH 8.2 (Kader and Gordon Mitchell, 1989).

Results and discussion

Soluble solids concentration: The SSC of the two cultivars evolved differently in the last two weeks before harvest but ended up with similar values. 'Black Diamond' showed a rapid SSC increase with values of 13.8% two weeks before harvest and 15% at harvest. In contrast, 'Fortune' SSC ranged between 14.6 and 14.8% during the same period (Fig. 1).

Higher SSC values were found in this study than those reported for other Japanese plum varieties like 'Black Amber' grown in California (Crisosto *et al.,* 2004), 'Songold' cultivated in south Africa (Taylor *et al.,* 1993), 'Pioneer' (Daza *et al.,* 2008) and 'Fortune' (Lozano *et al.,* 2009) both grown in Spain. These higher SSC values are probably a consequence of the hot and dry Tunisian summer climate as well as the orchard management skills, particularly irrigation management.

During cold storage, the increase in SSC was very low (0.2%) for 'Black Diamond' and nil for 'Fortune'. This little increase is probably due to water loss from the fruits since the relative humidity in the cold room was not precisely controlled. Perez Marin *et al.* (2010) also observed no significant changes in soluble solid content in the course of refrigerated storage for four of the six Japanese plum varieties they tested.

Titratable acidity: 'Black Diamond' and 'Fortune' had similar SSC values, their TA values differed considerably. Harvest TA values were around 0.94% malic acid for 'Black Diamond' and 1.24% for 'Fortune'. Crisosto *et al.* (2004) reported harvest TA values as low as 0.42 % malic acid for 'Black Diamond', whereas Lozano *et al.* (2009) found a value of 1.33% for 'Fortune' grown in Spain. 'Black Diamond' had lower values than 'Fortune' at all sampling dates. Measures during the last two weeks before harvest showed that the TA decrease was substantial for both varieties during fruit ripening (Fig. 2). Decreases were much slower during cold storage. A decrease of 0.2% malic acid was achieved in approximately 2 weeks before harvest *vs* 6 weeks during cold storage.

Sugar-to-acid ratio: The SSC/TA ratio for both varieties increased both during fruit ripening on the tree and cold storage (Fig. 3). Different SSC/TA values were recorded at harvest for 'Black Diamond' (15.99) and 'Fortune' (11.94). This difference persisted during cold storage. At the end of cold storage, the SSC/TA values were 19.15 for 'Black Diamond' and 15.12 for 'Fortune'.

Crisosto *et al.* (2004) suggested that the SSC/TA ratio be considered a good indicator of consumer acceptance. Optimal ratios are variety dependent. This study suggests that values of 19 and 15 at the end of cold storage be considered 'optimum' for 'Black Diamond' and 'Fortune', respectively. In contrast, Daza *et al.* (2008) reported a 5.5 sugar-to-acid-ratio as characteristic for the Japanese plum 'Pioneer' at harvest. This is very different from the values found in this study because 'Pioneer' exhibits lower

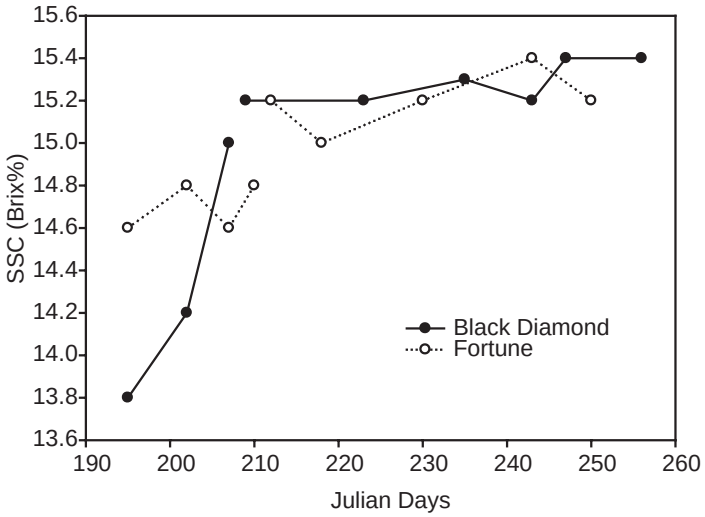

Fig. 1. Soluble solids concentration during ripening and cold storage

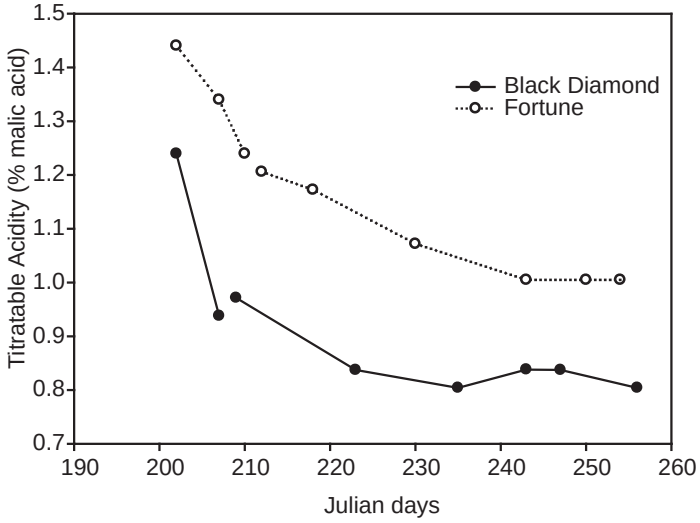

Fig. 2. Titratable acidity during ripening and cold storage

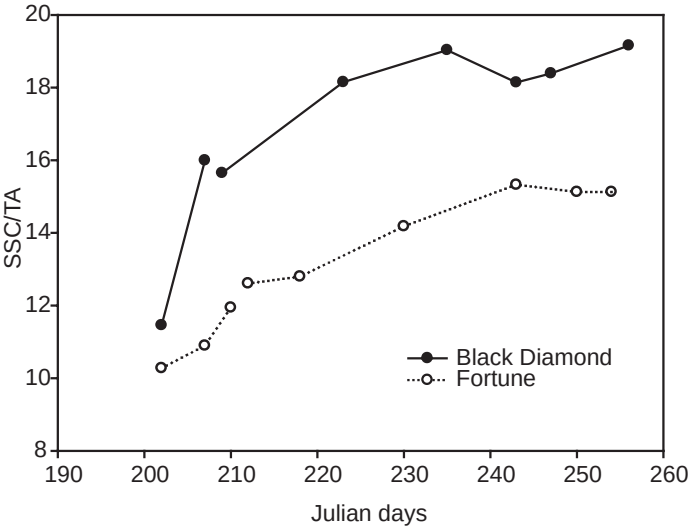

Fig. 3. Sugar to acid ratio during rapening and cold strorage

SSC and higher TA values. Crisosto *et al.* (2004) reported values of SSC/TA for 'Black Amber' at harvest as high as 28.2.

Fruit firmness: The evolution over time of fruit firmness (Fig. 4) showed a continuous slow decrease beginning two weeks before

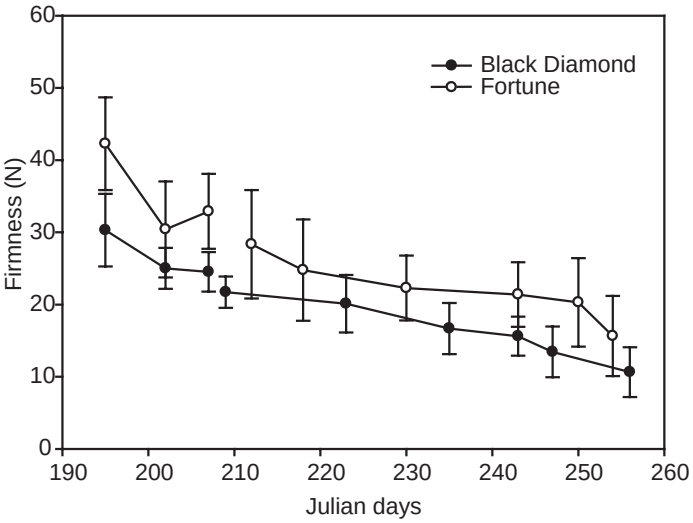

Fig. 4. Fruit Firmness during ripening and cold storage

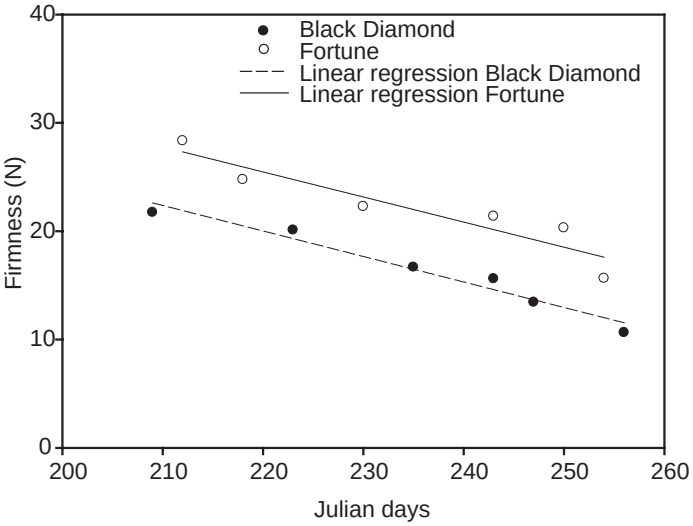

Fig. 5. Linear regression of fruit firmness over time

harvest (around day 210) and through the end of the storage period (around day 255). Firmness values measured by penetrometer were very different for the two studied varieties. At harvest time, 'Black Diamond' fruits were on average less firm (21.77 N) than 'Fortune' fruits (28.44 N). These values are higher than those reported by Gonzalez-Rossia *et al.* (2006) for 'Black Diamond' (14.7 N) and Lozano *et al.* (2009) for 'Fortune' (8.77 N). This is because fruits in the commercial orchard where the study was conducted were harvested early to be stored for a long period before commercialization. Values of fruit firmness at the end of the storage period were as low as 10.78 and 15.69 N for 'Black Diamond' and 'Fortune', respectively. According to Crisosto *et al.* (2004) these values prevented fruits from developing possible chilling injury symptoms occurring during cold storage.

Prediction of storage duration: Linear regression analysis was applied to the fruit firmness data to predict the rate of fruit softening during cold storage of 'Black Diamond' and 'Fortune'. Both linear regressions were highly significant with $r^2 = 0.96$ for 'Black Diamond' and 0.87 for 'Fortune'. Fig. 5 depicts the linear regression slopes of the two varieties. In other words, their fruit softening rates (N day^{-1}), were very close: 0.235 for 'Black Diamond' and 0.231 for 'Fortune'. We conclude that under the conditions mentioned in present investigations, 'Black Diamond' and 'Fortune' Japanese plums have a similar rate of softening of approximately 0.23 N day^{-1}. This softening rate can be used in conjunction with initial fruit firmness at harvest and the target firmness at commercial maturity to predict storage duration. For example, fruits harvested at 30 N and to be sold at 15 N can be cold stored for 65 days. This study allowed us to describe the evaluation of fruit quality attributes during ripening and cold storage for two Japanese plum cultivars 'Black Diamond' and 'Fortune' grown in Tunisia.

This study allowed us to give "optimal" values of fruit quality attributes for two Japanese plum cultivars "Black Diamond" and "Fortune" grown in Tunisia. SSC value over 15% combined with TA value under 1% malic acid, resulting in an SSC/TA ratio of at least 15 and fruit firmness between 10 and 15 N appeared to be adequate for Japanese plum after cold storage. The fruit firmness and TA were found to changed significantly during cold storage as Japanese plums are climacteric fruit. The fruit firmness appears to be a useful index for growers to determine harvest time and to predict cold storage duration. This study should be extended to other Japanese plum varieties cultivated in Tunisia and repeated to take into account year to year variation in fruit quality attributes due to climate.

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