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The effects of transportation temperature on the decay rate and quality of postharvest Ponkan (*Citrus reticulata* Blanco) fruit in different storage periods

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A R T I C L E I N F O

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A B S T R A C T

Ponkan (*Citrus reticulata* Blanco cv. Ponkan) is one of the widely grown and economically important citrus fruit species in China. Present study investigated the dynamic changes of Ponkan fruit' storability in different storage period and under alternating temperature during the postharvest transportation and shelf life, aiming to find out an efficient and energy-saving transportation scheme for Ponkan fruit at different storage stage. The results showed that, the elongation of storage time and the higher transport temperature led to the increase of decay rate. The juice yield continued to decrease, without affecting by the transportation temperatures. The rind color turn yellow rapidly (with the citrus color index (CCI) increased from 3.61 to 9.25) during the first two months, and remained stable during the following period. The higher transportation temperature accelerated the rind color development. The total soluble solids (TSS) increased during the first month (from 11.21% to 13.25%), remained stable in the second and third months, and then decreased slightly in the fourth month, which was not evidently influenced by the transportation temperature. The titratable acidity (TA) showed a continuous decline which was accelerated by the high transportation temperature. The ethanol and aldehyde contents continue to increase and were not significantly affected by the transportation temperature. The total flavonoids content decreased during the transportation and shelf life of the newly harvested Ponkan fruit, while remained stable and was not significantly affected by the transportation temperature in the four months of storage. The alternating temperature of transportation affected the storability of Ponkan fruit at different storage periods. These finding provided a theoretical basis for the selection of transportation temperature from economic perspective.

1. Introduction

Citrus industry is the largest fruit industry in the world. Postharvest storage, transportation and shelf life are the three important processes of the citrus fresh fruit industry (Zhou et al., 2014; García et al., 2016). The appropriate storage and transportation technology will be beneficial for the quality maintenance of citrus fruits.

Temperature is one of the important environment factors for the storage and transportation of citrus. In the mandarin, the appropriate storage temperature was determined to be 5 °C–10 °C (Tietel et al., 2010; Yun et al., 2012), and the commercially used shelf temperature is 20 °C (García-Martín et al., 2018; Saberi et al., 2018). The inappropriate high temperature might lead to a higher decay rate (Lee et al., 2015), water loss (Xie, 2003; Chalutz et al., 1985) and color degradation (Van Wyk et al., 2009) of citrus fruits. While the inappropriate low temperature (below zero) might lead to chilling injury and color degradation (Van Wyk et al., 2009; Fujisawa et al., 2001).

To obtain the best fruit quality during the shelf life, the duration of storage should also be considered during the appropriate temperature selection (Van Wyk et al., 2009). For example, the low temperature (6 °C) accelerated the increase of total sugars with the peak value appeared at the first month of storage in Cara cara navel orange, while the room temperature was more beneficial for the sugar content maintenance during the later storage period (Wang et al., 2007). In the long-term storage, the citrus stored under the higher temperature tend to contain the lower titratable acidity (TA) in the appropriate temperature

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scale (Wang et al., 2010).

Ponkan (*Citrus reticulata* Blanco cv. Ponkan) is one of the widely grown and economically important citrus fruit species in China. Present study aimed to investigate the dynamic changes of Ponkan fruits' storability in different storage period and under alternating temperature during the postharvest transportation and shelf life. The results will provide theoretical basis for the development of transportation strategy for the Ponkan fruits with different storage time.

2. Materials and methods

2.1. Materials

The study was carried out from November, 2014 to March, 2015. Disease and mechanical damage-free Ponkan fruit of uniform size and color were picked in November 1, 2014 from an orchard located in Quzhou city, Zhejiang Province, China. The selected fruit were put into sterilized plastic baskets and stored in the cellar. The average temperature of the cellar was detected using real-time temperature loggers, and the average temperature of November, December, January, February and March were detected to be 14.6 °C, 11.1 °C, 11.4 °C, 11.4 °C and 15.9 °C, respectively.

2.2. Transportation and shelf-life simulation

In each month, Ponkan fruit were moved out of the cellar, and transferred into 5 °C, 10 °C or 15 °C cold room respectively to simulate the commercial transportation conditions. After 3, 5 or 10 days, the fruit were moved out and transferred to the 20 °C house and stored for 7 days to simulate the shelf-life environment.

2.3. Decay rate

Fruit with obvious appearance of decay were recorded on each sampling day during the experimental period. Decay rate was calculated as the ratio of the decayed fruit number to the total fruits number. A total of 150 fruits were used for the decay rate calculation for each treatment.

2.4. Color analysis

Color measurement was carried out with a Hunter Lab Mini Scan XE Plus colorimeter (Hunter Associates Laboratory, Inc., Reston, VA, USA) at four evenly distributed equatorial sites of each fruit. Nine single fruit repetitions were done for each treatment. The CIE 1976 $L*a*b*$ color scale was adopted. Citrus color index (CCI) was calculated according to the following formula: $CCI = 1000 \times a* / (L* \times b*)$ (Tang et al., 2017).

2.5. Juice yield

The juice of the flesh was extracted using juice extractor. The obtained juice were filtrated and weighted. The juice yield was calculated as the weight percentage of the juice in the flesh. Three repetitions were done for each treatment, with three fruits in each repetition.

2.6. Ethanol and acetaldehyde contents analysis

The flesh of 2 g was grounded into fine powder in liquid nitrate, and mixed with 5 mL of saturated NaCl solution. The mixture was obtained for the headspace extraction-gas chromatography analysis. In brief, 3 mL of the mixture was put into the 10 mL headspace extraction bottles, heated at 60 °C water bath for 1 h. One mL of the gas was extracted from the head space of the bottle for the GC analysis. Ethanol and acetaldehyde production was determined with a gas chromatograph instrument (Agilent 6890 N, Folsom, CA, USA) with a FID column (HP-INNOWAX, 0.25 mm, 30 m, 0.25 μm, Agilent J&W, Folsom, CA, USA) according to the method described by Min et al. (2014) with modifications. The injector, detector, and oven temperatures were 150 °C, 160 °C, and 100 °C, respectively. Sec-butyl alcohol was added to each vial as an internal control. The results were calculated using standard curves for acetaldehyde and ethanol, respectively. Three repetitions were done for each treatment, with three fruits in each repetition.

2.7. Total soluble solids (TSS) and TA analysis

TSS contents were determined with a refractometer PR101-a (Atago, Japan) following the manufacturers' protocols, with nine fruits for each treatment, and two measurements per fruit. Titratable acidity was determined by titrated with 0.1 mol/L NaOH using T890 automatic titrator (Hanon Instruments Co. Ltd., China) with pH of 8.2 as titration end point (Lin et al., 2015). Three repetitions were done for each treatment, with three fruits in each repetition.

2.8. Total flavonoids analysis

Total flavonoids were determined according to the methods of Lin and Tang (2007) with slight modification. Briefly, the citrus peel were grounded into fine powder and stored in the −80 °C. The powder of 1 g was extracted with 5 mL of 80% ethanol for three times. The supernatants of three extractions were combined. For the flavonoids examination, 0.5 mL of fruit extracts was mixed with 1 mL H_2O and 75 μL 5% $NaNO_2$. After 5 min reaction, 150 μL 10% $AlCl_3$ was added, following by 6 min reaction. Finally, the mixture was added with 1 mL of 1 mol/L NaOH. Absorbance at 760 nm was read using a spectrophotometer (DU-8000 Beckman Coulter, USA). The content of total flavonoids was calculated as quercetin equivalent. Three repetitions were done for each treatment, with three fruits in each repetition.

2.9. Statistics

All experiments were performed with at least three repetitions. Results presented in the tables and figures were shown with standard deviations. All data were statistically assessed using SPSS version 20.0, and plotted by OriginPro 8.0. The differences were tested by one-way ANOVA. Multiple comparisons between the groups were performed using the LSD method.

3. Results

3.1. The dynamic changes of the decay rate

Decay is one of the most important reasons for the postharvest loss of citrus fruit. In present study, the decay rate was calculated during the period of storage, transportation and shelf life. A total of 150 fruits were used for the decay rate calculation for each treatment. The results showed that, the effect of storage will be reflected in the transportation and shelf life, with the decay rate during the transportation and shelf life increased with the elongation of storage time. The fruits transported and put on shelf immediately after harvest had a low decay rate (< 6%) during the shelf life (Fig. 1A). For the fruits stored for one month in the cellar at November, although the decay rate remained low during the transportation (similar to those without storage), it increased significantly during the shelf-life, especially for those transported at 10 °C and 15 °C (> 10%) (Fig. 1B). For the fruits stored for more than two month, a dramatically increase of decay rate occurred during both the transportation (2.17%–15.67% at day 10 of transportation) and shelf-life period (14.20%–24.83%), and the effects of transportation temperatures become significant (Fig. 1C–E).

At the transportation temperature of 5 °C, the decay rate was controlled at < 5% during the whole transportation period after different time length of storage (Fig. 1). However, the decay rate increased

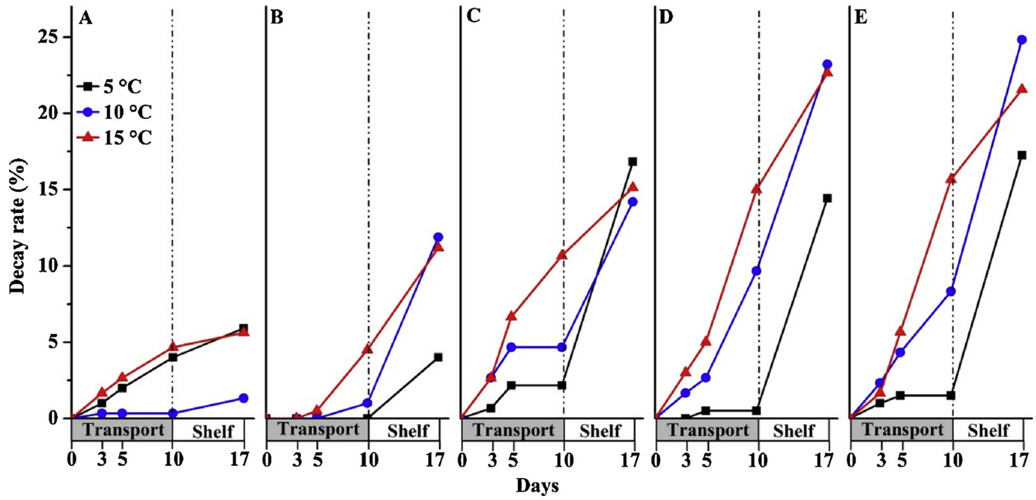

Fig. 1. Dynamic changes of decay rate of Ponkan fruit.

dramatically during the shelf life for the fruits having been stored for more than one month, especially for those transported under low temperatures (5 °C and 10 °C) (Fig. 1C–E), indicating that the temperature difference between storage and transportation had negative effects on the postharvest Ponkan fruits.

A, newly harvested; B, stored for 1 month; C, stored for 2 months; D, stored for 3 months; E, stored for 4 months

3.2. The dynamic changes of the juice content

Juice content is an important index for the evaluation of citrus fruit quality. In present study, the juice content of the flesh was calculated during the period of storage, transportation and shelf life. As shown in Fig. 2, the newly harvested Ponkan fruit had a juice content of 71.55%, and then decreased with the elongation of storage time, to a level of 62.07% after four months of storage ($P < 0.05$). During the transportation at 5 °C–15 °C, the juice contents were relatively stable. During the shelf life at 20 °C, there were slight decreases of juice contents in all the treatments, with the decrease being significant for the fruit transported under 15 °C after 0–1 month of storage ($P < 0.05$).

A, newly harvested; B, stored for 1 month; C, stored for 2 months; D, stored for 3 months; E, stored for 4 months. Vertical bars showed $LSD_{0.05}$ values.

3.3. The dynamic changes of the rind color

The CIE 1976 *L * a * b ** color scale was adopted for the evaluation of rind color during the storage, transportation of Ponkan fruit. As shown in the Fig. 3, The CCI value increased significantly with the storage time, from 3.61 of the newly harvested fruits to 10.46 of the fruits stored for four months. In the first three months of storage, the color change was dramatic (with CCI value increased from 3.61 to 10.09, $P < 0.05$), and tends to be stable afterwards (with CCI value increased from 10.10 to 10.46, $P > 0.05$). These results indicated that, the rind color change of Ponkan fruit was almost finished in the first three month after harvest, and then kept yellow afterwards.

The transportation temperature had significant effect on the rind color development of Ponkan fruits, especially on the newly harvested fruits, with the CCI value increased with the temperature. However, the differences were narrowed in the shelf-life under the shelf temperature of 20 °C ($P < 0.05$) (Fig. 3A). In the fruits after more than one month of storage, the effect of transportation temperature on rind color was not obvious, but the fruits at higher transportation temperature (15 °C) tend to have higher CCI value during all the periods (Fig. 3B–E). These results indicated that, higher temperature accelerated the color changes.

A, newly harvested; B, stored for 1 month; C, stored for 2 months; D, stored for 3 months; E, stored for 4 months. Vertical bars showed $LSD_{0.05}$ values.

3.4. The dynamic changes of the TSS and TA

TSS and TA are important indexes for the evaluation of taste quality of Ponkan fruits. In our results, the TSS and TA contents were detected during the storage, transportation and shelf life of Ponkan fruit. the newly harvested Ponkan fruit had TSS value of 11.21%, and tended to increase during the storage in the first two months ($P < 0.05$), then kept stable in the third month of storage ($P > 0.05$), with the highest TSS content appeared in the fruits after two to three months' storage (13.25%). The TSS value of the newly harvested fruits increased significantly during the shelf life after transportation at 5 °C and 10 °C ($P < 0.05$) (Fig. 4A). After one month of storage, the TSS value increased continuously during the transportation (Fig. 4B). After two and three months of storage, the TSS value showed no significant changes during the transportation and shelf life ($P > 0.05$), which were in a

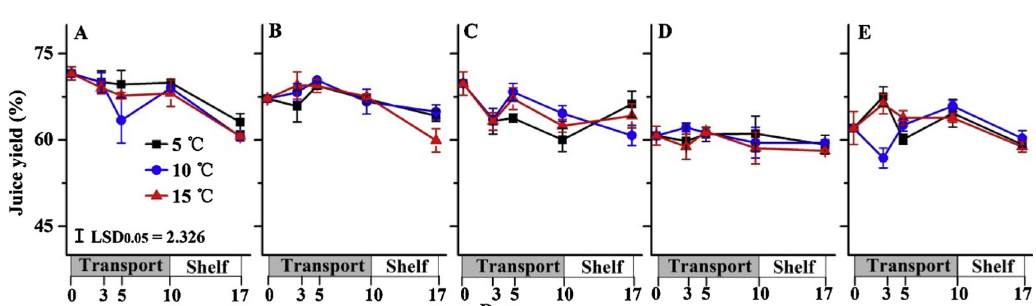

Fig. 2. Dynamic changes of juice content of Ponkan fruit.

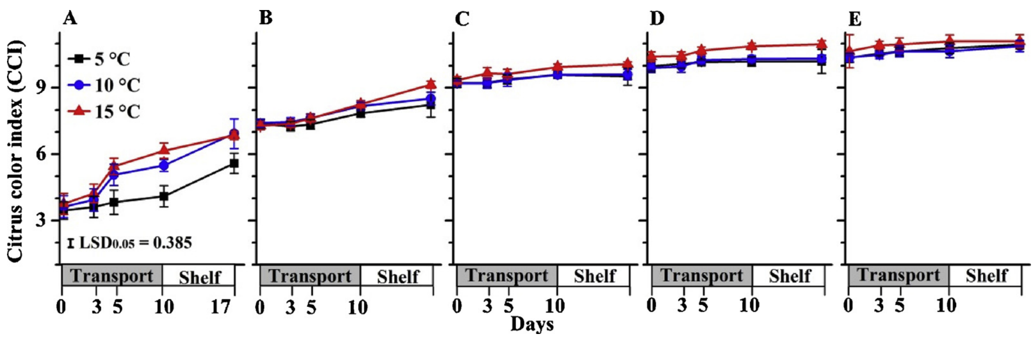

Fig. 3. Dynamic changes of CCI value of Ponkan fruit.

range of 13.01%–13.89%, being the highest during the whole postharvest period (Fig. 4C, D, E). In the fourth month of storage, the TSS value decreased significantly, especially for those transported under 15pC ($P < 0.05$) and then continued to decrease during the transportation and finally to a stable value (12.01%–12.84%) in the shelf life (Fig. 4E). The effects of transportation temperature seemed to be ruleless, indicating that the transportation temperature might have no significant effect on the TSS value of Ponkan fruit (Fig. 4A–E).

The newly harvested Ponkan fruit had TA content of 1.03 g/100 g FW, and decreased slowly during the first two months of storage after harvest ($P > 0.05$) (Fig. 4F–H). In the third and fourth month of storage, the TA content decrease dramatically ($P < 0.05$) and reached to the lowest level (0.36 g/100 g FW) in the fourth month of storage after harvest (Fig. 4I, J). During the transportation and shelf life, a significant TA decrease was seen for the newly harvested fruits and the fruits during the first three months storage, while a stable TA content was seen for the fruits with 4 months storage (Fig. 4F, J). The lower temperature alleviated the TA decrease during the transportation, which might be due to the lower metabolism activity in the lower temperature. However, the differences were narrowed in the shelf-life under the shelf temperature of 20 °C (Fig. 4H, I). In the fourth month of storage, the TA level becomes stable during the whole transportation and shelf-life, and the effect of transportation temperature was not significant (Fig. 4J).

A and F, newly harvested; B and G, stored for 1 month; C and H, stored for 2 months; D and I, stored for 3 months; E and J, stored for 4 months. Vertical bars showed $LSD_{0.05}$ values.

3.5. The dynamic changes of the ethanol and aldehyde content

Ethanol and aldehyde was the contributor of the unfavorable flavor of Ponkan fruit, which were important indexes for fruit senescence. The ethanol and aldehyde contents in the flesh were detected during the storage, transportation and shelf life of Ponkan fruit. Our results showed that, during the whole postharvest process (storage, transportation and shelf life), the ethanol content showed a trend of increase (Fig. 5A–E). The aldehyde content also kept increasing during the storage. For the fruits newly harvested or with 1–3 month's storage, aldehyde contents were relatively stable during transportation and shelf-life ($P > 0.05$) (Fig. 5F–I). However, for the fruits stored for 4 months, the aldehyde content showed a trend of increase during transportation and shelf-life. The low temperature (5 °C) transportation alleviated the increase of aldehyde content to a certain degree during transportation and shelf life (Fig. 5J).

A and F, newly harvested; B and G, stored for 1 month; C and H, stored for 2 months; D and I, stored for 3 months; E and J, stored for 4 months. Vertical bars showed $LSD_{0.05}$ values.

3.6. The dynamic changes of the flavonoids content

Flavonoids are the important bioactive compounds rich in the peel of citrus fruit related to the disease and stress resistance. The total flavonoids contents were detected during the storage, transportation and shelf life of Ponkan fruit. The flavonoids content of Ponkan fruit tend to be stable (0.27 mg QE / g FW - 0.30 mg QE / g FW) during the four months' storage ($P > 0.05$) (Fig. 1A–E). The newly harvested fruits had a significant decrease of flavonoids content during the transportation and shelf life, with a content of 0.16 mg QE / g FW - 0.18 mg QE / g FW at the end of the 7 days shelf life ($P < 0.05$) (Fig. 1A). For the fruits after storage for more than one month, the flavonoids content fluctuated in a range of 0.22 mg QE / g FW - 0.35 mg QE / g FW during the transportation and shelf life (Fig. 1B–E).

A, newly harvested; B, stored for 1 month; C, stored for 2 months; D, stored for 3 months; E, stored for 4 months. Vertical bars showed

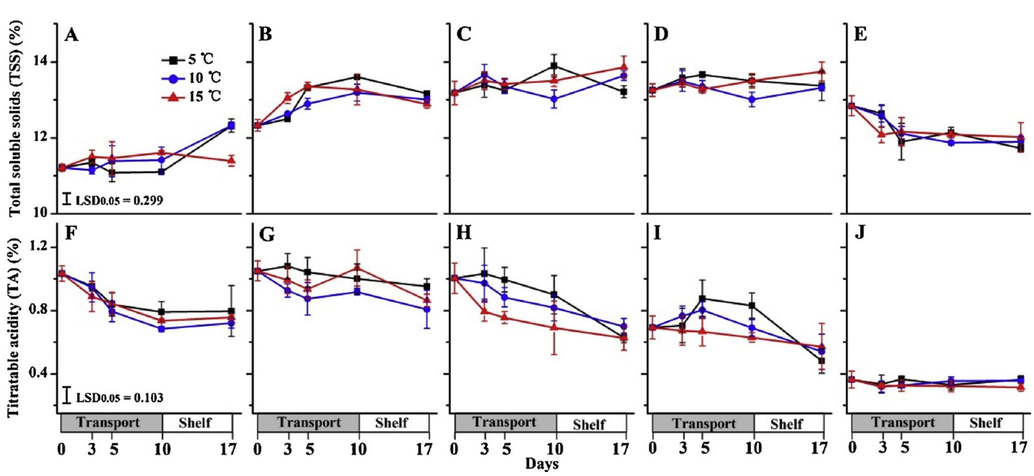

Fig. 4. Dynamic changes of TSS and TA of Ponkan fruit.

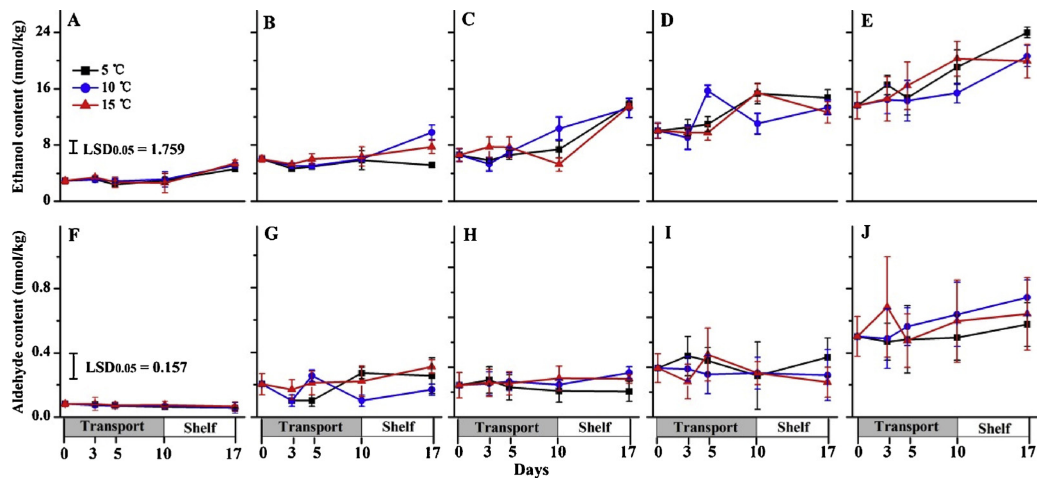

Fig. 5. Dynamic changes of ethanol and aldehyde content of Ponkan fruit.

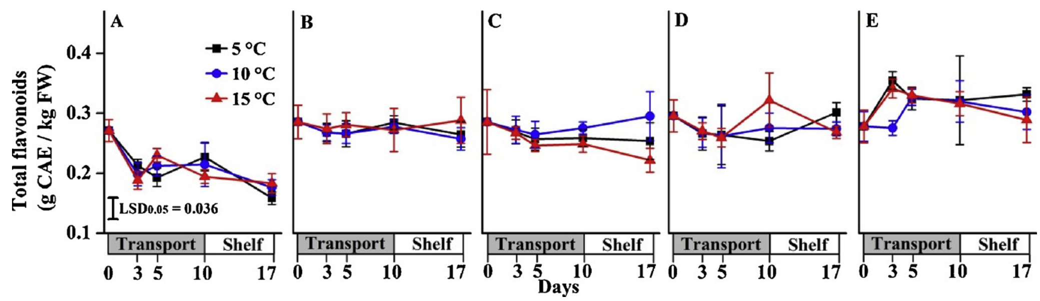

Fig. 6. Dynamic changes of total flavonoids content of Ponkan fruit.

$LSD_{0.05}$ values (Fig. 6)

3.7. General evaluation of the shelf quality of Ponkan fruit in different storage periods under different transportation temperatures

The general effects of transportation temperature on the shelf quality of Ponkan fruit, basing on the average value of decay rate, TSS, TA, CCI, juice yield, ethanol content, aldehyde content and total flavonoids content in the 7th day of the shelf life after 10 days of transportation, were evaluated comprehensively. The results were graphically presented as spider chart in Fig. 7. The intensity of each character were evaluated on a 0–2.5 scale. The results showed that, the effects of transportation temperature were mainly on the aspects of decay rate, TA, CCI and juice content. For the fruits newly harvested or in the early period of storage (< 1 month), the higher transportation temperature was beneficial for the decrease of TA ($P > 0.05$) and improvement of CCI ($P < 0.05$) (Fig. 7A, B). For the fruits with medium period of storage (2 month), a transportation temperature of 5 °C–15 °C was applicable, as the fruit quality was not significantly affected by the temperature (Fig. 7C), One-way ANOVA results of the mean scores of TSS, TA, CCI value, ethanol content and juice yield content indicated no significant differences ($p > 0.05$) among the three different transportation temperatures. However, for the long-term storage of more than 3 months, the higher transportation temperature was negative to the maintenance of fruits as it led to an increase of decay rate (Fig. 7D, E).

A, newly harvested; B, stored for 1 month; C, stored for 2 months; D, stored for 3 months; E, stored for 4 months. TF, total flavonoids. The values of different indexes were standardized as the ratio of value in each time point to the average value of all the five time points

4. Discussion

The postharvest citrus fruits will experience a process of senescence and quality deterioration. Commercially, the Ponkan fruit will be picked at the green ripe stage, with the TSS ≥ 8.5, TA ≤ 1.0 and TSS/TA ≥ 8.0, according to the agriculture standard system of citrus (NY/T 716-2003). Then, the fruits undergo a rind color development, TSS increasing and TA reducing process during the postharvest stage, and

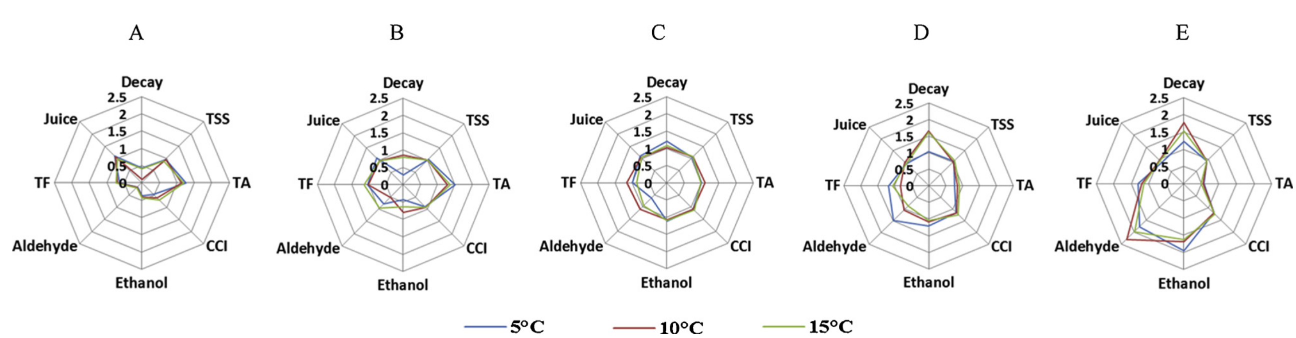

Fig. 7. The general effects of transportation temperature (10 days) on the shelf quality of Ponkan fruit.

then reach to the quality requirement of merchandise shelf period (Liu et al., 2010). With the elongation of storage time, the quality deterioration happened, with the ethanol and aldehyde contents in Ponkan fruit increased (Zhang and Tan, 1991). The inappropriate postharvest environments accelerate the decaying and quality deterioration process. Among the environment factors, temperature is the most important one.

The appropriate temperature ranges for postharvest processing varied among different citrus fruit types. In grape fruit ‘Shamouti’, ‘Valencia’ oranges and lemon, the chilling injury happened at the temperature lower than 12 °C during the storage, with increased rot and pitting rate (Chalutz et al., 1985). In Ponkan fruit, the low temperature significantly reduced the decay rate during storage, with the decay rate in 13.5 °C lower than that in 25 °C (Lee et al., 2015). In fact, the minimally processed Ponkan fruits can be stored for 120–150 days at 10 °C, with decay rate of lower than 30% (Tang et al., 2017). In present study, the decay rate of fruits varied significantly among three transportation temperatures, with the decay rate increased with temperature during the transportation. However, after moving to the shelf at 20 °C, the decay rates of fruits transported under low temperatures increased dramatically and the difference among transportation temperatures narrowed.

The inappropriate temperature affected the taste quality of citrus fruits. According to Chalutz et al. (1985), the respiratory rate increased 2–2.5 folds for each 10 °C increase of environmental temperature. The vigorous metabolism led to an increase of water loss in the juice sac (Xie, 2003; Chalutz et al., 1985). TSS and TA contents of citrus fruits were also sensitive to the temperature. The citrate reduced more slowly under lower temperature (Lin et al., 2016). Treated under an appropriate high temperature (30 °C) for 5 d will reduced the juice acidity in early-season ‘Miho’ Satsuma mandarins by 0.3%–0.5%, which resulted in an increase in ripening ratio from 5.5 to 6.0 at harvest to 7.5–8.0 (Tietel et al., 2010). Chalutz et al. (1985) had reported that impropriate storage temperatures caused the accumulation of bad flavor compounds including ethanol and aldehyde in citrus fruit. In present study, we found that with the elongation of storage time, the TSS value showed a trend of increase and the TA contents showed a trend of decrease. TA content was sensitive to the temperature, with the higher transportation temperatures were beneficial for the TA decrease. The ethanol and aldehyde content showed a trend of increase during storage, transportation and shelf life, while seem not to be affected by the transportation temperature (5 °C–15 °C).

The inappropriate temperature also affected the rind color of citrus fruits, as the biosynthesis of carotenoids and the degradation of chlorophyll were highly sensitive to the temperature (Stewart and Wheaton, 1971; Young and Erickson, 1961). The optimum storage temperature range for carotenoid biosynthesis and accumulation of citrus appears to be between 15 °C and 25 °C, with those fruit stored at 20 °C showed maximal color development that continued over a longer period than fruit stored at 30 °C (Wheaton and Stewart, 1973). Excessively high or low temperature might have negative effects on the rind color development. For example, the ‘Palmer Navel’ sweet orange fruit shipped at 4.5 °C had a better rind color than fruit shipped at -0.6 °C. Intermediate holding temperatures of between 11 °C and 15 °C were most effective in limiting the negative effects of extended, sub-zero shipping temperatures on rind color and re-initiated rind color development. A relatively high holding temperature (20 °C) led to the color degradation (Van Wyk et al., 2009). In present study, we found that a higher temperature (15 °C) accelerated the yellow turning of the Ponkan fruit’s rind, indicating a beneficial effect of high transportation temperature.

The secondary metabolism was partially affected by the postharvest temperature. Previous studies found that the low temperature storage at 4 °C (Lo Piero et al. (2005) and 8 °C (Rapisarda et al., 2001) might induce the accumulation of anthocyanins in the blood orange as well as the genes involving in anthocyanins synthesis. However, for other flavonoids in citrus fruit, the contents during the postharvest period tend to be stable. According to the previous study of Zhang et al. (2010), the flavonoids content in the postharvest Ponkan fruit stored at 20 °C slightly increased in the early stage, reached to the peak in the 15th day, and then decrease. Shen and Ye (2012) found that the flavonoids of Ponkan fruit showed no significant change during the 60 days storage period at 10 °C. Kevers et al. (2007) found that the phenolics contents of fruits and vegetables tend to be stable and were not significantly affected by the storage. Our results were partially agreed with these previous studies.

Alternating temperatures had been found to be beneficial for the quality maintenance of citrus fruits. Alternating temperatures of either 20/15 °C or 25/15 °C were found to have a more favorable effect on rind color development than a constant temperature of 20 °C or 25 °C (Wheaton and Stewart, 1973). However, the dramatic changes of temperatures will led to negative effect, thus, the cold-chain transportation (Tietel et al., 2011) and changing the temperature gradient during moving out of the storage room was recommended. Obenland et al. (2008) found that, for the navel oranges stored at 5 °C, increase the temperature gradually by transferring to 13 °C for 4 days before transferring to shelf at 20 °C can maintain the fruit quality effectively.

In present study on Ponkan fruit, we found that the elongation of storage time led to the increase of decay rate, which could be reflected during the later process of transportation and shelf life. In general, the appropriate temperature for the transportation changed during the period of storage. For the Ponkan fruits newly harvested or in the early period of storage (< 1 month) which were susceptible to decay, the higher transportation temperature of 10 °C and 15 °C will accelerated the formation of commercial quality (Fig. 7A, B). For the fruits with medium storage period (2 month), a transportation temperature of 5 °C–15 °C was applicable, as the fruit quality was not significantly affected by the transportation temperature (Fig. 7C). However, for the long-term storage of more than 3 months which were more susceptible to decay, a lower transportation temperature was more favorable as it decreased the decaying of Ponkan fruits (Fig. 7D, E).

5. Conclusion

The alternating temperature of transportation affected the storability and quality of Ponkan fruit in different storage periods. The decays of Ponkan fruit happened mainly in the transportation and shelf life, and increase with the elongation of storage time, which was reflected during the later process of transportation and shelf life. The temperature of the postharvest treatments affected the decay rate, rind color and acid contents of Ponkan fruit. The appropriate transportation temperature varied among Ponkan fruits in different storage period. For the fruits newly harvested or in the early period of storage (< 1 month), the higher transportation temperature of 10 °C and 15 °C were beneficial as it accelerated the formation of commercial quality of Ponkan fruits. For the fruits with medium storage period (2 month), a transportation temperature of 5 °C–15 °C was applicable, as the fruit quality was not significantly affected by the transportation temperature. However, for the long-term storage of more than 3 months, a lower transportation temperature was more favorable, as it decreased the decaying of Ponkan fruits. The results of present study provided a general understanding on the dynamic changes of Ponkan fruits’ storability in different storage period and under alternating temperature during the postharvest transportation and shelf life. In addition, the results provided a theoretical basis for the selection of transportation temperature from economic perspective.

Acknowledgement

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