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EFFECT OF STORAGE TEMPERATURES ON RIPENING BEHAVIOR AND QUALITY CHANGE OF VIETNAMESE MANGO CV. CAT HOA LOC

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ABSTRACT

Vietnamese mango fruits cv. Cat Hoa Loc (*Mangifera indica* L.) were harvested at 75-84 days after fruit set and held at seven different temperatures from 8±1^{0}C to 24±1^{0}C and at ambient temperature for storage. Variation on quality of mango fruits cv. Cat Hoa Loc in low temperature were less than compared with these in ambient temperature (29-33^{0}C). Evaluation for quality attributes and storage life of each storage temperature were investigated to find out the limitation for mango stored at various temperatures. Changes in ripening behavior expressed as skin colour, fruit firmness and chemical properties of the fruit stored at 20 and 24^{0}C were equal to the fruits stored at ambient temperature. Lower storage temperatures could extend storage life over high storage temperatures. The result of this study showed that the fruits could not be stored at 11 and 8^{0}C for a long period because the fruits developed chilling injury symptoms and uneven ripening. The suitable storage temperature for Cat Hoa Loc mangos that could extend storage life to about 19 days without chilling injury was 14^{0}C. The fruit losses of each storage temperature and cause of the end of storage life were also obtained and discussed in this study.

KEYWORDS: Chilling Injury, Fruit Quality, Low Temperature, Storage Life, Vietnamese Mango

INTRODUCTION

Mango (*Mangifera indica* L.) is a major tropical fruit in both domestic and export markets of Vietnam. Among Vietnamese mango cultivars, Cat Hoa Loc mango is the most popular cultivar because of good appearance, delicious taste and flavour. Its production ranks the first among commercial mango cultivars in Vietnam. The Vietnamese government supports the expansion of the production area for Cat Hoa Loc mango. At the mature green stage, Cat Hoa Loc mango fruit usually turns to full ripening within 4-5 days at ambient temperature (29-33^{0}C) thereby limiting distribution and marketing options (Ba, 2007; Tai, 2008).

Temperature is an important factor that affects fruit quality and shelf life (Medlicott, 1990; Nunes et al., 2007). Proper temperature management during handling and storage is essential to retard ripening, preserve the fresh-market quality and extend shelf life. Low temperature storage is one of the very popular methods for storage life extension of mangos. The sensitivity of mangos to temperatures below 10^{0}C depends on fruit maturity, cultivar, duration and temperature of exposure (Medlicott, 1990). Some mango cultivars can be stored at 5^{0}C, but others must be stored above 10^{0}C or 13^{0}C. At 13^{0}C or lower, fruit softening can occur, flavour development is impaired, and fruit may taste acidic. The suitable temperatures for mango fruit ripening (i.e. with acceptable eating quality) were considered about 21- 24^{0}C. Above 24^{0}C, skin colour development is retarded, and the fruit may retain some green colour on the skin. The mango cv. Tommy

Atkins normally ripped with acceptable flavour and aroma after storage for 18 days at 5^0C, and 3 days at 20^0C (Mohammeda and Brecht, 2002).

As high quality, Cat Hoa Loc mango fruit are mostly sold at supermarkets where shelf temperatures are around 23-25^0C (Hung, 2008). Although some studies refer to the prolongation of Cat Hoa Loc mangos, there is still a need for more information on effects of storage temperatures on ripening behavior and quality changes. These were the objectives of our work.

MATERIALS AND METHODS

Experimental Material and Storage Conditions

Mature green mango fruits cv. Cat Hoa Loc from My Xuong Commune, Cao Lanh district, Dong Thap province were harvested at 75-84 days after fruit set and transported to the Southern Fruit Research Institute (SOFRI), Tien Giang province, (Vietnam) within 6 hours. At the SOFRI, uniform mango fruits in colour, shape, specific gravity (1.00-1.02), and weight (480-520g) were selected as described by Tai (2008). The fruits were held at room temperature – 29-33^0C (T0), 24±1^0C (T1), 20±1^0C (T2), 17±1^0C (T3), 14±1^0C (T4), 11±1^0C (T5) and 8±1^0C (T6) for storage until fruits were ripe and soft enough for eating or discarded due to shriveling, decay or chilling, such that the fruits were not accepted by the five experts of the staff.

Physical and Chemical Properties

The colour parameters of each individual mango was assessed using the CIE $L^*C^*h^0$ system (1986). The luminosity (L*), chroma (C*), and hue angle (h^0) values of skin and flesh were measured with a Minolta CR-400 Chroma Meter (Minolta, Tokyo, Japan) calibrated to a white plate. Skin colour was measured at the equatorial region of fruit and flesh colour was measured near seed.

Weight loss of fruit was determined using a digital balance, referencing to the initial and interval weights of the fruit. The result was reported in percentage of weight loss (AOAC, 1994).

Fruit firmness (kg/cm^2) of the fruit was determined by using a handle penetrometer FT20 (Wagner Instruments) for fruit provided with 8 mm stainless steel plunger tips (AOAC, 1994).

Mango juice was extracted from the sample with a juice extractor, and clear juice was used for the analysis. Total soluble solids content (TSS) was determined at 22^0C, with a digital refractometer ATAGO, Model PAL-a (Japan) using 2 to 3 drops of juice obtained by squeezing the fruits (AOAC, 1994). Titratable acidity (TA) was analyzed by titration 10-ml of sample juice with 0.1 N NaOH to a pH 8.1 endpoint using an Orion 950 Titrator (Thermo Electron Corporation, Beverly, MA). The results were expressed as a percentage of citric acid presented in the samples.

Starch content was determined according to Widdowson and McCance (1935). The mango flesh was cut up finely and well mixed. Portions of 100g were extracted with about 200 ml of cold 95% alcohol and stored overnight. The flesh was next extracted with 100 ml of 80% ethanol solutions at 75^0C in a Soxhlet apparatus and stored for about 16 hours, and then the alcohol from the united extracts was evaporated off under reduced pressure at a temperature always below 30^0C. The residue was made up to 200 ml in a graduated flask (solution A). 100 ml of solution A were measured in to a graduated 500 ml flask, diluted with water, almost neutralized with N/10 NaOH and cleared with basic lead acetate and saturated sodium phosphate solutions (Archbold & Widdowson, 1931). The solution was made up to volume and filtered. Reducing sugars were determined in this cleared filtrate by Lane and Eynon (1923) copper titration method, in which methylene blue was used as an internal indicator. Starch content was calculated by the following formula:

Starch content (%) = Reducing sugars (%) * 0.9

In each storage temperature, sixth replicates of fruits were randomly sampled at 4-day intervals for above assessments.

Sensory Values

In each storage temperature, twenty-five replicates of fruits were randomly sampled at 2-day intervals for the above assessments.

Shriveling of each individual mango was assessed using a visual rating scale 1-5; where 1 = no signs of shriveling, 2 = minor signs of shriveling, 3 = moderate shriveling, 4 = severe shriveling and 5 = extreme shriveling (Nunes et al., 2007).

Decay of each individual mango was accessed using a visual rating scale from Ketsa et al. (2000) with slight modifications. The scales were 1-5; where 1 = no decay, 2 = 1–25% decay, probable decay (brownish/grayish sunken minor spots), 3 = 26–50% decay, slight to moderate decay (spots with decay and some mycelium growth), 4 = 51–75% decay, moderate to severe decay and 5 = 76–100% decay, severe to extreme decay (the mango was either partial or completely rotten).

Chilling injury of each individual mango was assessed using a visual rating scale 1-5; where 1 = no visible symptoms of injury, 2 = trace (2–5% of the total fruit surface damaged), 3 = slight (up to 25% pitting and/or scalding), 4 = moderate (25–50% chilling damage) and 5 = severe (>50% of the fruit's surface showing damage) (Ketsa et al., 2000).

The shriveling index (SI), decay index (DI), chilling injury index (CI) were determined by multiplying the number of fruits in each category with their score, and then dividing this by the total number of fruit assessed (Junmatong et al., 2012).

The rating values of 2 of SI, CI, and DI were considered as the maximum acceptable quality before the fruit became unmarketable and was used to calculate the maximum shelf life for the fruit at each storage temperature (Ba, 2007; Nunes et al., 2007; Tai, 2008).

Overall Acceptability and Storage Life

Overall acceptability was rated on a scale of 1-5, with 1 being dislike very much and 5 being like very much. The components for rating included sensory value, physical and chemical properties and panel taste by five experts of the research team. Storage life was the period of storage that mango fruit still had the overall acceptability score not less than 3 (Tai, 2008; Hien, 2010).

Statistical Analysis

A completely randomized design was used and the experimental data were subjected to analysis of variance (ANOVA). Tukey's multiple-range test was used for significant difference test at the 95% confidence level of each variable.

RESULTS AND DISCUSSIONS

Change in Physical and Chemical Properties

Figure 1 shows that the C* values of skin and flesh of Cat Hoa Loc mango fruits increased during storage. The variation in C* values of both skin and flesh at high temperature was more than at low temperature and variation in C* value of flesh was more than of skin. After 12 days storage, variation in C* values of skin of fruit at 20, 17, 14, 11 and 8^0C were 12.30, 7.90, 5.23, 2.11 and 1.36 whereas these of fruit stored at 29^0C and 24^0C were 13.72 and 13.32 after 4 and 8 days stored, respectively (Figure 1a). At the end of storage, variation in C* values of skin of fruits kept at 17^0C and 14^0C were 13.10 and 11.76 while variation in C* values of flesh were 30.21 and 27.08, respectively (Figure 1b). The result showed that change in C* value of skin at 14^0C was slow through 12 preceding days of storage but rapid in the last 8 days of storage, whereas change in C* value of flesh was almost regular.

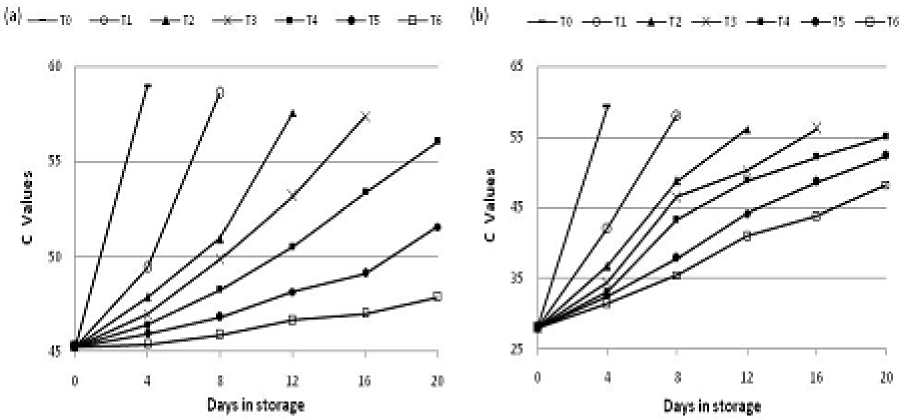

Figure 1: Change in Chrome (C*) of Skin (a) and Flesh (b) of Cat Hoa Loc Mango Fruit Stored at Various Temperatures

The colour parameter h^0 in skin and flesh decreased during storage and variation of h^0 values in both skin and flesh at high temperature was more than at low temperature (Figure 2). After 12 days storage, variations in h^0 value of skin at 20, 17, 14, 11 and 8^0C were 18.06, 14.77, 9.53, 5.86 and 1.19 while of flesh were 19.02, 15.01, 12.62, 8.58 and 7.67, respectively. Skin colour quality of fruit ripened at 13-30^0C was influenced by a number of factors; although minimum chlorophyll concentration in the skin occurred around the time that skin colour reached a maximum. Carotenoid formation and the development of blemishes also affected skin colour, but at 22 and 30°C, carotenoid formation had reached a maximum before chlorophyll had reached a minimum (O'Hare, 1995; Baloch and Bibi, 2012).

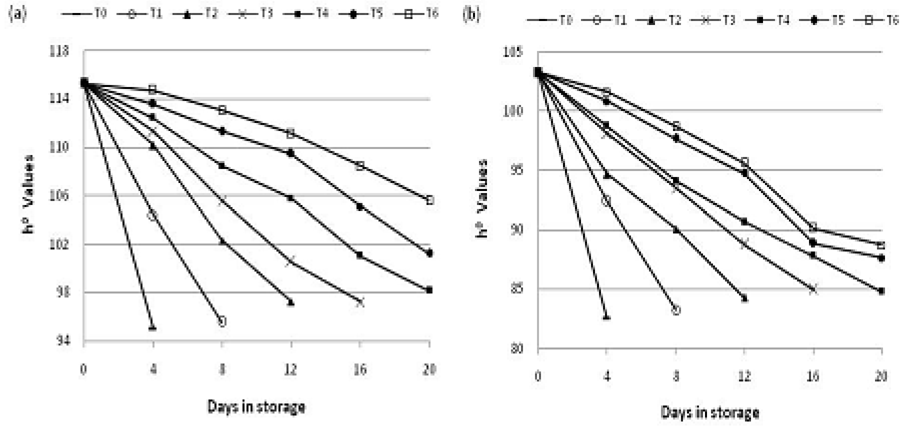

Figure 2: Change in Hue Angle (h^0) of Skin (a) and Flesh (b) of Cat Hoa Loc Mango Fruit Stored at Various Temperatures

Figure 3 presents the effect of temperature on L* values. The change of L* values of skin were slight, decreasing from 68.53 down to about 65 at all treatments (Figure 3a) while the L* values of flesh decreased sharply from 84.09 down to 68.58 and 75 at 14-29^0C and below 11^0C, respectively (Figure 3b).

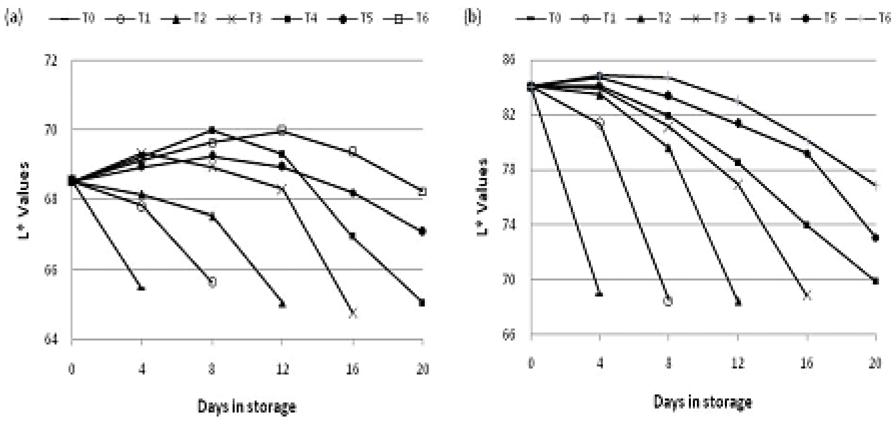

Figure 3: Change in Luminosity (L*) of Skin (a) and Flesh (b) of Cat Hoa Loc Mango Fruit Stored at Various Temperatures

Skin colour of Cat Hoa Loc mango fruit is a major appeal to consumers as a fruit with light yellow colour (Ba, 2007; Tai, 2008). Changes in the colour of the skin and flesh result from both chlorophyll degradation and carotenoid synthesis during mango ripening (Medlicott et al., 1986) which turns skin colour from green to yellow with ripening of Cat Hoa Loc mango fruits. The change of hue angle and chroma values indicates that the fruits ripen at high temperatures quicker than low temperatures. Moreover, at the ripening stage the skin colour of fruit stored at below 24^0C is yellow with a trace of green (about 52 in C* value and 97 in h^0 value). Medlicott et al. (1986) reported that Tommy Atkins mango fruit ripened at 22^0C develops a good colour because of the extensive chlorophyll breakdown in the skin. (Jacobi et al., 2000) reported that the rate of skin colour development differs between the varieties and the maturity of fruit, and depends on the storage conditions, particularly temperature. The changes of hue angle and chroma values at low temperature in Cat Hoa Loc mango fruit were similar in Tuu Shien mango fruit. Stored at 1^0C to 6^0C, the skin colour index of Tuu Shien mango fruit did not change up to 2 weeks, after which it changed from 1.8 to 2.1 (Le et al., 2010).

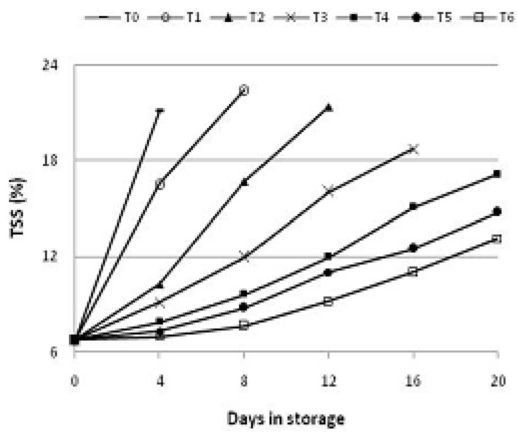

Figure 4: Change in TSS (%) of Cat Hoa Loc Mango Fruit Stored at Various Temperatures

The total soluble solids contents (TSS) increased with the ripening process and were high in case of high storage temperature. TSS increased during storage in spite of storage temperature; it increased from about 6.78% to 21.12, 18.72 and 14.78% at 29-33, 17 and 11^0C, respectively (Figure 4). After 12 days storage, the TSS of fruit stored at 8^0C was the lowest (7.65%) while TSS of fruit stored at 24^0C was the highest (22.43%). Storage temperature showed significant effects ($p<0.05$) on total soluble solids content of mango. In the case of Cat Hoa Loc mango fruit, the TSS at ripening stage should be at least 20% to be accepted by the consumer (Hoa and Hien, 2001; Ba, 2007). Tai (2008) had reported that the TSS difference depends on the days after fruit set or density and temperature storage. The increase in TSS was the outcome of conversion of carbohydrates into simple sugars through a complex mechanism during storage, and the conversion rate increased with the increase in temperature. The increase in TSS might be due to the alteration in cell wall structure and breakdown in storage. Kittur et al. (2001) was considered this conversion is also one of the important indexes of the ripening process in mango and other climacteric fruit. Manzano et al. (2001) also observed that temperature of storage affects the TSS. Ahmad et al. (2001) reported that bananas kept at higher temperatures showed greater TSS than those at lower temperatures.

Starch content of Cat Hoa Loc mango fruit was hydrolyzed during ripening, and decreased as temperature increased. At mature green, it was 11.64%, but at the end of storage it was 6.59% and 3.92% at 8^0C and 14^0C respectively while at ambient temperature starch content could be detected by only traces (Figure 5). After 12 days storage, starch content was 0.11, 2.11, 4.02 and 5.53% at 20, 17, 14 and 11^0C, respectively.

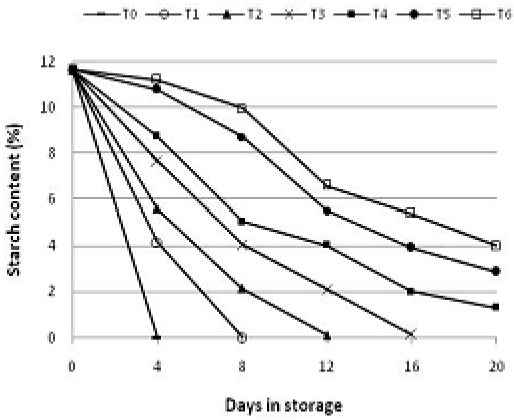

Figure 5: Starch Content (%) of Cat Hoa Loc Mango Fruit Stored at Various Temperatures

At 8^0C, change in starch content was slow in the first 8 days of storage (decreasing from 11.64% to 9.97%), but was very rapid in the 4 subsequent days (decreasing from 9.97% to 6.59%). The trend of change in starch content of this study was similar to those obtained by Tai (2008) and Hien (2010). These were results of starch being converted into sugar and accompanied by the brake down of acids making the sweet taste. Temperatures within 13 to 30°C have been reported to little affect on TSS of cv. Tommy Atkins (Medlicott et al., 1986) although other researchers have reported significant effects (Thomas, 1975; Le et al., 2010).

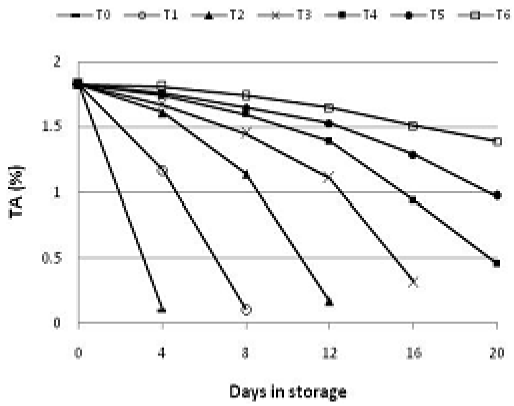

Figure 6: Change in Titratable Acidity (TA,%) of Cat Hoa Loc Mango Fruit Stored at Various Temperatures

The change in titratable acidity (TA) of Cat Hoa Loc mango fruit during storage at various temperatures is presented in Figure 6. The TA deceased at high temperature more than at low temperature. At the end of storage, the highest amount of titratable acidity was 1.39% at 8^0C followed by 0.97% at 11^0C while it was 0.46 at 14^0C and around 0.11% at 20-29^0C. The decreasing trend of TA during the storage period might be due to the degradation of citric acid and that could be attributed to ripening and their further utilization in metabolic processes in the fruit. High acidity in ripened mango fruit at low temperature has been reported by O'Hare (1995) and Baloch et al. (2012).

Firmness decreased during storage regardless temperature storage, but the decrease in fruit kept at low temperature was less than high temperature (Figure 7). From 7.93 kg/cm^2 at green stage, after 12 days of storage, firmness decreased down 1.23, 3.34, 5.30, 6.38 and 6.99 kg/cm^2 at 20, 17, 14, 11 and 8^{0}C respectively while it was 1.04 kg/cm^2 at 29^{0}C after only 4 days of storage. Firmness is one of the important quality parameters that play a significant role in fruit selection by the consumer. Cat Hoa Loc fruit was considered as waste when firmness value was less than 1.05 kg/cm^2 (Ba, 2007; Linh, 2007). This trend is due to the cell wall digestion by pectinesterase, polygalacturonase, and other enzymes and this process was increased by an increase in storage temperature (Narain et al., 1998).

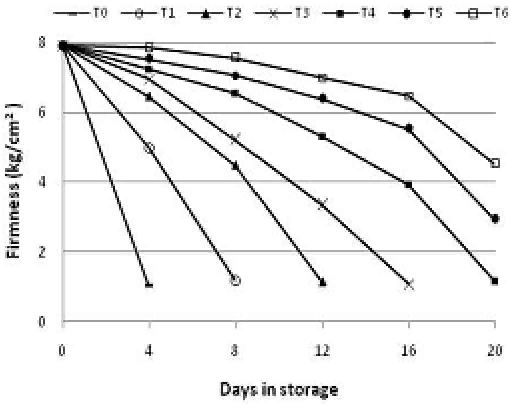

Figure 7: Change in Firmness (kg/cm^2) of Cat Hoa Loc Mango Fruit Stored at Various Temperatures

Figure 8 shows the increasing trend of weight loss of Cat Hoa Loc mango fruits during storage at different temperatures. At above 11^{0}C, the loss of weight significantly increased following an ascending order of storage period with the highest loss in weight of mango fruit observed at the last day of storage. The highest percent weight loss was 11.56% at ambient temperature for 4 days, and the lowest was 6.45% at 8^{0}C for 20 days. The reduction in weight of fruits in storage was attributed to the physiological loss in weight due to respiration, transpiration and other biological changes taking place in the fruit. These results were attributed to shriveling of fruits due to higher water loss of fruits stored at high temperature (Rathore et al., 2007).

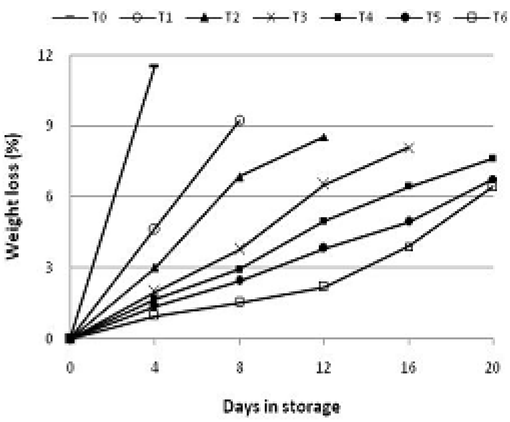

Figure 8: Change in Cumulative Weight Loss (%) of Cat Hoa Loc Mango Fruit Stored at Various Temperatures

Sensory Values

Figure 9 shows the SI and DI of Cat Hoa Loc mango fruit stored at various temperatures. Trends of change of both SI and DI similar, and it was coming soon at high temperatures but late at low temperatures. Scores of SI of fruits stored at 29^0C after 6 days storage was 2.3 while they were 2.2, 2.4, 2.3 and 2.4 after 10, 14, 16 and 20 days stored at 24, 20, 17 and 14^0C, respectively (Figure 9a). At chilling temperatures, SI was come earliest at 8^0C followed by 11^0C. It was 0.2 and 0.7 after 16 days storage and 2.2 and 2.6 after 20 days storage at 8^0C and 11^0C, respectively. DI occurred in all treatments regardless storage temperature, and DI increased with storage period (Figure 9b). At 29^0C, it was 1.8 after 4 days storage and 2.8 after 6 days storage. DI was coming soon at high temperature and later with low temperatures. It was 2.4 after 10 days storage at 24^0C, but was 2.7, 2.3 and 2.1 after 14, 16 and 20 days stored at 20, 17 and 14^0C, respectively; after 20 days storage DI was 2.2 and 2.5 at 11 and 8^0C. It may be that main damage to mango fruit at high temperature was anthracnose disease while at 8 and 11^0C fruit was spoilt by both anthracnose disease and disorder (Le, 2010).

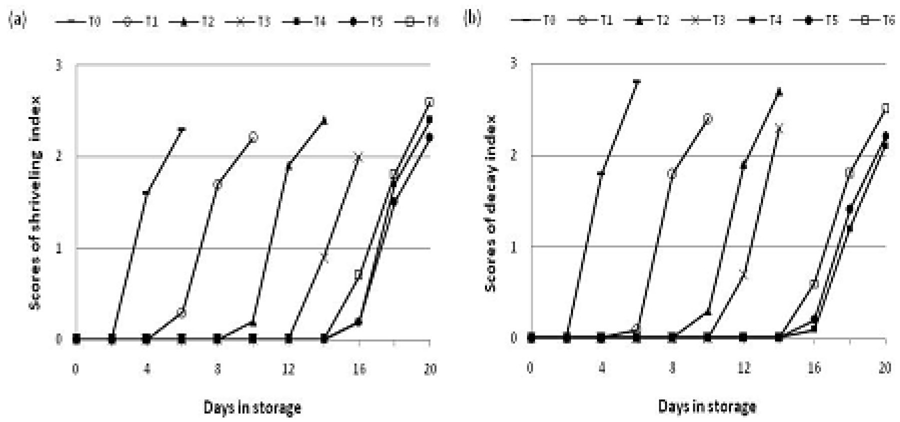

Figure 9: Shriveling Index (a) and Decay Index (b) of Cat Hoa Loc Mango Fruit Stored at Various Temperatures

CI of mango fruit at chilling temperatures is presents in Figure 10. CI increased with decreased storage temperature and storage period. After 14 days storage at 8^0C and 11^0C, it was 0.4 and 0.0, but in 4 subsequent days, it increased to 2.4 and 1.8 respectively while CI symptoms were not observed at higher storage temperatures. These findings are correlated with Hien (2010) who reported that Cat Hoa Loc mango fruit was sensitive to chilling when stored at 13^0C.

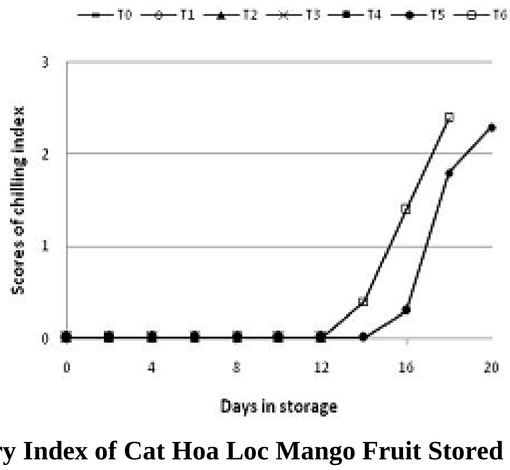

Figure 10: Chilling Injury Index of Cat Hoa Loc Mango Fruit Stored at Various Temperatures

Overall Acceptability and Storage Life

The scores of overall acceptability of fruits stored at 29, 24, 20 and 17^0C were 4.8, 4.9, 4.5 and 4.1 after 4, 8, 12 and 16 days stored while that of the fruits stored at 11^0C and 8^0C after 19 and 17 days were 3.1 and 3.0, respectively (Table 1). After these storage periods, all OA decreased quickly below 3.0 (not show here). Although fruits stored at below 17^0C could be kept for around 17-19 days, fruit quality did not score as high in OA as fruit stored at higher temperatures. Baloch et al. (2012) reported that optimum quality scores for cv. Kensington were achieved by ripening fruit at 18-22^0C.

The result shows that time required for ripening of mango fruits stored at low temperatures was longer than of fruit stored at high temperatures. These were 4.3, 8.0, 11.9 and 15.8 days of storage life at 29, 24, 20 and 17^{0}C respectively (Table 1). At these storage temperatures, the score of OA was above 4.0 with the highest of 4.9 at 24^{0}C. The OA of fruit at 20^{0}C was 4.5 because the starch content and TA was at limit, but the storage life was limited by softening and decay (Figure 7, Figure 9b). On the contrary, the end of storage at 11^{0}C and 8^{0}C, the quality of fruit was very low (OA about 3.0) because of fruit until green and the development of chilling injury symptoms. This suggested that the critical minimum temperature to Cat Hoa Loc mango was around 12-13^{0}C. These results were in agreement with those of Hien (2010) who observed that chilling injury symptoms on Cat Hoa Loc mango fruit occurred at 11^{0}C after two weeks of storage.

Table 1: Storage Life, Overall Acceptability and Causes of the End of Storage Life of Cat Hoa Loc Mango Fruit during Storage

Storage temperatures	Storage life (days)	Overall acceptability	Causes of the end of storage life
Ambient temperature (29-33^{0}C)	4.3	4.8	Overripe, Softening, Decay
24^0 C	8.0	4.9	Overripe, Softening, Decay
20^0 C	11.9	4.5	Softening
17^0 C	15.8	4.1	Softening
14^0 C	19.8	3.4	Softening
11^0 C	19.3	3.1	Chilling injury, Decay, Uneven ripening
8^0 C	17.4	3.0	Chilling injury, Decay, Uneven ripening

In general, the results demonstrated the effect of various temperatures on ripening date and quality of Cat Hoa Loc mango fruits. Fruit stored at high temperature, 29^{0}C and 24^{0}C, had good quality, but the storage life was not more than 8 days. Fruits ripened at 24^{0}C for 8 days storage achieved the highest quality with 4.9, 22.43 and 0.11 in overall acceptability, TSS and TA, respectively. All physical-chemical quality parameters of fruits stored at 29-33^{0}C were tantamount these of fruits stored at 24^{0}C but ripening day could be extended to about 4 days. At low temperatures, 20^{0}C, 17^{0}C and particularly 14^{0}C, softening of the fruits was coming before the change in colour, TSS, TA and starch content limited the storage life. After storage at 14^{0}C for 19.8 days, firmness value was 1.76 kg/cm^2 while TSS, TA, and starch content were 17.13, 0.46 and 1.29% respectively. At chilling temperature (8-11^{0}C), CI and DI are the major factors limited the storage life; even though firmness value, TSS, TA and starch content were not reaching the minimum quality of ripen fruit. After storage at 11^{0}C for 19 days, chroma and hue angle values of skin, overall acceptability, TSS, TA and starch content were 51.59, 101.23, 1.3, 14.78, 0.97 and 3.92 while CI and DI were 2.4 and 2.2 respectively. They present that at this storage temperature (11^{0}C), Cat Hoa Loc mango fruit cannot ripen normally. Because of CI, DI and uneven ripening, the storage life of Cat Hoa Loc mango fruit at 8^{0}C is 17.4 days.

CONCLUSIONS

The results from this research showed that Cat Hoa Loc mango fruit stored at 29-33^{0}C maintain good quality throughout 4 days of storage. The fruits ripened with the best quality and highest overall acceptability after storage at 24±1^{0}C for 8 days and at 20±1^{0}C for 11.9 days. Fruit storage at 17±1^{0}C could extended storage life to 15.8 days, but the quality of fruit is not as good as of the fruits storage at 20±1^{0}C. Although at 14±1^{0}C, storage life of fruit could extend to 19.8 days, the sensory and chemical values were not high. The results suggested that Cat Hoa Loc mango fruit could kept at 14±1^{0}C, but the fruits should be transferred to high temperature for normal ripening with good qualities. At 8±1^{0}C and 11±1^{0}C, Cat Hoa Loc mango fruits developed chilling injury symptoms during storage so that application of new technologies to reduction chilling injury of mango, such as treatments with salicylic acid or methyl jasmonate (Aguilar et al., 2001; Junmatong et al., 2012), are of great interest.

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