Effect of Storage Temperature on Shelf-life of Banana (*Musa* spp., AAA Group, Cavendish Subgroup) at Ripened Stage

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Key words: Banana, Low-temperature storage, Browning

Summary

The bananas at ripened stage are associated with susceptibility toward softening, discoloration and decay. It is difficult to extend their shelf life and prevent postharvest losses in fruits. The temperature is the most important factor affecting banana storage. The aim of this study is to evaluate the effect of different storage temperatures on the color change, fruit firmness, ethylene production and respiration rate in banana at ripened. Banana fruits at ripened stage 4 (4th stage) of *Musa* spp., Giant Cavendish, and AAA Group 'Pei Chiao' were stored at 10 ℃, 15℃, 20℃ and room temperature (25 ± 2℃) for 6 days. The 15℃ treatment resulted in higher value of color change than 10℃, 20℃ and control treatment. Fruits stored at 10℃ and 15℃ showed high value in fruit firmness and lower value in ethylene production and respiration rate throughout 6 days, respectively. These results demonstrated that low temperature may extend the shelf-life of bananas after ripening. On the other hand, in 10℃ treatment, the pulp of banana fruit was unripe and the peel was not completely turn to yellow. Our results suggested that 15℃ was suitable for storage of banana at ripened stage as compared with other treatments.

Introduction

Musa spp., AAA Group 'Pei-Chiao', Cavendish Subgroup are the main commercial varieties of banana. The Cavendish subgroup have set the standards in terms of taste, yield and post-harvest characteristics expected of an export banana (Promusa, 2006). In 2016, world

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production of banana fruits was estimated at more than 113 million tons (FAOSTAT, 2016). In Asia, The Philippines account for approximately 87 percent of total export volumes from Asia (FAO, 2017). In Taiwan, the main varieties of banana are 'Giant Cavendish' (Cavendish group, AAA), which has the best quality, excellent tasting and has been a focus for export to Japan (Chen and Chao, 2004). The principal planting area is in Pingtung County, southern of Taiwan, with planting areas around 3,435 hectares.

In general, banana is transported from the place of production to far places for purchasing and consumption (Ilyas *et al*., 2007). The flesh bananas after ripening suffer from post harvest loss in both quality and quantity during marketing period. The quality losses are mainly due to biological deterioration including ethylene production, high respiration rate, compositional changes, high enzyme activity and many others (Humble and Reneby, 2015; Kader, 2004). Moreover, they may also result from the effect of environmental factors such as temperature, humidity, and the concentration of ethylene and carbon dioxide. The quality losses are shown as fruit softening, loss of aroma, senescence spot, decay and microorganism growth. The quantity losses are of greater concern in developing countries.

Therefore, the postharvest handling technology was developed and played a key role to solve this problem. Low temperature treatment is the most commonly used technique to store horticulture commodity to retard senescence, reduce respiration rate and ethylene production (Hailu *et al*., 2013).

The objective of this study is to investigate the effect of temperature storage, on extension shelf-life of 'Pei-Chiao' banana fruit at ripened stage.

Materials and methods

1. Plans materials

Banana fruit (*Musa* spp., Giant Cavendish, AAA Group) at yellow ripening stage (4^{th} stage More yellow than green) was obtained from a commercial ripening room located at Guozhong road, Dali district, Taichung city, Taiwan then transported to Department of Horticulture, National Chung Hsing University. Banana fruit was separated and selected for uniformity of shape, color, size for use in the experiment.

2. Experiment

The banana fruits were separated into 4 groups and stored in difference temperatures, fruits in the first group were stored at room temperature (25±2℃) as the control group and fruits from the second to the fourth group were stored at 10, 15 and 20℃, respectively. All of the treatments

were treated for 6 days and samples were collected every day to investigate ethylene production, respiration rate, and browning occurrence. Whereas, the fruit firmness and color measurement were determined on 0, 2, 4, and 6 days during the treatment period.

3. Firmness

The firmness of pulp was measured at three different location, which includes high, middle and low portion of banana fruit. On each fruit, the peel were separated from pulp before being sudjected to the measurement by using Sun Rheo Meter (COMPAC-100, Sun Scientific Co., Ltd., Tokyo, Japan). The probe was driven into the fruit at the rate of 100 mm/min to a depth of 10 mm from the fruit surface by using a 5 mm diameter flat probe and expressed as kg.

4. Color measurement

Peel color measurement includes lightness, chroma and hue angle value. Four individual banana fruits were used for determination of peel color and the measurement was performed at three different locations around the center of the fruit peel by using a Hunter Lab Scan colorimeter (MiniScan XE Plus, MSXP-4500S, USA). Results were presented as L* denoted the lightness or darkness, C denoted Chroma and H°denoted Hue angle which is converted from L*, a and b.

5. Browning index

Browning spot was evaluated by using a score index. The score was visually determined from the percentage of banana fruit surface with spots with a scale from 1 to 6; 1 for no browning, 2 for 1-20%, 3 for 21-30%, 4 for 31-50%, 5 for 51-80% and 6 for 81-100% browning. The attributes of brown spot was calculated as below:

Browning = ∑ (number of browning spots in given score × score value) / total number of banana fruit surface (cm^2)

6. Determination of ethylene production

Ethylene production was measured, by placing one fruit into a 2.0 L airtight acrylic jar with a rubber stopper then incubated for 2 h at 25℃. A 1.0 mL of gas sample was withdrawn from headspace of the airtight acrylic jar by using a syringe and injected into a gas chromatograph [Shimadzu, Model GC-8A, Japan, with a flame ionization detector (FID)]. The injector temperature was 130℃, the column temperature was 90℃ and the detector temperature was 130℃. The ethylene production was calculated by [(Sample peak height (cm) × fold) - (Air peak height (cm) × fold) / (Standard peak height (cm) × fold] × Standard conc. (ppm) × (Volume (L) / Fresh weight (kg)) and ethylene production was expressed as μL $C_2H_4.kg^{-1}h^{-1}$.

7. Determination of respiration rate

Respiration rate was measured, by placing one fruit into a 2.0 L airtight acrylic jar with a rubber stopper then incubated for 2 h at 25℃. A 1.0 mL of gas sample was withdrawn from

headspace of the airtight acrylic jar by using a syringe and injected into an infrared gas analyzer (IR-analyzer, Maihak, Model UNOR 610). The respiration rate was calculated by [(Sample peak height (cm) - Air peak height (cm)) / Standard peak height (cm)] × Standard conc. × 10 × (Volume (L) / Fresh weight (kg)) and respiration rate was expressed as $mLCO_2.kg.^{-1}.h^{-1}$.

8. Statistical analysis

The statistical analysis was performed by using SAS 9.0 (Institute Inc., 2000) and the data was subjected to one-way analysis of variance (ANOVA) for a completely randomized design (CRD) statistical model. Mean values among treatments were compared by least significant difference (LSD) range test at the 5% ($\rho \leq 0.05$) level of significance.

Results

The change in color from green to yellow continued to increase during the storage period (Fig. 1-2).

A faster change in color was shown in control and 20℃ treatment compared to 10℃ and 15℃ treatment. After 2 days of storage in control and 20℃, L* and C* values were decreased. On the other hand, the L* and C* values in 10℃ and 15℃ treatment were gradually increased throughout 6 days of storage. The low temperature plays a role in the color change of banana fruit by retarded ripening. The treatment of 10℃ and 15℃had higher hue angle value in comparison with the control and 20℃ treatment (Fig.3).

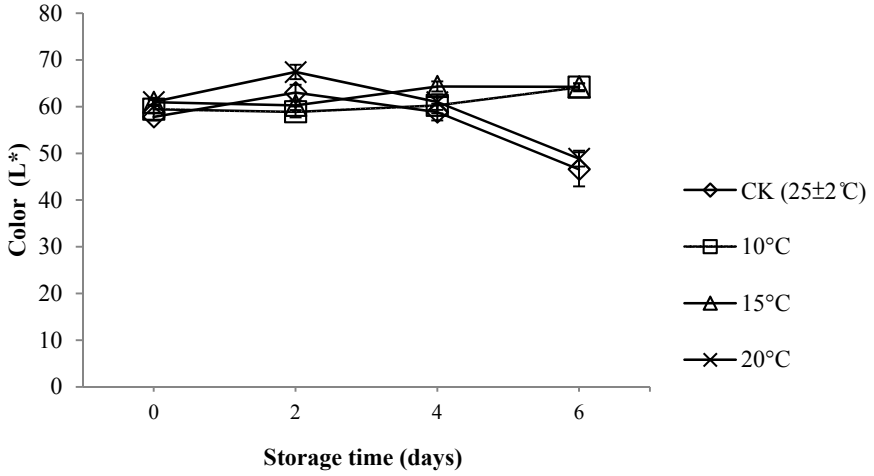

Fig. 1. Effect of storage temperature (CK 25±2, 10, 15 and 20℃) on color change (Lightness) of banana fruit at ripened stage.

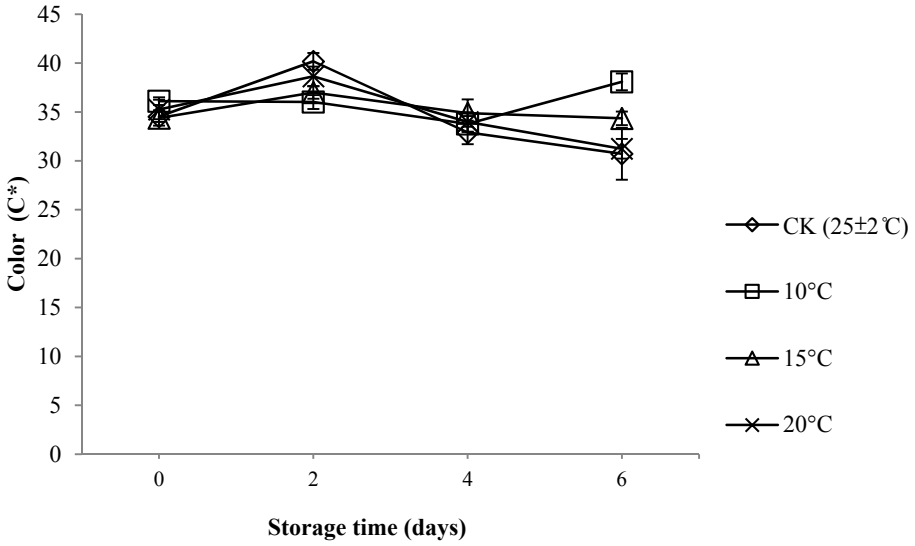

Fig. 2. Effect of storage temperature (CK 25±2, 10, 15 and 20℃) on color change (Chroma) of banana fruit at ripened stage.

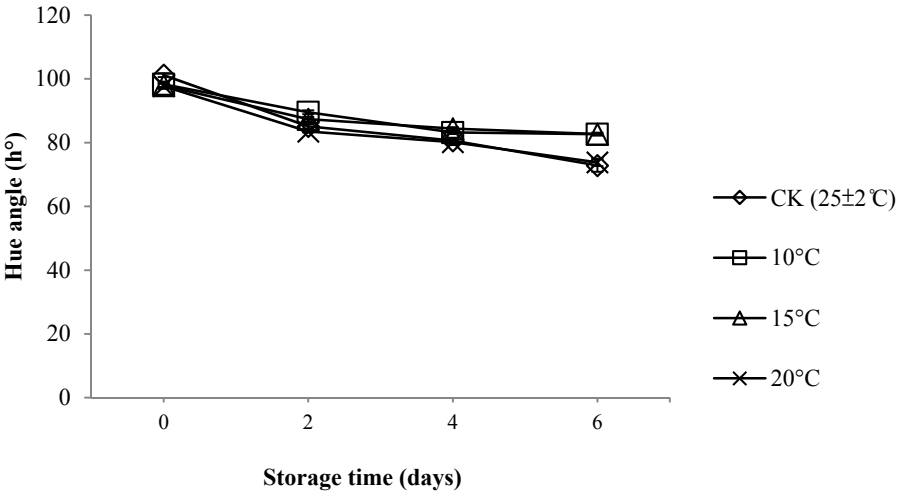

Fig. 3. Effect of storage temperature (CK 25±2, 10, 15 and 20℃) on color change (Hue angle) of banana fruit at ripened stage.

Results from this study indicated that the hue angle value at high temperature was declined during storage. Results from storage temperature experiment suggested that two low

temperature treatments (10℃ and 15℃) showed positive result of maintaining the coloration value (lightness, chroma, and hue angle value) in banana fruit as compared with the control and 20℃ treatment.

Effect of storage temperature on browning index and the appearance of banana fruit at ripened stage were shown in Fig. 4-6.

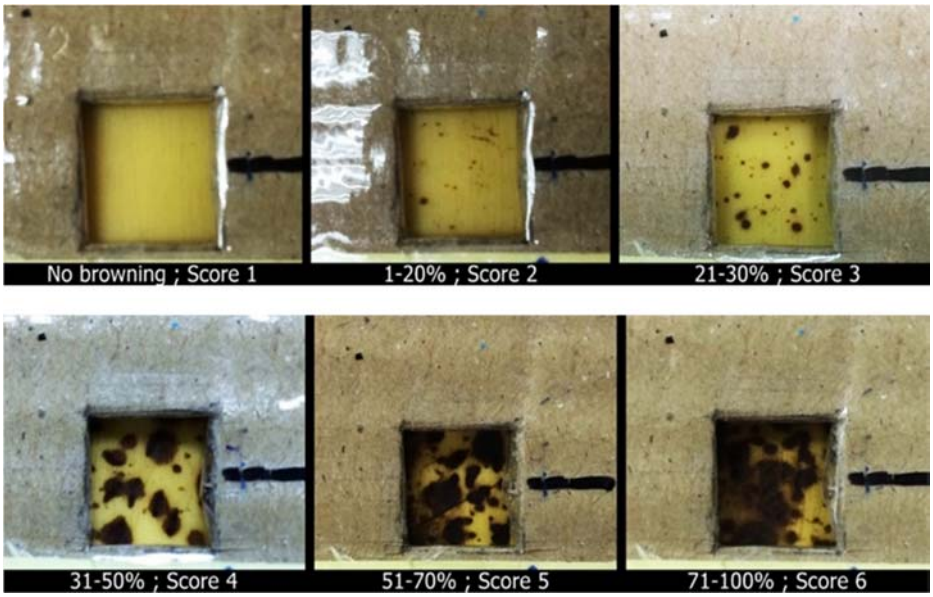

Fig. 4. The scales of browning index or senescence spot index of banana fruit at ripened stage; score 1, no browning; score 2, 1-20%; score 3, 21-30%; score 4, 31-50%; score 5, 51-70% and score 6, 71-100%.

On storage day 2, the control (CK 25±2℃; score 1.75) began to show browning, while no significant difference in the browning was observed in 10℃, 15℃ and 20℃ treatment (score; 1.00, 1.00 and 1.00, respectively). Moreover, a continuous increase in browning was noticed throughout the storage in control fruits (CK 25±2℃). Whereas, the browning index was significantly suppressed in 10℃ and 15℃ treatments compared with 20℃ treatment and control (CK 25±2℃) starting from storage day 3 until the end of storage. Furthermore, our results revealed that chilling injury symptoms appeared on the peel of banana fruits as characterized by dull or dark brown streaks and failure to ripen in 10℃ treatment.

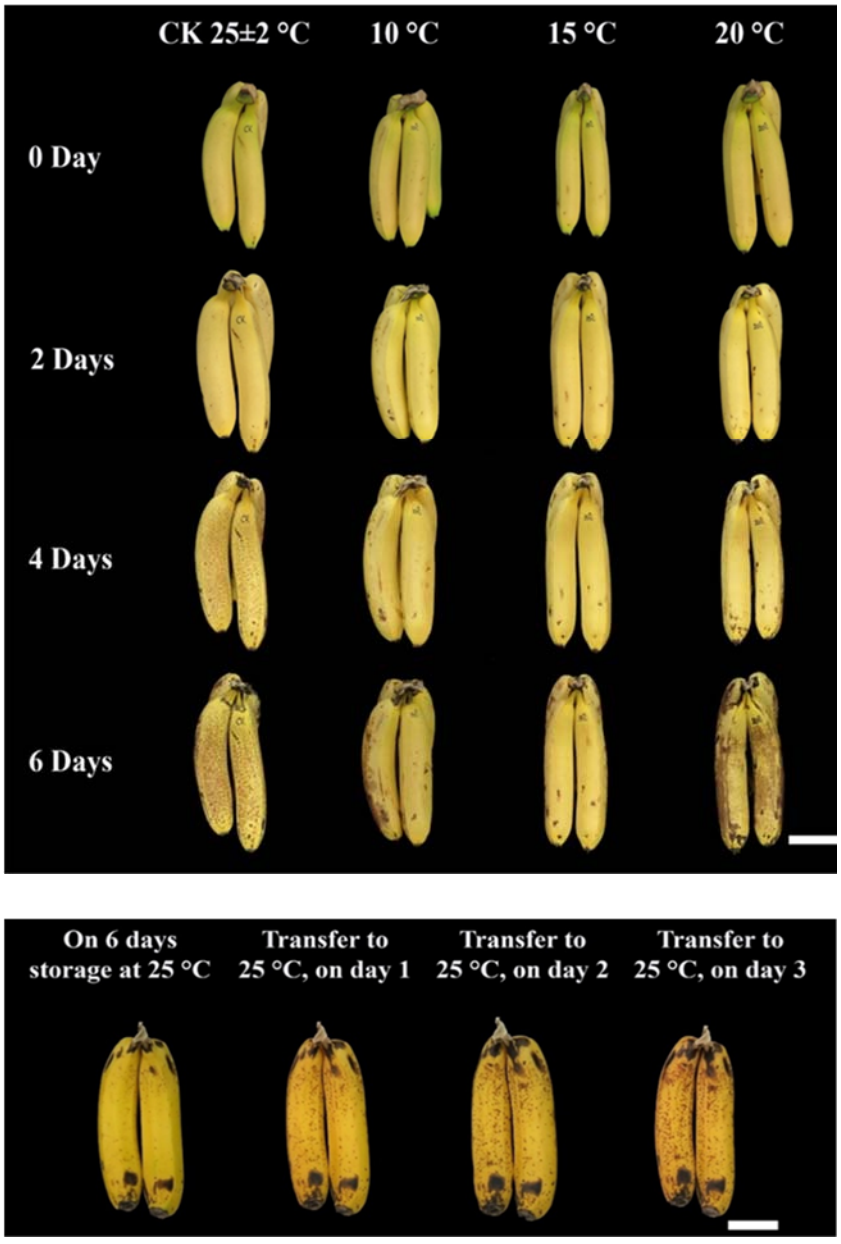

Fig. 5. Effect of storage temperature (CK 25±2, 10, 15 and 20℃) on the appearance of banana fruit at ripened stage (above) and effect of storage temperature at 15℃ for 6 days then transferred to 25℃ for 3 days (below) on the appearance of banana fruit at ripened stage (with bar = 5 cm).

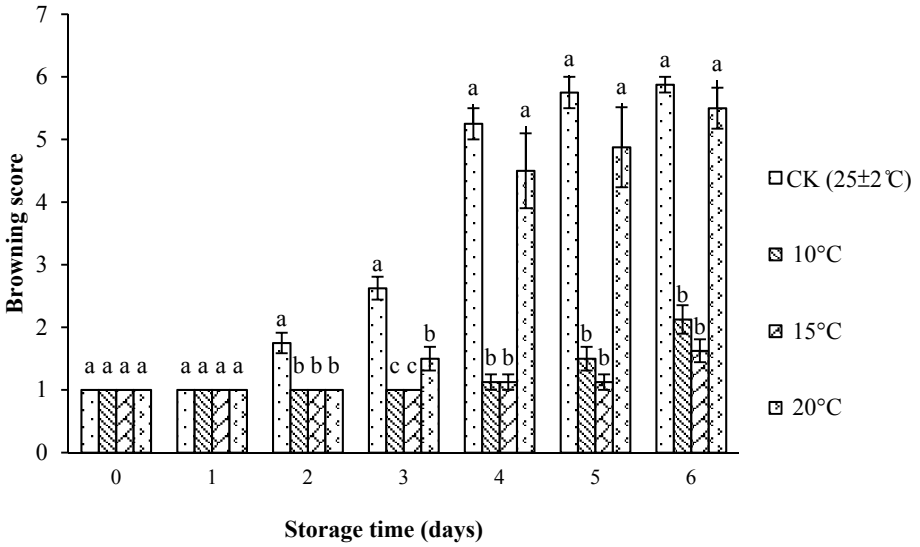

Fig. 6. Effect of storage temperature (CK 25±2, 10, 15 and 20℃) on browning index of banana fruit at ripened stage.

The best treatment during storage period was the 15℃ treatment by having a slight browning, however after being transferred to 25℃, browning symptoms occurred within 1 day. These results demonstrated that the low-temperature treatment may reduce or delay the browning in banana fruit at ripened stage.

Effect of storage temperature on the firmness of banana fruit at ripened stage as shown in Fig. 7 On 0 day, all of treatments no significant different in fruit firmness whereas during storage the fruit firmness was decreased throughout 6 days. On day 2, the control (CK 25±2℃) treatment was rapidly decreased in firmness, while in 10℃ and 15℃ treatment were gradually decreased in firmness. Since on day 4 until the end of the storage in 10℃ and 15℃ treatment were significantly retained in fruit firmness compare with control (CK 25±2℃) and 20℃ treatment. This demonstrated that the low-temperature (10℃ and 15℃) could retain in fruit firmness of banana fruit at ripened stage. Effect of storage temperature on ethylene production of banana fruit at ripened stage was shown in Fig. 8, throughout 6 days of storage in the control (CK 25±2℃) treatment, ethylene production was rapidly increased. While in the 10℃, 15℃ and 20℃ treatments ethylene production as gradually increased throughout the storage period. There was an ethylene peak on the 4^{th} day in the control (CK 25±2℃), 10℃, 15℃ and 20℃ treatments (5.31, 0.80, 1.20 and 2.01 μL $C_2H_4.kg^{-1}.h^{-1}$, respectively).

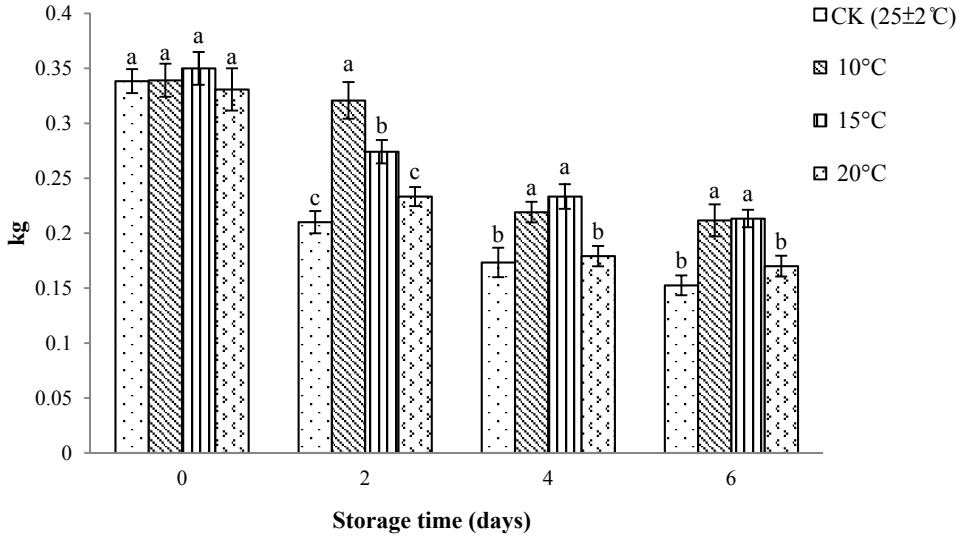

Fig. 7. Effect of storage temperature (CK 25±2, 10, 15 and 20℃) on fruit firmness of banana fruit at ripened stage.

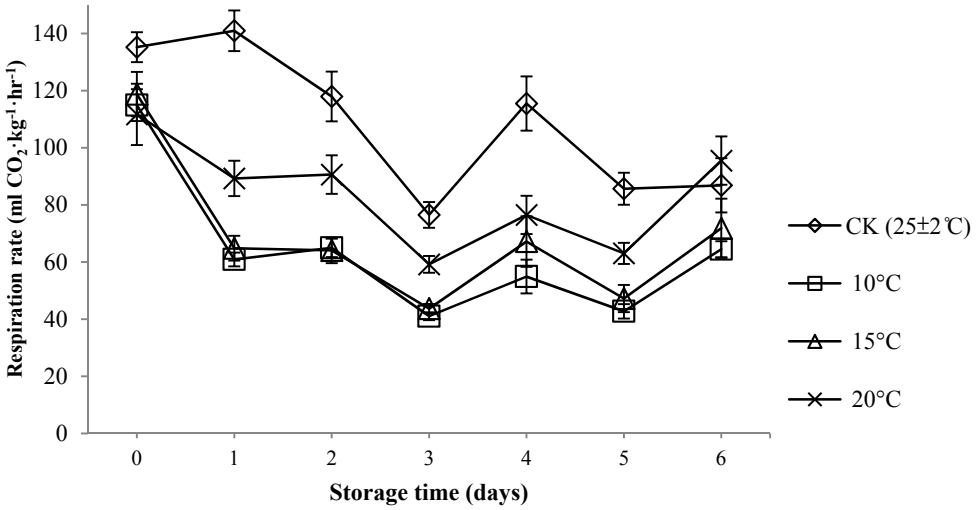

Fig. 8. Effect of storage temperature (CK 25±2, 10, 15 and 20℃) on ethylene production of banana fruit at ripened stage.

Similar to ethylene production, there was one respiration peak in the all treatments on the 4th day with control (CK 25±2℃) treatment having the higest respiration rate (115.52 mL $CO_2.kg^{-1}.h^{-1}$) as shown in Fig. 9. Whereas, in the 10℃ and 15℃ treatments, the respiration rate (54.92 and 67.12 mL $CO_2.kg^{-1}.h^{-1}$, respectively) were lower. These results demonstrated that the low-temperature (10℃ and 15℃) may inhibit ethylene production and respiration rate of banana fruit at ripened stage.

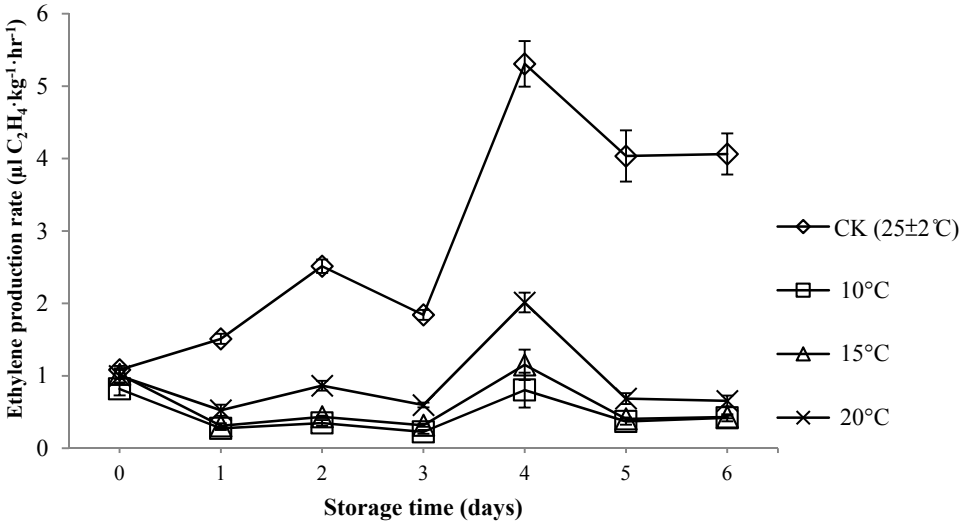

Fig.9. Effect of storage temperature (CK 25±2, 10, 15 and 20℃) on respiration rate of banana fruit at ripened stage.

Discussion

Wang and Camp (2000) reported that low temperatures caused retard development of fruit color than high temperatures. This report is consistent with our results in which the treatments of 10℃ and 15℃ had a positive result in maintaining the color change (lightness, chroma, and hue angle value) in contrast with the control and 20℃ treatments. Meanwhile, Porat *et al*. (2001) studied the peel of citrus fruit and observed that low temperature could inhibit chlorophyll degradation and that may explain why low temperature may maintain the color change in fruits.

The 10℃ and 15℃ treatments also displayed a significant decrease in browning of

banana fruit. Trakulnaleumsai *et al*. (2006) studied the effect of temperature on peel spotting in 'Sucrier' banana fruit and found that 12℃ may decrease peel spotting and delay color change in the peel of banana fruit which might be due to the temperature effect on enzyme activity. Nonetheless, we found that chilling injury symptoms on the peel of banana fruits as characterized by dull or dark brown streaks and failure to ripen may occur in the 10℃ treatment. Similar to the browning results, the fruit firmness in 10℃ and 15℃ treatment was gradually decreased and significantly retained when compared to the control (CK 25±2℃) and 20℃ treatment. These results demonstrated that lower temperature plays an important role to slow down fruit browning process and changes in fruit firmness.

The low temperature treatment were the most common technique for commodity storage because it may retard senescence, reduce enzymatic processes including suppressed ethylene production and respiration rate (Hailu *et al*., 2013). In this study, we investigated the effect of storage temperature on ethylene production and respiration rate of banana fruit at ripened stage. Our results showed that in the 10℃ and 15℃ treatments, ethylene production and respiration rate were lower throughout the storage as compared with the control (CK 25±2℃) and 20℃ treatments. Results from this study were consistent with Yang *et al*., (2013) study on low temperature induces chilling tolerance in 'Hayward' kiwifruit, where they observed that low temperature (12℃ for 3 days) may significantly alleviate chilling injury in kiwifruit by maintaining lower ethylene production and respiration rate. Low temperature has been reported to reduce oxygen (O_2) levels and increase carbon dioxide (CO_2) levels around the commodity (Irtwange, 2006). In terms of respiration rate, low temperature might play a role in interrupting respiration in plant cells (Platenius, 1942). Results from this study indicated that the 15℃ treatment was the best treatment to extend the shelf-life of banana fruit at ripened stage. In addition, the 15℃ treatment might achieve a storage life of more than 6 days without moving to the room temperature. In case of moving to the room temperature for only one day, the banana fruit may develop the browning symptoms on the peel of the fruit.

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溫度對延長香蕉後熟後櫥架壽命的影響

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關鍵字：香蕉、低溫儲存、褐化

摘要催熟後的香蕉易伴隨軟化、變色和腐爛，因而難以延長櫥架壽命，造成採收後損失，其中貯藏溫度為最重要的條件因子。本研究目的是評估不同溫度貯藏對香蕉後熟後顏色、果實硬度、乙烯產量和呼吸速率的影響。供試材料為催熟後之 4 級北蕉'Pei Chiao'果實，貯藏在 10℃、15℃、20℃ 和室溫 (25±2℃)6 天後進行調查。其中以貯藏在 15℃之果實果皮轉色最佳，優於 10℃，20℃和室溫。貯藏於 10℃和 15℃之果實硬度較高而乙烯生成率及呼吸率較低，顯示，低溫可延長後熟香蕉之櫥架壽命。然而，經 10℃處理之香蕉，有果肉未軟化、果皮未完全轉黃等不良品質表現。因此，本研究結果顯示，後熟香蕉貯藏於 15℃具有較長櫥架壽命。

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