PHYSICAL AND BIOCHEMICAL CHANGES IN COOL-STORED RIPENING BANANAS OF TWO DIFFERENT DESSERT CULTIVARS

Những biến đổi vật lý và hóa sinh khi chín của hai giống chuối sau thời gian bảo quản lạnh

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SUMMARY

This research was conducted to investigate the effect of low temperature on ripening quality of two banana cultivars (Kluai Khai, Musa AA Group, and Kluai Hom Thong, Musa AAA Group) grown commonly in Thailand for export. Bananas were stored at low temperatures (6, 10, 14°C) for various times, and then ripened at room temperature (28°C). Changes in colour, texture, a sensory attribute (chilling injury), decay, TA and TSS were analyzed. Both banana cultivars were susceptible to chilling injury (CI) when stored at 6° and 10°C. CI symptoms were shown clearly in bananas after a few days stored at 6°C while they appeared in bananas stored at 10°C after ripening. CI resulted in several physical and biochemical changes such as the discoloration of peel, abnormal changes of pulp texture, low content of titratable acidity and total soluble solids, and rapid rot development. Storage of bananas at 14°C for 3 weeks did not show CI symptoms after ripening.

Key words: Banana, chilling injury, Musa AA Group, Musa AAA Group, low temperature storage, peel discoloration.

1. INTRODUCTION

Corn Banana is an important world food crop. It contains a high sugar level and has a low acid content. It also contains high mineral and vitamin levels, which give a delicious characteristic flavor and texture. It ranked fourth after rice, wheat and maize, in terms of gross domestic product, with a world production of about 70 million tons in 2003 (UNCTAD, 2003).

For the successful marketing of edible bananas, the best way to prolong the shelf life is holding banana at low temperature. However, banana is extremely susceptible to chilling injury...
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For most banana cultivars grown in ASEAN countries, the limiting temperature below which chilling damage occurs is around 12-13°C (Pantastico et al., 1990). CI symptoms of banana include pitting, peel discoloration, abnormal ripening, hardening of the central placenta, complete loss of flavour, flow of clear latex, subepidermal brown streaking, appearance of water-soaked areas and abnormal high susceptibility to mechanical damage and decay (Grierson et al., 1967; Nguyen T. B. Thuy, 2006). At temperatures below 12 oC, dark brown colouration spreads along the peel latex vessels. Chilling also affects the ripening physiology by delaying the climacteric rise and sometimes producing multiple peaks of respiration (Murata, 1969).

Numerous postharvest studies describe the physical and chemical changes under low temperature storage conditions. But this study aims to investigate the physical and biochemical changes in cool-stored ripening banana fruits of two common cultivars grown in Thailand for export.

2. MATERIALS AND METHODS

2.1. Experiment design

Banana cvs. ‘Kluai Khai’ (Musa cavendishii [Musa acuminata] AA Group) and ‘Kluai Hom Thong’ (Musa AAA Group) were harvested at commercial maturity (80% maturity - light full ¾ of fruit), in a plantation in the Petchaburi province (Western Thailand). Dehanded bananas were placed in cardboard boxes and transported by refrigerated truck (25°C) to Kasetsart University within 3 hours of harvest. In the laboratory, hands were selected for uniformity of size and colour. They were cleaned in a solution of 0.5% magnesium sulfate (MgSO₄) to remove latex from the cut surface. The fruits were then dipped for 2-3 min in 500 ppm thiabendazole (TBZ) solution to control fruit rot, and allowed to dry at ambient temperature.

To compare the development of chilling injury and physical and biochemical changes between two banana cultivars (Kluai Khai and Kluai Hom Thong) after stored at low temperatures, the experiment was a completely randomized design (CRD) with 4 replications. Banana hands were randomly placed in corrugated cardboard boxes (40 x 48 x 22 cm) and stored at three low temperatures: 6, 10, 14°C and room temperature (28-30°C), RH 85%. Then the stored banana fruits were randomly transferred to room temperature every 3 days and left at room temperature to develop CI and checked after ripening (yellow fruit with green tip which is stage 5 of the colour index). Banana fruits were analysed for CI symptoms, physical and biochemical changes.

2.2. Analytical methods

2.2.1. Chilling injury (CI) assessment

CI in banana fruits was scored visually. The change in colour in bananas (cvs. Kluai Khai and Kluai Hom Thong) upon chilling, was different from the dark browning observed during CI in other fruit such as lychee. It is a rather grey brown. A rating scale from 1 to 5, based on the intensity of surface browning, was used; score 1 = no chilling injury; score 2 = mild injury; score 3 = moderate injury; score 4 = severe injury; score 5 = very severe injury. At score 2 there was no visible browning on the skin surface but if the epidermal tissues were peeled, grayish areas were observed close to the surface. Cross-section of the peel showed that these areas were globular in shape. At score 3 there were more such areas, which were larger and darker. At score 4 grayish brown patches were visible on the skin. Cross section of the peel showed larger and darker areas than at score 3. At score 5 there were relatively large dark patches on the skin surface. Nine banana hands from each treatment were observed.

2.2.2. Colour development

Change in colour of banana peel and pulp was determined using a colorimeter. Banana peel was measured at the central part at both sides. Banana pulp was measured immediately after cutting at the same part. L and b values were recorded where: L = brightness, ranging from 0 (black) to 100 (white); b = yellow/blue hue component ranging from -60 to 60. Thirty fruits from each treatment were measured.

2.2.3. Determination of fruit texture

Firmness of banana peel and pulp were determined using a fruit firmness tester (Effegi). Measurement of banana peel was made by a spherical plunger 0.2 cm in diameter. Unripe and ripe banana pulps were measured with a plunger 0.5 cm and 1.1 cm in diameter, respectively. The plunger was inserted to the depth of 0.5 cm and the force recorded in Newtons. Thirty fruits from each treatment were measured.
2.2.4. Determination of titratable acidity (TA) and total soluble solids (TSS)

Analysis of TA and TSS was followed by the method of A.O.A.C (1984). Ten grams of pulp tissue per each sample was homogenized in 30 ml distilled water for 5 min. After blending, the sample was centrifuged at 7000 rpm for 15 min. The supernatant was collected for measuring TA and TSS. Three samples per each treatment were analyzed.

TSS was measured by hand refractometer (Atago, Japan). The value was expressed in percent. TSS = reading value x dilution factor.

TA was determined by titrating the pulp extract with 0.1N sodium hydroxide (NaOH) using phenolphthalein as indicator and expressed as percent malic acid.

2.2.5. Fruit rot assessment

Fruit rot in banana was assessed visually. The decayed incidence was expressed as percentage of decayed fruits. Nine banana hands from each treatment were assessed.

2.3. Statistical analysis

Differences between treatments (\( P < 0.05 \)) were determined by analysis of variance (using time as repeated measure) and Wilcoxon rank-sum test. On percentage data of rot incidence, an arsine square root transformation was performed to stabilize the variance, before the data were subjected to analysis of variance. Where possible, means were compared using Duncan’s new multiple range test (DMRT).

3. RESULTS

Banana fruits were stored at three levels of low temperature (6, 10 and 14°C). These were compared with a control at room temperature (28°C).

Chilling injury symptom

CI symptoms developed more rapidly after removal from the chilling temperature and placement at room temperature. Severe discoloration was observed on the peel after 3 days storage at 6°C, followed by a period of ripening at room temperature. The ripening was shown after 8 and 9 days in cv. Kluai Khai and Kluai Hom Thong, respectively. Instead of a fully bright yellow colour on the peel of naturally ripened bananas, the fruits showed a dull yellow with some dark patches on the skin surface. On day 6, the CI symptom in cv. Kluai Hom Thong was more severe than that of cv. Kluai Khai. Most parts of the fruit turned black and became rotten. However, both cultivars were not acceptable at this time. Blackening in bananas stored at 10°C took about 4 or 5 days, when transferred to room temperature. The development of CI was thus more rapid compared to that in bananas during low temperature storage. On the other hand, bananas stored at 14°C for upon 18 days ripened naturally when transferred to room temperature, similar to the fresh fruits continuously held at this condition. CI symptoms of ‘Kluai Khai’ and ‘Kluai Hom Thong’ bananas at ripe stages were shown in Figure 1 and 4.

Changes in colour of peel

After removal from cold storage and ripened at room temperature, the brightness (L value) and hue (b value) in the peel of bananas stored at chilling temperatures (6 and 10°C) continued to decrease, in both cultivars. However, L and b values in the peel of bananas stored at 6°C were lower than those of bananas stored at 10°C. In contrast, L and b values of bananas kept at 14°C were almost stable (Figure 2 and 3).

Changes in texture of pulp

CI was accompanied by changes in texture of both the peel and pulp. After an exposure at low temperatures and ripened at room temperature, the firmness of the peel of bananas stored at 6°C remained high in both cultivars, whereas it slightly changed in bananas stored at 10 and 14°C. Similarly, the pulp of both banana cultivars held at 6°C was firmer than that of bananas stored at higher temperatures (\( P < 0.01 \)). The firmness of pulp of bananas cv. Kluai Khai stored at 10 and 14°C moderately declined over time whereas it changed a little in bananas cv. Kluai Hom Thong at the same temperature (Figure 5).

Changes in total soluble solids

The concentration of TSS in bananas cv. Kluai Hom Thong remained lower than that of bananas cv. Kluai Khai after storage at low temperature, followed by ripening at room temperature (\( P < 0.001 \)). The level of TSS was not different during 6 days of storage at any of the temperatures. Thereafter, TSS in both banana cultivars stored at 10°C slowly decreased while it remained at higher level in bananas stored at 14°C (Figure 6).

Changes in titratable acidity

After a removal from the cold room and ripening at room temperature, bananas cv. Kluai Hom Thong showed a higher level of TA (\( P < 0.001 \)). At the beginning of storage, the level of TA in the pulp of both banana cultivars stored at low temperatures was not significantly different.
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Fig. 1. Chilling injury symptoms in the peel of banana after storage at 6°C and 10°C and transferred to 28°C for ripening. Vertical bars indicate standard deviations of means.

Fig. 2. Changes in peel colour (L value) of banana after storage at 6°C, 10°C and 14°C and transferred to 28°C for ripening. Vertical bars indicate standard deviations of means.

Fig. 3. Changes in peel colour (b value) of banana after storage at 6°C, 10°C and 14°C and transferred to 28°C for ripening. Vertical bars indicate standard deviations of means.
Fig. 4. Peel discolouration and pitting symptoms in ripened bananas cv. Kluai Khai after storage for 6 days (A) and 12 days (B) at low temperatures; and bananas cv. Kluai Hom Thong stored at the same conditions (C, D)
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Changes in titratable acidity

After a removal from the cold room and ripened at room temperature, bananas cv. Kluai Hom Thong showed a higher level of TA \((P<0.001)\). At the beginning of storage, the level of TA in the pulp of both banana cultivars stored at low temperatures was not significantly different. In bananas stored at 10°C, TA showed only a slight fluctuation, in both cultivars. It also remained stable in ‘Kluai Khai’ bananas stored at 14°C, but it slightly increased in ‘Kluai Hom Thong’ bananas stored at that temperature (Figure 7).
Decay

The fungi rapidly developed in both banana cultivars after removal from the cold room and ripening at high temperature. Banana hands showed the typical symptoms of crown rot and anthracnose. The rot was severe in both banana cultivars stored at 6°C. All banana hands stored at this temperature showed rot incidence after 6 days of storage. All banana hands rotted after 18 days storage at 10°C. Rot increased at a lower rate in bananas stored at 14°C. However, the rot became severe at the end of the storage (Figure 8).

4. DISCUSSION

Banana is extremely susceptible to CI. The CI symptoms include pitting of the peel, peel discoloration and abnormal ripening of the pulp.

In most cultivars, the temperature below which chilling damage occurs is between 12-13°C (Pantastico et al., 1990).

The susceptibility of banana fruits to CI varies according to the cultivar, maturity stage at harvest, ripening stage, size and other factors (Abilay, 1968). In the cultivars studied CI occurred more rapidly at 6°C than that at 10°C. We thereby corroborated the findings of Gemma et al. (1994). We found that there was no significant difference in the visible CI symptom between two banana cvs. Klai Khai and Klai Hom Thong stored at 6 and 10°C (Figure 1, 4). This finding is in agreement with Chitrakoolsup (1982), who also showed that these two cultivars were more sensitive to CI than several other banana cultivars grown in Thailand.
The visual symptom frequently occurs in bananas stored at low temperatures is a peel discolouration. The fruits stored at 14°C showed a brighter green colour than those held at 10°C. In contrast, the fruits kept at 6°C turned dark brown after a short period of storage. The difference in the peel colour of bananas apparently due to the effect of low temperatures. Bananas held at temperatures lower than 10°C were subjected to CI and colour development was severely retarded (Abd El-Wahab, 1973). After transfer to room temperature for ripening, the peel of banana fruits stored at 14°C showed a bright yellow colour, the same as the fruits naturally ripened at room temperature without low temperature storage. The colour of the peel commonly varies from a dull yellow to a grayish yellow or gray in the fruits stored at lower temperatures (Figure 2, 3, 4). The discolouration which appeared in the peel of bananas subjected to CI is due to the browning substances found around the vascular tissues of fruits injured by chilling, unlike in the tissues of healthy fruits (Murata et al., 1967). The mesocarp discolouration was also reported in avocado stored at low temperature (Zauberman and Jobin-Decor, 1995).

CI also caused the changes in the texture of banana fruits kept at low temperatures (Figure 5). The pulp firmness of bananas stored at 14°C was softer than that of bananas stored at lower temperatures in both unripe and ripe stages (Figure 5). This suggests that chilling temperatures cause an abnormal ripening in bananas. Higher level of pulp firmness in chilled bananas could be a result of incomplete starch degradation.

The most striking chemical changes, which occur during the postharvest ripening of banana, were the hydrolysis of starch and accumulation of sugar (von Loesecke, 1949). In our study, we used TSS as expression of sugar content, since sugar takes a big part in the TSS of the banana fruits. The changes in TSS in bananas after storage were similar to those of TA (Figure 6, 7). After ripening at room temperature, level of TSS in chilled fruits was also lower than that of fruits held at non-chilling temperature. It is apparently that abnormal ripening in bananas was a result of CI. Under chilling temperature, the starch-sugar conversion was retarded. We therefore corroborated the findings of Aziz et al. (1976 a, 1976 b). Several changes in bananas stored at chilling temperature suggest that a breakdown in the coordination of the various ripening processes, as if cells did not receive the “signals” which initiate ripening.

Wolf (1958) found that acidity in the banana was at a maximum when the fruits turned yellow. In our study, TA in the banana fruits ripened at room temperature changed with a similar trend. Nevertheless, fruits held at lower temperatures showed a gradual and slight increase in the TA. After ripening, TA content in the pulp of chilling-injured fruits was lower than that of fruits stored at non-chilling temperature (Figure 7). This phenomenon may be attributed to the complete failure of chilled fruits to ripen. Our result is in agreement with the finding of Abd-El Wahab (1973). Conversely, a higher TA content was found in the pericarp of tomatos stored at low temperature as compared with the control fruits ripened without chilling storage (Hall, 1967).

Banana fruits held at temperature lower than 10°C deteriorated more rapidly than those held at room temperature (Abd El-Wahab, 1973). Crown rot and anthracnose were major diseases caused by the deterioration of bananas. There was a symptom of crown rot on the surface of banana crown stored at chilling temperature. However, crown rot and anthracnose developed more rapidly when bananas were transferred to room temperature for ripening. They occurred in both chilling-injured and non-chilling fruits, but more so in chilled banana hands (Figure 4, 8). This suggests that bananas stored at chilling temperature lost their resistance to prevent fungi infection.

5. CONCLUSIONS

Banana cultivars Kluai Khai (Musa AA Group) and Kluai Hom Thong (Musa AAA Group) studied were extremely sensitive to CI. Storage of bananas at 6 and 10°C caused CI in fruit including peel discolouration and abnormal ripening (after transfer to high temperature). CI resulted in several physical and biochemical changes such as the abnormal development of peel color, abnormal firmness of pulp, changes in titratable acidity and total soluble solids, and rot development. CI symptoms were shown clearly in bananas after few days stored at 6°C while they appeared in bananas stored at 10°C after ripening. Storage of bananas at 14°C upon 3 weeks did not result in CI. The fruits normally ripened after transfer to room temperature (28°C), similar to fresh fruit held at room temperature.
REFERENCES


