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Changes in Pigments and Fruit Quality in Papaya from Different Harvesting Seasons

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Abstract The changes in pigment and fruit quality in 'Khak Dam' and 'Holland' papaya harvested in summer (April-May, 2012) and winter (December 2012-January 2013) seasons were studied. The results showed that papaya from different growing seasons were no different of color change in peel and pulp, but tended to increase during storage. Papaya harvested in winter season had L*, a* and b* values of the peel higher than summer season. Chlorophyll a and b contents in 'Khak Dam' and 'Holland' papaya decreased rapidly after 2 days in storage with were no different between harvesting seasons. However, 'Holland' papaya had rapidly decreased in chlorophyll a and b than 'Khak Dam' papaya. Carotenoid content slightly increased during storage with no significantly different among harvesting seasons. Fruit firmness decreased approximately 120-140 N when compared to the beginning, with no significantly different among seasons. 'Khak Dam' papaya appeared to decrease fruit firmness higher than 'Holland' papaya but had no significantly different between these two cultivars at the end of storage. At the end of storage, papaya harvested in winter season had the eating quality as shown by TSS/TA ratio which approximately 20 and 30 higher than summer season for 'Khak Dam' and 'Holland' papaya, respectively. Papaya harvested in summer season showed the percentage of weight loss 2 and 3 times higher than in winter for 'Khak Dam' and 'Holland' papaya, respective, but not different at the end of storage ranged from 13.2-15.7%.

Keywords: papaya, pigment, chlorophyll, and carotenoid

Introduction

Papaya fruits are rapidly ripening after harvest. The maturity index can be obtained by change in the peel color from green to yellow. The change in some pigments can explain by the degradation of chlorophyll in concomitant with the induction of carotenoid synthesis (Solovchenko *et al*., 2006). The yellow skin develop during ripening process mostly uniform for import cultivars like

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‘Holland’ papaya but for Thai cultivars including ‘Khak Dam’ papaya always showed uneven skin color development. ‘Khak Dam’ papaya is one of the Thai’s favorite for fresh consume, red-orange flesh and good flavor are the additive quality for consumer. However, the skin color was not completely development at the ripe stage, only at the stylar end. It is difficult to identify the right stage with better quality for consumer demand. This coloration can confuse customers as the fruit appears to be ripe with soft pulp, but showed little yellowing on the fruit skin. For ‘Holland’ papaya, this more planted and consumed recently in Thailand, the even yellow skin development, more firm and sweeter than ‘Khak Dam’ papaya. In general, papaya fruit for fresh consumption is harvested according to color, and mostly consumer’s preferred papaya of a particular skin color; e.g., ‘Holland’ papaya appeared yellow skin when it became fully ripe but not found in Khak Dam’ papaya.

Pigments responsible for papaya color are chlorophyll (green) and carotenoid (yellow). Background color in papaya changes from green to yellow during ripening through chlorophyll disappearance, which makes yellow pigments visible as reported in apples. The ripening of most fruits is characterized by a rapid decrease in chlorophyll levels coupled with a rapid increase in pigment levels (Slabaugh, 1982).

Factors affecting fruit color are primarily genetically determined. In addition, environmental factors such as nutrients, temperature and light conditions can have an effect on pigments composition and on the final color of the fruit skin (Brouillard and Dangles 1994, Brouillard *et al*. 1997, Mol *et al*. 1998). It has been reported that, in comparison with shaded, sunlit skin of apples possesses high levels of flavonoids (Merzlyak and Chivkunova, 2000; Merzlyak *et al*., 2005), contains lower quantities of Chlophyll and higher amounts of carotenoid (Merzlyak *et al*., 2002).

Understanding the pigment changes during ‘Khak Dam’ and ‘Holland’ papaya ripening is important since we may be able to manipulate coloring in some way to better co-ordinate softening and color change. The purpose of this project was to determine the concentrations of chlorophyll a and b and carotenoid in the skin of this two-papaya cultivar as fruit grown from different season and continue study during fruit ripened at room temperature (25±1°C).

The aim of this work was to elucidate the effects of growing seasons on quantity of some pigments and fruit quality of ‘Khak Dam’ and ‘Holland’ papaya during ripening.

Materials and methods

Sample preparation

Papaya fruit cv. Khak Dam and Holland was purchased from an orchard in Sakeao Province, Thailand during summer (April-May 2012) and winter season (December 2012-January 2013). Fruit samples were carefully picked for homogeneous color and size of forty-eight fruit samples were used. Samples were clean with chlorinated water and air dried before storage at room temperature. The experimental was designed as completely randomized design (CRD) and divided into two seasons; summer and winter. Fruit physiological and biochemical compositions changes during storage were recorded immediately after harvest and during storage at room temperature until fully ripe stage.

Data recorded

Peel and pulp color change during storage were measured by Color Flex spectrophotometer and report in term of L*, a* and b* values. The L* value represented the lightness, a* value represented in the redness (positive value) and greenness (negative value) and b* value represented the yellowness (positive value) and blueness (negative value). Peel color was measured at the central part of the fruit, with 4 positions in the opposite direction. Fruits were then cut through the longitudinal for two pieces and 6 positions were measured for pulp color.

Pulp firmness was measured by using fruit firmness tester; the 0.5 and 1.1 cm diameter plunger head were used for mature and ripe stages, respectively. Each side of fruit sample was measured in duplicate by press the plunger head down to 0.5 cm depth. The data was report in term of newton (N).

Total soluble solids (TSS) content was measured from fruit juice of 5g papaya, grinded for 5 minutes in mortar and then filtered through sheet cloth. A drop of fruit juice was use for measurement the TSS content by using hand refractometer and report as %brix.

Titratable acidity (TA) content was also measured from the fruit juice that was prepared by TSS content. Five milliliter of fruit juice was diluted with 20 ml of distilled water in order to avoid the error from reading the end point (pale pink). Two drop of 1% phenolphthalein was use as indicator by dropping in the juice flash and mixed well. The sample was titrated with 0.1 N NaOH until the juice color apparent the pale pink for at least 30s that was represented end point of titration. The percentage of acid in the fruit juice was then calculated as following equation:

$$\% \text{ titratable acidity} = \frac{\text{conc.of NaOH (N)} \times \text{NaOH vol. (ml)} \times \text{meq.weight of malic acid} \times 100}{\text{sample volume (ml)}}$$

The percentage of weight loss was obtained the different between the initial weight and one at the end of each storage time according to the formula;

% weight loss = [(initial weight – final weight)/initial weight] × 100

Extraction and analysis of chlorophyll and carotenoid content (Dere *et al*., 1998) One gram of papaya peel for chlorophyll and carotenoid was weighted then extracted with 10 ml of 95 %methanol by grinding in mortar for 5 minutes. The sample was filtered through whatman #1 filter paper and centrifuged at 2,500 rpm for 10 minutes. The supernatant was collected and the absorbance was read at 400-700 nm on spectrophotometer. After scanned spectrum for the maximum absorbance, 662, 646 and 470 nm was optimum wavelength for chlorophyll a, b and total carotenoid content analysis. The amount for pigment content was reported in term of µg/g fresh weight. The amount of these pigments was calculated according to the formulas of Lichtentaler and Wellburn (1985) as showed in following formulas:

Chlorophyll a = 15.65 A666 - 7.340 A653

Chlorophyll b = 27.05 A653- 11.21 A666

Total carotenoid = (1000 A470- 2.860 Chl a- 129.2 Chlb)/245

Results and discussions

Fruit skin color development

Skin color parameters (L*, a* and b*) were different between cultivar, appeared to be higher in ‘Holland’ than ‘Khak Dam’ papaya from the beginning of storage. L* and a* values increased quadratic in response to an increase in storage duration in both cultivars, while a linear trend (slowly developed) was observed in papaya harvested from summer season. Winter season showed development of yellowness of the fruit skin than summer season markedly in ‘Holland’ papaya (Table 1).

Pigments development

At the beginning, chlorophyll a content was highest in ‘Holland’ papaya harvesting in winter season (22.6 µg/g fresh weight), significantly different from fruit sample harvested in summer and from ‘Khak Dam’ harvested in both season at the content was about 16.2 µg/g fresh weight. On days 2, the reduction of chlorophyll a content was markedly in ‘Holland’ papaya about 5 times lowers than ‘Khak Dam’ papaya but not significantly different between seasons and cultivar at the end of storage (Figure 1A). Chlorophyll b content

showed higher in fruit harvested in summer (18 µg/g fresh weight) than winter season (14 µg/g fresh weight), it was higher in 'Holland' than 'Khak Dam' papaya by about 2-6 µg/g fresh weight (Figure 1B). Carotenoid content slightly increased during storage, it was higher in 'Holland' than 'Khak Dam' papaya approximately 0.2 µg/g fresh weight. However, none significantly different was found between harvesting season, the content were about 0.6 and 0.4 µg/g fresh weight in 'Khak Dam' and 'Holland' papaya, respectively at the beginning.

Table 1. Change in peel color (L*, a* and b* values) in 'Khak Dam' and 'Holland' papaya harvested in different season, stored at room temperature for 6 days

Color parameters	Cultivars	Harvesting season	Days in storage			
			0	2	4	6
L* value	Khak Dam	Summer	33.8±3.3b	36.8±4.6c	40.6±6.3c	47.3±6.6b
		Winter	35.5±2 .6b	44.6±5.3b	51.1±5.4b	58.0±1.6ab
	Holland	Summer	47.8±2.7a	59.5±3.0a	59.1±2.3a	58.2±2.3ab
		Winter	48.4±2.6a	60.4±3.2a	59.4±3.4a	60.5±1.9a
a* value	Khak Dam	Summer	-8.0±1.1b	-5.9±3.1c	-1.1±0.9c	6.0±2.1c
		Winter	-8.4±0.8a	1.7±0.5b	6.1±2.2b	12.2±2.7b
	Holland	Summer	-9.3±1.5a	11.6±2.6a	18.0±2.8a	21.8±4.8a
		Winter	-10.6±1.2a	15.5±4.3a	20.0±4.0a	22.7±2.0a
b* value	Khak Dam	Summer	15.6±3.9b	19.8±2.6c	24.9±3.1b	32.9±1.5b
		Winter	14.5±2.1b	26.5±2.4b	52.8±2.7a	49.3±4.5a
	Holland	Summer	36.7±2.9a	47.8±4.7a	48.9±5.0a	50.3±3.0a
		Winter	30.6±3.7a	47.8±4.7a	48.9±5.0a	50.3±3.0a

Mean with the same letter in the same column for each color parameters are not significantly different at $p<0.05$

The higher content was found at the end of storage at approximately 1 µg/g fresh weight for 'Khak Dam' papaya while it was about 1.1-1.2 in 'Holland' harvested in summer and winter season, respectively (Figure 1C). None significantly different of chlorophyll a and b and carotenoid contents were found between harvesting season in 'Khak Dam' and 'Holland' papaya (Figure 1A-C). Although carotenoid levels in these two harvesting season showed none significantly different, it was appeared to be higher in 'Holland' than 'Khak Dam' papaya from the beginning (Figure 1C).

During 6 days in storage, chlorophyll a and b levels rapidly decreased after 2 days in storage in 'Holland' rather than 'Khak Dam' papaya (Figure 1A-B). The levels decreased from approximately 2.5 to 20 times in 'Khak Dam' and 'Holland' papaya, respectively. The decrease in chlorophyll a and b content in these two papaya cultivars appeared in the times of carotenoid synthesis induction. The content of carotenoid increased more in 'Holland' than 'Khak Dam' papaya and significantly different was found between harvesting seasons.

The low level of chlorophyll a and b in 'Holland' cultivar after 2 days in storage may be due to the more carotenoid level that have short wavelength and

can absorb the light. Chlorophyll content increased from fruit set and throughout fruit developed, and decreased as the fruit aged (Yang and Lee, 2001) or during storage duration.

Generally, the ratio of chlorophyll a to chlorophyll b decreased after 6 days in storage, indicating a significant reduction in the green-yellow pigment relationship. In addition, yellowing (b* value) or loss of green color, this is considered the major consequence of chlorophyll degradation. Finally, none significantly difference among harvesting season was observed for carotenoid content, which averaged 1.0 and 1.2 μg/g fresh weights for 'Khak Dam' and 'Holland' papaya, respectively.

Environmental factors including temperature and light had been reported to affect skin color development in many kinds of fruit. One report in tomato showed that, high field temperature during the hot period could have a negative impact on carotenoid biosynthesis (Dumas *et al*., 2003; Toor *et al*., 2006). Also, the growing area had not a significantly affected on the color of ripe fruit pulp.

The red color of the fruit pulp of 'Khak Dam' and 'Holland' papaya (expressed by a* value parameter). However, significantly different was found when compared between cultivar, 'Holland' papaya showed higher a* value than 'Khak Dam' papaya.

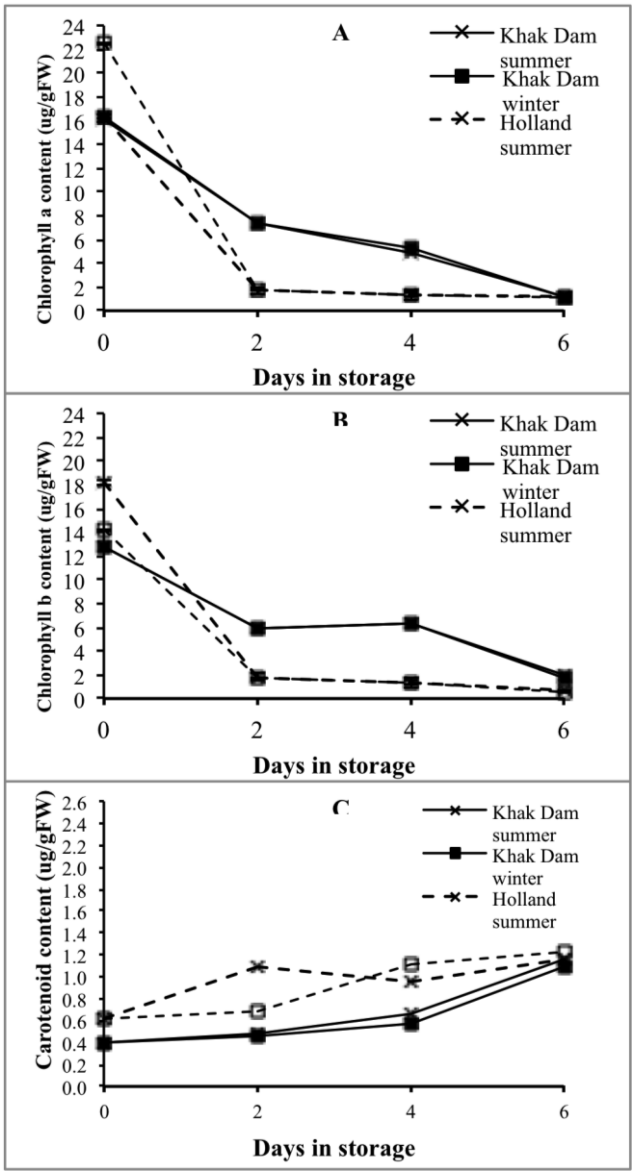

Fig. 1. Chlorophyll a (A), chlorophyll b (B) and carotenoid (C) content in the papaya peel in 'Khak Dam' and 'Holland' papaya harvested in different seasons, stored at room temperature for 6 days.

Changes in fruit quality

Pulp color as reported by a* value scale (redness when positive value) showed none different between cultivar and harvesting seasons at the beginning.

The effect of harvesting seasons on redness pulp color was found in 'Khak Dam' papaya, it was seem to be higher in winter than summer season.

However, the redness of pulp increased during storage duration, from approximately 25 and reached a maximum on days 6 (30 by average).

Significantly different between cultivar was found, more redness in 'Holland' than 'Khak Dam' papaya, but not different between harvesting seasons (Table 2). The different in pulp color noted between fruits were probably associated with variation in fruit carotenoid content (Medlicott *et al*., 1992). At the beginning of storage, 'Khak Dam' papaya showed higher pulp firmness than 'Holland' papaya both in summer and winter season. In between cultivar, they were not significantly different in pulp firmness; however, papaya from winter season seemed to be firmer than papaya from summer season (Table 2). During 6 days in storage, rapidly reduction of pulp firmness was found in 'Khak Dam' than 'Holland' papaya. The reduction was at about 140 and 125.5 N when calculated from the beginning and was not affect by growing season. Although the pulp of 'Khak Dam' papaya had firmer than 'Holland' papaya from the beginning, this cultivar showed higher rate of pulp softening than 'Holland' papaya (Khurnpoon and Siriphanich, 2012). The reduction of pulp firmness in many fruit varies among stage, cultivar and tissue composition especially cell wall composition (Brummell and Harpster, 2001). One experiment shown that, water-soluble pectin in 'Khak Dam' papaya markedly increased after storage paralleled with the reduction of pulp softening (Khurnpoon and Siriphanich, 2012). Also, the respiration rate and ethylene production were higher in 'Khak Dam' than 'Holland' papaya. Ethylene had been reported to involve in activated cell wall degrading enzymes and enhanced the rapidly ripening in fruit, known as ripening hormone (Nishiyama *et al*., 2007).

Eating quality, which evaluated by TSS/TA ratio was shown in Table 2. 'Holland' papaya gave higher TSS/TA ratio than 'Khak Dam' papaya from the beginning with no significantly different between harvesting seasons. During storage at room temperature, the TSS/TA ratio continuously increased and reached a maximum on days 6. At the end of storage, papaya harvested from winter season had higher TSS/TA ratio than summer season approximately 20 and 30 for 'Khak Dam' and 'Holland' papaya, respectively. The ratio was 68.3 and 81.1 for 'Khak Dam' papaya and 90.6 and 126.5 for 'Holland' papaya harvested from summer and winter season, respectively.

Note in Table 2, that the percentage of weight loss in fruit harvested in summer about 2-3 times higher than winter season. The rate of increase was higher during the first 2 days of storage but not different at the end, ranged from 13.2-15.7%. Fruit harvested in summer seemed to have a high rate of

weight loss and 'Holland' papaya showed higher rate than 'Khak Dam' papaya during 4 days in storage.

Table 2. Change in pulp color (a* value), pulp firmness and TSS/TA ratio in 'Khak Dam' and 'Holland' papaya harvested in different season, stored at room temperature for 6 days

Quality parameters	Cultivars	Harvesting season	Days in storage			
			0	2	4	6
a* value	Khak Dam	Summer	23.9±1.4a	26.4±2.4ab	25.9±2.6b	27.3±2.7b
		Winter	24.1±1.0a	25.0±2.4b	26.2±2.5ab	28.5±3.2ab
	Holland	Summer	26.5±4.4a	29.2±3.7a	29.3±2.9a	30.1±1.3a
		Winter	27.3±3.1a	28.5±4.0a	29.7±2.7a	30.2±1.4a
Firmness (Newton)	Khak Dam	Summer	155.5±9.6a	141.1±3.9a	80.4±5.4a	19.4±2.0a
		Winter	161.0±3.5a	139.1±2.6a	74.1±2.8b	16.9±1.5b
	Holland	Summer	140.3±4.4b	122.6±3.1b	55.9±1.9c	12.5±1.0c
		Winter	142.0±3.3b	120.8±2.4b	59.5±2.9c	18.0±1.1a
TSS/TA	Khak Dam	Summer	11.8±1.5b	16.0±2.0b	37.2±8.2b	68.3±1.7c
		Winter	11.1±1.2b	15.2±0.5b	32.0±2.6b	81.1±2.1b
	Holland	Summer	15.0±0.5a	24.6±5.2a	49.7±2.1a	90.6±9.0b
		Winter	14.1±0.9a	23.3±2.7a	54.7±13.9a	126.5±0.4a
Weight loss	Khak Dam	Summer	0.0±0.0	7.5±2.6b	13.8±2.3b	15.7±4.9a
		Winter	0.0±0.0	4.9±2.0c	8.0±3.8c	14.9 ±0.9a
	Holland	Summer	0.0±0.0	12.7±3.1a	16.9±1.8a	13.2±3.8a
		Winter	0.0±0.0	4.7±1.1c	10.0±2.8c	15.4±4.2a

Mean with the same letter in the same column for each quality parameters are not significantly different at $p<0.05$

Conclusion

Papaya harvesting from different seasons were no different of color change in peel and pulp, but tended to increase during storage. Fruit harvested from winter season had L*, a* and b* value of the peel higher than summer season. Chlorophyll a and b contents in 'Khak Dam' and 'Holland' papaya decreased rapidly after 2 day in storage with no different between harvesting seasons, higher rate of reduction in 'Holland' than 'Khak Dam' papaya.

Carotenoid content in papaya pulp slightly increased during storage with no different among harvesting seasons. Fruit firmness had no significantly different among harvesting seasons; approximately 120-140 N decreased from the beginning. Papaya harvested from winter season had the TSS/TA ratio higher than summer season, approximately 20 and 30 for 'Khak Dam' and 'Holland' papaya, respectively. Fruit weight losses harvested in summer and winter season were not significantly different, increased by up to 13.2-15.7% at the end of storage.

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