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Effect of canopy positions on physicochemical quality of Mandarin Fruit cv. 'Shogun' during Storages

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Abstract The effect of canopy positions (upper, middle and lower) on quality of mandarin fruit cv. 'Shogun' stored at 20°C and 10°Cwas investigated. The results showed that the canopy positions influenced the appearance and peel colour which the peel of fruits from the upper part had more yellow and chroma value than the fruits from middle and lower parts which the peel had more green colour. The canopy positions had no influenced on the fruit pulp colour. The fruits from the upper part had total soluble solids (TSS), antioxidant activity (AA), ascorbic acid (AsA), total phenols (TP) and total flavonoids (TF) contents higher than the fruits from middle and the lower parts whilst total acidity (TA) of the fruits from different canopy positions was similar. During storage, most physicochemical quality attributes seemed constant, except TA which decreased on day 7 and antioxidant activity of the fruits stored at 10 ℃ which decreased on day 21. In conclusion, the canopy positions had influenced on 'Shogun' mandarin fruit quality which the fruits from the upper part had quality higher than the fruits from middle and lower parts.

Keywords: Mandarin fruit, postharvest quality, canopy positions, bioactive compounds

Introduction

'Shogun' mandarin (*Citrus reticulate* Blanco) is a famous commercial mandarin fruit in Thailand. Its origin is believed in Southeast Asia. In Thailand, 'Shogun mandarin is commercially grown in southern Thailand, especially in Yala, Pattani and Narathiwat provinces (Chelong and Sdoodee, 2013); however it has recently been distributed to other provinces in southern Thailand (Dorji and Yapwattanaphun, 2011). Compared to other mandarin fruit grown in Thailand, 'Shogun' mandarin fruit have specific characteristics with bigger size, sweet taste and soft waternary juice (Chelong and Sdoodee, 2012). Recently

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‘Shogun’ mandarin fruit has been highly demanded in both domestic market and export (Chelong and Sdoodee, 2012).

Canopy position influences the colour appearance and quality characteristics of fruit due to the microclimate around individual fruits (Moon *et al*., 2011; Lewallen and Marini, 2003; Awad *et al.*, 2001) which may lead to considerable variation in the upper, middle and lower canopy positions (Moon *et al*., 2011). The light exposure of different canopy position obviously influence the average level of photosynthetically active radiation which the lower part of canopy has the lowest one (Jakopic *et al*., 2009). Drogoudi and Pantelidis (2011) reported that apple fruits from the high sunlight exposed canopy such as upper part of tree had higher quality characteristics such as TSS and bioactive compounds including TP content and antioxidant activity. Moon *et al*. (2011) reported the influence of canopy locations on quality of ‘Shiranuhi’ mandarin which the fruit from upper part of the tree had the highest quality including fruit diameter, pulp weight and soluble solids content when compared to the fruits from the middle and the lower parts of the tree. Marini *et al.* (1991) and Lewallen and Marini (2003) indicated that sunlight or carnopy position influences soluble solids content, ground colour and firmness of peach fruits which the fruit from shaded branches had greener ground colour than the fruit from non-shaded branches. By contrast, Krishnaprakash *et al*. (1983) addressed that fruit from the top part of canopy has lower quality than the fruits from other parts of the tree.

In this study, we observed the quality characteristics including the colour of peel and pulp, TSS, TA and bioactive compounds of ‘Shogun’ mandarin fruit harvested from different canopy positions, upper, middle and lower parts of the tree during storage at 20 and 10 ℃.

Materials and methods

Plant materials

‘Shogun’ mandarin fruits were obtained from the orchard in Pratiu district, Chumphon province, Thailand. Along the upper, middle and lower canopy position, the fruit at the age of 300 days after anthesis were harvested from 10 trees (100 fruit per canopy position). They were delivered to postharvest laboratory at King Mongkut’s Institute of Technology Ladkrabang, Prince of Chumphon campus within 30 min after harvest and then screened for uniformity in size and without any defects from physical damages and insects and diseases attacks. One hundred fruits from each canopy position were place in carton box and stored at 20 or 10 ℃, 90±2 %RH. Ten fruits of each canopy position were collected separately for measuring peel colour during storages. Ten fruits were sampled for physicochemical quality measurements during storages.

Colour measurement

The peel and pulp colour were measured using a Minolta CR400 colorimeter (Minolta Co. Ltd. Japan). The fruit were measured at the middle part of the fruit. Brightness (L^*), hue (°h) and chroma (C) values were recorded.

Total soluble solids and Total acidity determination

Total soluble solids (TSS) content was determined using a refractometer (ATAGO, Japan). The result was recorded as °Brix. Total acidity (TA) content was determined using a standard method of Association of Official Analytical Chemists (A.O.A.C., 1990). The fruit juice was titrated with 0.1 N NaOH by using 1% (w/v) phenophthalene as the indicator. The volume of used NaOH at the end point was calculated and the result was expressed as the percentage of citric acid (% citric acid).

Antioxidant activity assay

Antioxidant activity was determined using the ferric reducing antioxidant potential (FRAP) method which described by Benzie and Strain (1996). Five grams of the fruit pulp was homogenized with 15 mL of distilled water and then filtered through Whatman No.1 filter paper. One mL of filtrate was diluted with 9 mL distilled water before assay. A 0.5 mL of the diluted filtrate was reacted with 2.5 mL of FRAP reagent, consisting of acetate buffer pH 3, 10 mM 2,4,6-tripyridyl-1,3,5-triazine (TPTZ) and 20 mM ferric chloride hexahydrate in the ratio of 10:1:1. The reaction was incubated at ambient temperature for 30 min and then the absorbance at 630 nm was recorded using a visible spectrophotometer. The data were present as µmole Trolox equivalents per g fresh weight (µmole TE g^{-1} FW).

Total phenols and Flavonoids content assay

TP content was assayed using the method described by Slinkard and Singleton (1977) and TF content was determined using a method described by Jia *et al*. (1999). The filtrate extracted from antioxidant activity assay was used to determine the both compounds. One mL of the filtrate was diluted with 9 mL distilled water before TP determination. The reaction was started when 1 mL of the diluted filtrate was mixed with 1 mL of 50% (v/v) Folin–Ciocalteu reagent solution and then 2 mL of saturated Na_2CO_3 solution was added. The mixture was left at ambient temperature for at least 30 min. The absorbance at 750 nm was recorded. TP content was present in term of µg gallic acid per g fresh weight (µg GA/g FW). For TF content assay, 0.25 mL of the filtrate (without diluted) was mixed with 1.25 mL of distilled water, 75 µL of 0.5% $NaNO_2$. The mixture was held at ambient temperature for 6 min and 150 µL of 10% $AlCl_3 \cdot 6H_2O$ was then added and allowed to stand for 5 min. After that, 0.5 mL of 1 N NaOH was added. The absorbance at 510 nm was recorded and calculated using a standard curve of catechin. The data were expressed as µg catechin per g fresh weight (µg catechin g^{-1} FW).

Total ascorbic acid assay

AsA content was determined according to the method of Hashimoto and Yamafuji (2001). Three grams of the fruit pulp was homogenised with 20 mL of cold 5% metaphosphoric acid and then filtered through a Whatman No.1 filter paper. A 0.8 mL of filtrate was reacted with 0.4 mL of 2% di-indophenol and then, 0.8 mL of 2% thiourea and 0.2 mL of 1% dinitrophenol hydrazine were added. The mixture was incubated at 37 °C for 3 h and then 1 mL of 85% sulphuric acid was added and again incubated at ambient temperature for at least 30 min. Absorbance at 540 nm was measured. Total ascorbic acid content was present as µg ascorbic acid per g fresh weight (µg AsA g^{-1} FW).

Statistical analysis

The data are shown as the mean of 10 fruits and standard error bar. Statistical analysis was carried out using ANOVA. Least significant difference (LSD) test ($p < 0.05$) was used to compare the different among canopy positions (upper, middle and lower).

Results

Visual appearance and Fruit colour

The appearance of 'Shogun' mandarin fruit harvested from the different canopy positions (upper, middle and lower) was shown in Figure 1. The fruits from the upper canopy had yellow colour whilst the fruits from both middle and lower canopies had green colour. Similarly, the °*h* value of the fruits from the upper canopy showed more yellow (°*h* ~84) whilst that of the fruits from the middle and lower canopies showed more green (°h ~100) (Figure 2A). The peel L^* value of the fruits from the all canopy positions was similar and the peel C value of the fruit from the upper canopy was obviously higher than that of the fruits from middle and lower canopies (Figure 2B and 2C). Figure 3 showed that the canopy position had no influence on the fruit pulp colour; however, the pulp C value of the fruit from the upper canopy was slightly higher than that of the fruit from the both middle and lower canopy. During storage at both 20 and 10 °C, both fruit peel and pulp colour attributes of the fruits from each canopy position remained constant. The results suggested that the canopy position had influenced on the fruit appearance and the development of yellow colour of the fruit peel.

Figure 1. Appearance of 'Shogun' mandarin fruits harvested from top, middle and lower parts of the tree

Total soluble solids and Total acidity content

The highest TSS content of the fruits harvested from the upper canopy, followed by the fruits from the middle and lower canopies was shown in Figure 4A. The fruits from the lower canopy had the lowest TSS content. The TSS content of the fruits from all different canopy positions remained constant during stored at both 20 and 10 °C. The TA content of fruits from different canopy positions was similar and it was decreased during stored for 7 days, after that it was constant throughout the both storage conditions (Figure 4B).

Antioxidant activity, Ascorbic acid, Total phenols and Flavonoids contents

Bioactive compounds such as antioxidant activity assayed by using FRAP assays, AsA, TP and TF content of the mandarin fruit harvested from different canopies were shown in Figure 5 and 6. The result showed that antioxidant activity of the mandarin fruits from the upper part of the tree was higher than that of the fruit from the both middle and lower canopies which they were similar (Figure 5). At 20 °C, the antioxidant activity of the fruits from all canopy positions was decreased and no significant difference was found during

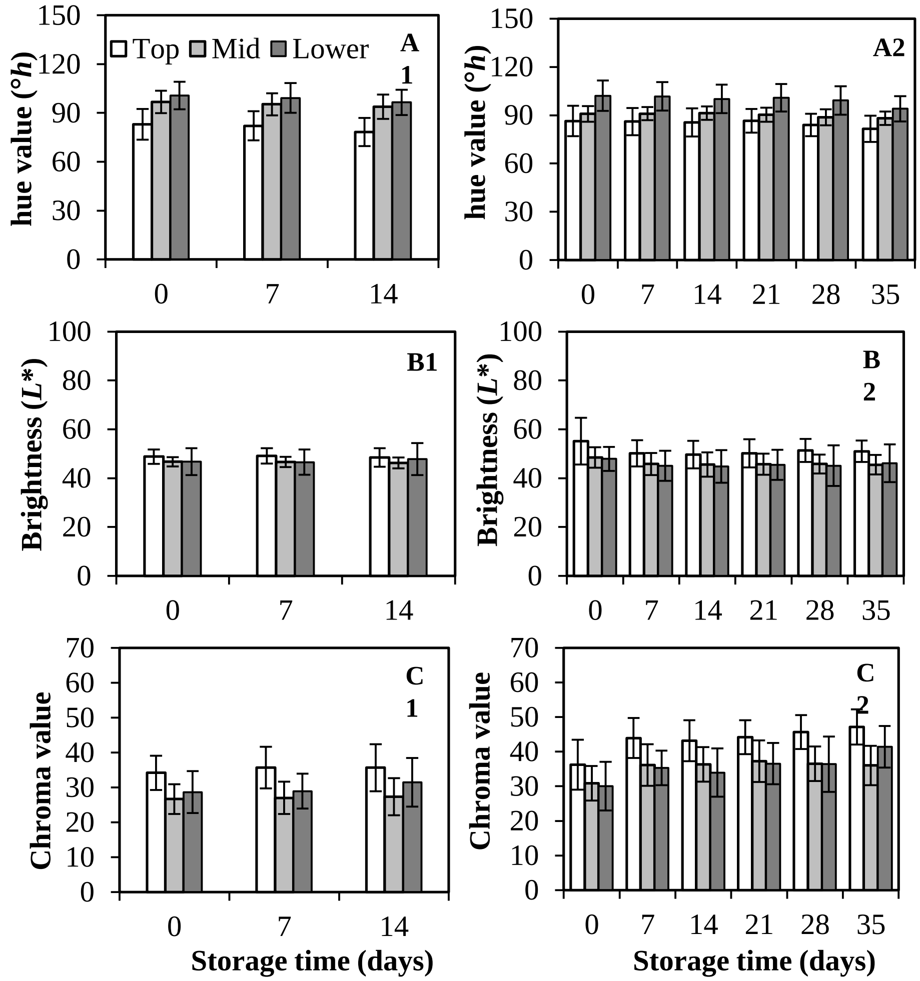

Figure 2. Hue (°*h*) , brightness (*L**) and chroma values of 'Shogun' mandarin fruit peel harvested from different parts of the tree during stored at 20 and 10°C

storage. Similarly, antioxidant activity of the fruits stored at 10 ℃ was decreased during storage for 7 days and then remained constant until day 28, after that it was rapidly decreased in all fruits; however, the antioxidant of the fruit harvested from the upper canopy was higher than that of the fruit from the middle and lower parts of the tree throughout the storage. These indicate that the fruits from the top of the canopy had higher antioxidant activity and it was maintained by cold storage. AsA, TP and TF contents of 'Shogun' mandarin fruits harvested from different canopy positions was shown in Figure 6. AsA and TP contents of the fruits from the upper part were significantly higher than those of the fruits from the middle and the lower parts (p<0.05). TF content of the fruits from the upper part was slightly higher than that of the fruits from the middle and lower parts. During storage, AsA content of the fruits stored at both 20 °C and 10°C seemed constant and that of the fruits from the upper part was still higher than that of the fruits from other parts. TP content of the fruits from the upper part stored at the both temperatures was decreased during stored for 7 days and then remained constant until day 28, after that it was increased, whilst that of the fruits from the other parts seemed constant during storage. TF content of the fruit from all canopy positions stored at 20 °C and 10°C was close and slightly increased during storage.

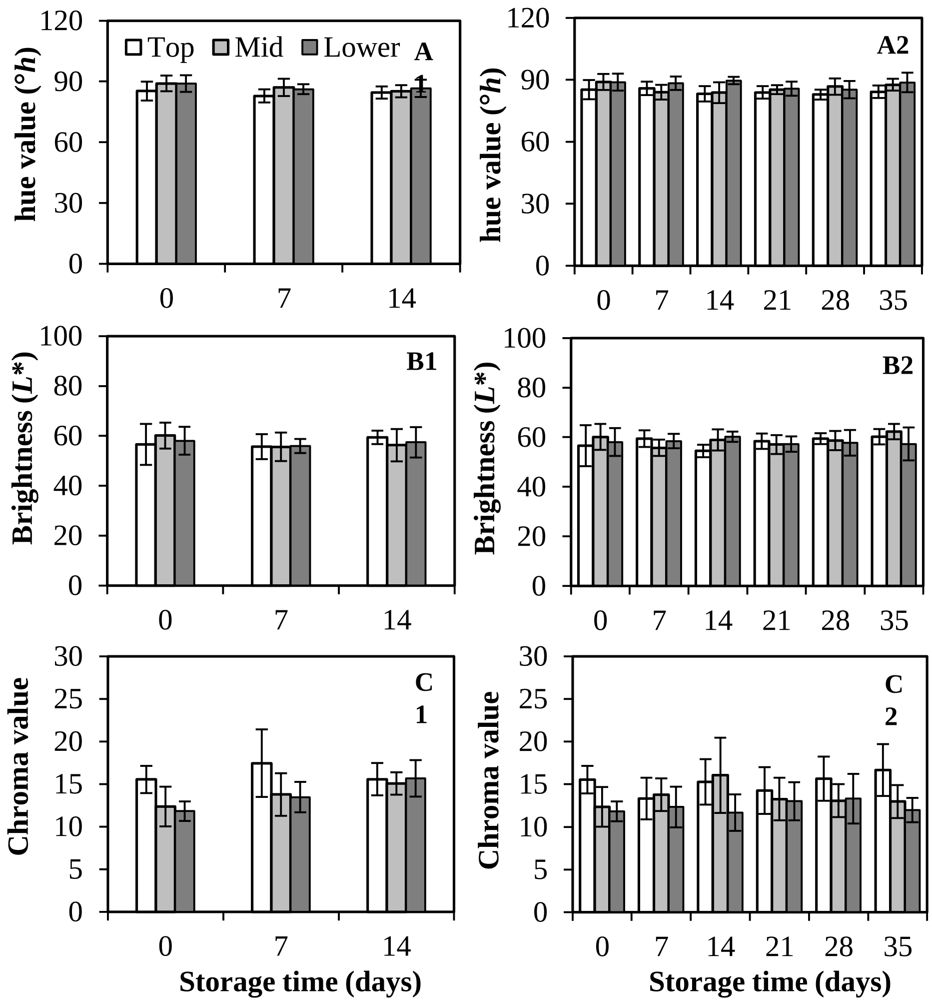

Figure 3. Brightness (A), hue (B) and chroma (C) values of 'Shogun' mandarin fruit pulp harvested from different parts of the tree during stored at 20°C (1) and 10°C (2)

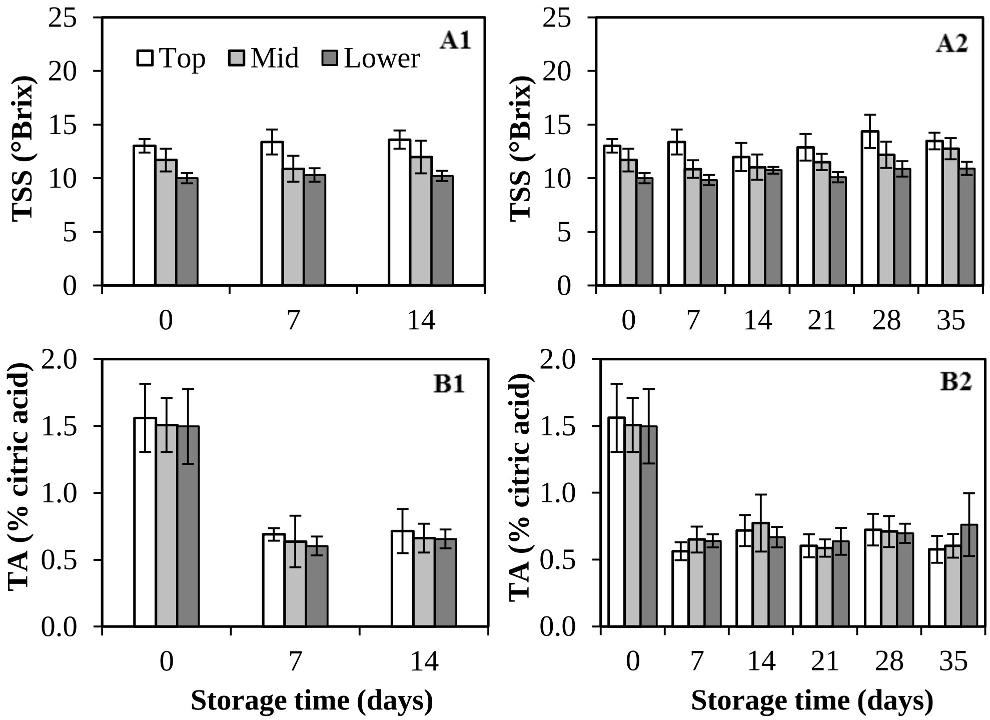

Figure 4. Total soluble solids (TSS) (A) and total acidity (TA) (B) of 'Shogun' mandarin fruit pulp harvested from different parts of the tree during stored at 20 °C (1)and 10°C (2)

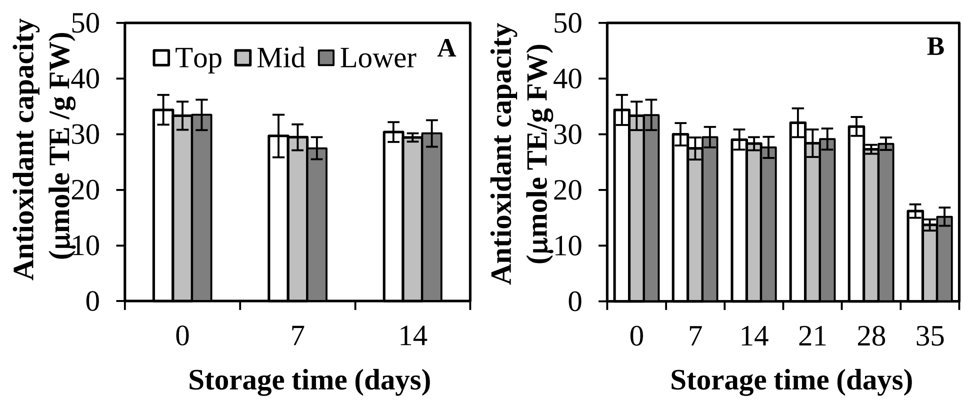

Figure 5. Antioxidant capacity of 'Shogun' mandarin fruit pulp harvested from different parts of the tree during stored at 20 °C (A) and 10°C (B)

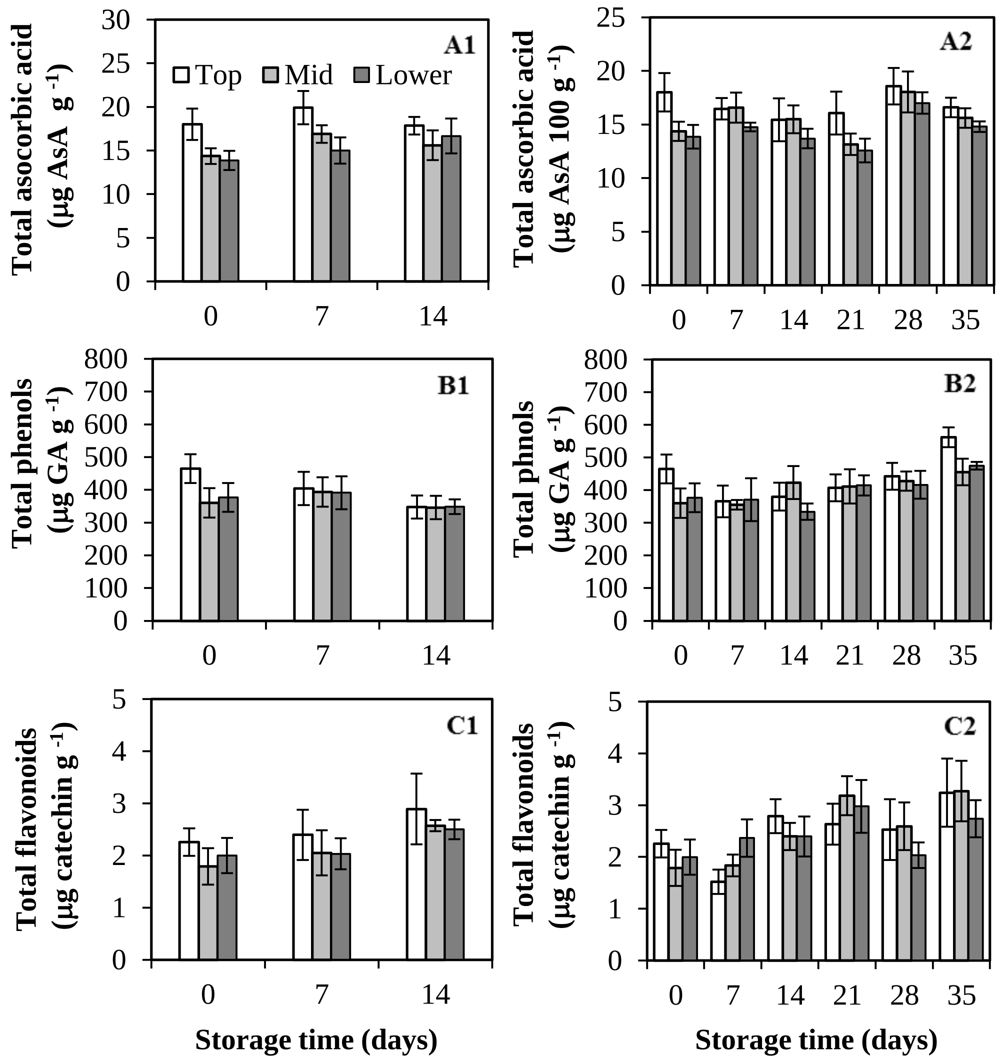

Figure 6. Total ascorbic acid (A), total phenols (B) and total flavonoids (C) contents of 'Shogun' mandarin fruit pulp harvested from different parts of the tree during stored at 20 °C (A)and 10°C (B)

Discussion

The recent reports showed the influence of canpy position on physicochemical quality of mandarin fruit cv. 'Shogun' during storage. Canopy position had afftected on visual appearance, especially peel colour of the fruit. The yellowness of peel colour of the mandarin fruits harvested from the upper canopy might be related to the high sun-light exposure when compared to the other parts of the tree. This is in the agreement with a previous report that peach fruits harvested from the exterior canopy were redder than the fruit harvested from the interior canopy, due to the sun radiation exposure (Lewallen and Marini, 2003). Moreover, Unuk *et al*. (2012) addressed that the fruits in the top part of the tree were more colourful than the fruits from lower canopy, due to higher light exposure. Lewallen and Marini (2003) and Marini *et al.* (1991) also suggested that fruits from shaded branches, low light exposure, had greener ground colour. In the similar vein, the present work reveals that the mandarin fruits harvested from the middle and lower canopies had greener ground colour than the fruits from the top of the canopy.

It is commonly acknowledged that sugar accumulation in fruit is positively correlated with cumulative solar radiation and is a consequence of increased translocation of photosynthates from sources (leaves) to sinks (fruit) (Yakushiji *et al*., 1998). The recent work revealed that the fruit from upper part of the tree contained total soluble solids higher than the fruits from middle amd lower parts, respectively. Moon *et al*. (2011) had explained that high sun-light exposure of the upper part of the tree stimulated TSS content of the 'Shranuhi' mandarin fruits when compared to the fruit harvested from the middle and lower canopies.which due to the translocation of photosynthates. Moreover, Feng *et al*. (2014) also addressed that apple fruits harvested from a canopy position where mostly contacted to sun radiation had high fructose, a major sugar in apple, content. However, the recent results show that canopy position had no effect on TA content of the fruit. In the similar vein, Daito *et al*. (1981) addressed that canopy position had no influence on organic acid content of Satsuma mandarin. In contrast, Moon *et al*. (2001) reported that the mandarin fruit from the upper part of the tree had lower acidity than that of the fruit from middle and lower canopies. These indicated that the effect of canopy position on TA content of the mandarin fruit is still uncleared. However, the high TSS content of the 'Shogun' mandarin fruits harvested from the upper canopy is obviously related to more sun-light exposure when compared to the middle and lower canopies. Moreover the similar result had also been reported for apple fruits (Drogoudi and Pantelidis, 2011).

Recently, most consumers have concerned the bioactive compounds content having health benefit in fresh commodities. The present work showed that the canopy positions had influenced on bioactive compounds including antioxidant activity, AsA, TP and TF contents of the mandarin fruits which the fruit from the upper canopy had higher amount of bioactive compounds than the fruit from the middle and lower canopies. These might be related to the sun-light exposure. The upper part of the tree was generally more contact sun radiation than the middle and lower canopies. Feng *et al*. (2014) reported that phenolic acids and flavonoids levels of apple fruits harvest from the outer canopy (high light exposure) were higher than those of the fruits from interior canopy (lower light exposure). Bioactive compounds such as phenolic acids and flavonoids are widely known that synthesized through the pentose phosphate, shikimate, and phenylpropanoid pathways (Randhir *et al*., 2004) which lower light exposure induces shikimate levels resulting in the inhibition of these bioactive compounds or other secondary metabolites (Feng *et al*., 2014). Drogoudi and Pantelidis (2011) reported that TP content and antioxidant activity of apple fruit were greater in the fruit harvested from the upper part of the tree which exposed to more sunlight. These suggested that bioactive compounds of the mandarin fruits were most directly responded to light availability.

It is conclused that the canopy postions had influenced on visual, eating and nutritional qualities of 'Shogun' mandarin fruits. The mandarin fruits harvested from the upper part of the tree had higher overall quality including skin yellowness, TSS and bioactive compounds contents such as antioxidant activity, AsA and TP contents than the mandarin fruit harvested from middle and lower canopies. Refrigerated storage (10 ℃) could extend shelf-life of the fruit and maintain the amount of antioxidant activity and AsA content of the mandarin fruits.

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