International Food Research Journal 23(3): 1027-1032 (2016)
Journal homepage: *http://www.ifrj.upm.edu.my*

Quality and bioactive compounds of ripe 'Kluai Nam Wa' and 'Kluai Khai' bananas during storage

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Article history

Received: 8 April 2015
Received in revised form: 10 September 2015
Accepted: 17 October 2015

Keywords

Ripe banana fruits
Storage temperature
Quality
Senescence spots
Bioactive compounds

Abstract

The aim of this work was to determine quality changes in ripe 'Kluai Nam Wa' (*Musa* ABB group) and 'Kluai Khai' (*Musa* AA group) banana fruits held 25 or 13°C. Skin blackening and senescence spots appeared on both 'Kluai Nam Wa' and 'Kluai Khai' banana fruit held at at 25°C for 8 days. No senescence spots were detected on 'Kluai Khai' held at 13°C for 16 days. Storage at 13°C maintained both skin and pulp colour and delayed the fruit softening. Bioactive compounds of 'Kluai Khai' banana fruit were higher than 'Kluai Nam Wa' banana fruit. An increase in antioxidant was found in both banana fruit held at 25°C. Antioxidant of 'Kluai Khai' banana fruit held at 13°C increased during storage whilst that of 'Kluai Nam Wa' banana fruit decreased. Storage at 13ºC could maintain total phenols and total flavonoids of the bananas during storage.

Introduction

Banana is an economically important fruit crops in many tropical countries. It is classified as a tropical climacteric fruit belonging to the family *Musaceae,* genus *Musa* (Ketsa, 2000). Eating bananas are generally occurring hybrids among the various subspecies of *Musa acuminate* and interspecific hybrids between *Musa acuminate* and *Musa balbisiana* and are highly diverse which estimates of the numbers of cultivars occurring worldwide range from 300 to 1000 (Ploetz *et al.*, 2007). Bananas originated in tropical rainforest in South and Southeast Asia regions. In Thailand, banana is one of economically important fruits for local and export market. There are many banana cultivars, including AA, AAA, AAB and ABB groups, grown in Thailand and other Southeast Asia countries. *Musa* AA group cv. 'Kluai Khai', *Musa* AAA group cv. 'Hom Thong' and *Musa* ABB group cv. 'Kluai Nam Wa' are three economically important bananas grown in Thailand. *Musa* AA group and *Musa* ABB group banana fruits are most abundant in Southeast Asia and 70% of *Musa* ABB group are grown in Thailand (Ploetz *et al*., 2007).

Bananas are considered to be a high energy and nutrients fruit involving oligosaccharides content, vitamins, minerals (especially K) and phenolics, which are related to high antioxidant capacity (Bennett *et al*., 2010; Ummarat *et al.*, 2011). Balasundrum *et al.* (2006) and Bennett *et al.* (2010) suggested that banana fruit pulp consists of high levels of total free phenolics; gallic acid, catechin, gallocatechin and naringenin. Kondo *et al*. (2005) reported that compared to other tropical fruits such as guava, mango and rose apple, banana had higher DPPH free radical scavenging activity. However, the amount and changes in these bioactive compounds depends on cultivars and maturity (Ploetz *et al.*, 2007; Thaipanit and Anprung, 2010; Fernando *et al.*, 2014). The most important quality attributes for banana fruit are skin colour, softening and aroma. Skin blackening and senescence spots are the key factors limiting consumer visual acceptability (Ketsa, 2000; Promyou *et al*., 2008). Generally, shelf-life of banana fruit is approximate 10-15 days at ambient temperature due to physiological climacteric attribute (Zhang *et al*., 2010). Approximately, 20-30% of banana fruit is lost after harvest due to poor postharvest handling, storage and ripening (Li and Jia 2008). After onset of ripening, the shelf-life of banana fruit in market is less than 5 days, especially in tropical countries which the ambient temperature is about 29 ± 3ºC. Storage at ~ 13ºC is recommended for storage and

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transportation of banana fruit. Promyou *et al*. (2008) suggested that at below 12ºC, banana fruit cannot be stored to prolonged its storage life due to rapid skin blackening. Regarding to the short shelf-life of ripe banana in market, the postharvest quality changes in the ripe 'Kluai Nam Wa' and 'Kluai Khai' banana fruit (the popular local cultivars in Thailand) held at 13ºC and 25ºC were investigated in this study.

Materials and Methods

Raw materials

'Kluai Nam Wa' (*Musa* x paradisiaca, ABB Group) and 'Kluai Khai' (*Musa acuminate,* AA group) banana fruits at 80% maturity were derived from a banana orchard at Prateaw District, Chomphon Province. Bunches were transported to the laboratory within 30 min of harvest. They were then dehanded and the hands were selected for uniformity of colour, size and being free from physical damages. The hands were cleaned with tap water, air-dried at room temperature and leaved at room temperature (25±2°C) for 48 hours (until the fruit peel turned to yellow). Forty hands were then held at 25ºC or 13ºC for 16 days. Ten hands of each treatment were sampled in every 4 days to investigate visual appearance, peel and pulp colour, firmness and bioactive compounds including total antioxidant capacity (TAC) content, total phenolics (TP) content and total flavonoids (TF) content.

Visual appearance and colour measurement

Visual appearance of banana fruits was monitored by taking photo of the fruit during storage. Peel and pulp color was measured by using a HunterLab MiniScan@ XE Plus (Hunter Associates Laboratory Inc., USA). The lightness (L^*), greenness or redness ($-a^*$ or $+a^*$) value and blueness or yellowness ($-b^*$ or $+b^*$) values were recorded. Peel colours were expressed as lightness (L^*) and yellowness (b^*) and pulp colours were expressed as whiteness index (WI) using the equation $100-[(100-L^*)^2 + a^{*2} + b^{*2}]$ 0.5 (Bolin and Huxsoll, 1991) and yellowness (b^*).

Firmness measurement

Five fingers of each hand were randomly sampled for firmness measurement. The finger was peeled and the measurement was taken at the middle part of the finger using a TA Plus Texture Analyzer (Lloyds, England) with a 6 mm cylindrical probe. The result was expressed as the maximum force (N) of measurement.

Total antioxidant capacity (TAC) measurements

A 5 g of the fresh banana pulp was homogenized with 25 mL of 80% methanol and then centrifuged for 15 min at 6000 rpm. Supernatant was collected and then 1 mL of supernatant was diluted with 20 mL distilled water. The solution was used to assay bioactive compounds.

TAC content was determined using ferric reducing antioxidant potential (FRAP) assay as described by Benzie and Strain (1996). FRAP reagent consisted of acetate buffer pH 3, 10 mM 2,4,6-tripyridyl-1,3,5-triazine (TPTZ) and 20 mM ferric chloride hexahydrate in the ratio of 10:1:1 (v/v/v). The reaction started by mixing 5 mL of FRAP reagent and 0.5 mL of the extract sample and leaved at room temperature for 30 min. The absorbance at 630 nm was recorded. TAC content was present in term of µM trolox equivalents per g fresh weight (µM TE/g FW).

Total phenols (TP) and total flavonoids (TF) content measurements

TP content was assayed using the method described by Slinkard and Singleton (1977). The reaction began when 1 mL of the sample solution was added into the solution of 1 mL 50% (v/v) Folin–Ciocalteu reagent solution and 2 mL 7 M Na_2CO_3 solution. The mixture was incubated at room temperature for 30 min. The absorbance at 750 nm was recorded. TP content was expressed in term of mg gallic acid per g fresh weight (mg GA/ g FW).

Total flavonoid content was determined using a method described by Jia *et al*. (1999). The reaction started when 0.25 mL of the extract was mixed with 1.25 mL of distilled water, 75 µL of 0.5% $NaNO_2$. The mixture was leaved for 6 min and then 150 µL of 10% $AlCl_3.6H_2O$ was added and allowed to stand for 5 min. After that, 0.5 mL of 1.0 M NaOH was added. The absorbance of the mixture was measured at 510 nm. The data were expressed as mg catechin equivalents per g fresh weight (mg catechin/ g FW).

Statistical analysis

All data were analyzed by using ANOVA and the difference between the means was performed with Duncan's multiple range test at $P < 0.05$ by using SAS (9.1) software. The results are presented as means (n=10) ± S.D.

Results and Discussion

Visual appearance

It is widely accepted that the skin blackening and senescence spots are the major factors limiting the

Table 1. Appearance of 'Kluai Nam Wa' and 'Kluai Khai' banana fruits stored at 25°C for 8 days and at 13°C for 16 days

Storage	'Kluai Namwa'	'Kluai Khai'
Day 0		
Day 8, 25°C		
Day 16, 13°C		

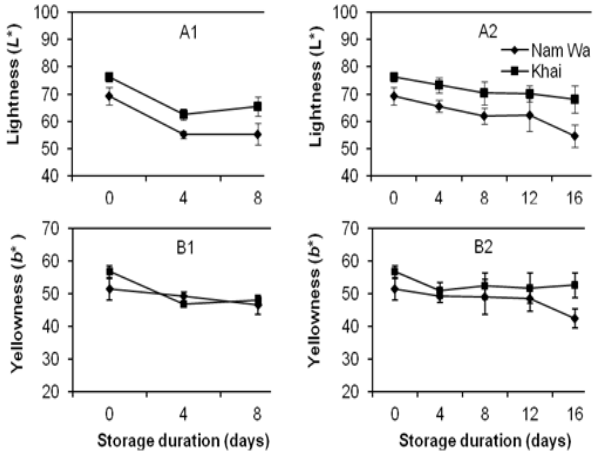

Figure 1. Lightness (L^* value) (A) and yellowness (b^* value) (B) of the bananas peel stored at 25°C (1) and at 13°C (2) during storage. Data represent the mean of ten replications ± SD

shelf-life and consumer acceptability of banana fruit during storage. Both symptoms appear rapidly on the ripe banana fruit skin during storage. Thus, the changes in visual appearance involving colour and certain physicochemical quality of both ripe 'Kluai Nam Wa' and 'Kluai Khai' banana fruits during storage at 25°C and 13°C were investigated. Table 1 shows the visual appearance of the both banana fruits held at 25°C for 8 days and at 13°C for 16 days. Skin blackening and senescence spot of 'Kluai Nam Wa' banana fruit were more severe than those of 'Kluai Khai' banana fruit at both storage temperatures. No skin blackening and senescence spots were found on 'Kluai Khai' banana fruit held at 13°C for 16 days. Generally, the senescent spots or superficial brown flecks appeared on banana fruit peel is recognized as the typical physiological disorder at the latter phase of fruit ripening and the spots gradually increase in size and number as the fruit advance in ripening process (Ketsa, 2000). Thus, the changes in skin colour of banana fruit during storage were coincident with visible skin browning and senescence spots (Chen *et al.*, 2008). Choehom *et al.* (2004) reported that the senescent spots and flecks rapidly increased on *Musa* AA 'Sucrier' fruit after storage for 4 days at ambient temperature (29-30°C). In this work we found that the onset of senescent spots and flecks on 'Kluai Nam Wa' fruit held at 13°C was detected on day 12 of storage (data not shown) whilst no senescent spots of 'Kluai Khai' banana fruit held at the same temperature were found over storage. This indicates that the shelf-life of 'Kluai Nam Wa' fruit stored at 13°C was less than that of 'Kluai Khai' banana fruit which could be stored longer than 16 days. Similarly, a previous work indicated that storage at 12-18°C effectively controlled senescent spotting on ripened banana fruits during storage (Ketsa, 2000). Moreover, no chilling injury symptom of 'Kluai Khai' banana fruit held at 13°C was found.

Skin colour

Figure 1 shows the changes in peel colour of both 'Kluai Nam Wa' and 'Kluai Khai' banana fruits during storage. L^* value of the both banana fruits held at 25°C markedly decreased during storage for 4 days and then remained constant. The similar change was also detected in b^* value of 'Kluai Khai' banana fruit held at the same temperature whilst that of 'Kluai Nam Wa' remained constant over storage. At 13°C, L^* and b^* values of 'Kluai Khai' was retained over storage but those of 'Kluai Nam Wa' remained constant for 12 days, after that both L^* and b^* values decreased significantly throughout the storage ($P< 0.05$) (Figure 1A2 and 1B2). The decrease in both L^* and b^* value of 'Kluai Nam Wa' banana fruit after 12 days of storage might relate to the appearance of skin blackening and senescence spots. Similarly, Chen *et al.* (2008) reported that the reduction of L^*, chroma and hue values of *Musa* AAA Group banana fruit during storage were related to senescent spots and flecks.

Pulp colour

The WI and b^* value of banana fruits pulp are presented in Figure 2. WI of 'Kluai Nam Wa' banana fruit was higher than that of 'Kluai Khai' banana fruit and the b^* value of Kluai Khai' banana fruit was higher than that of 'Kluai Nam Wa' banana fruit. WI of both banana fruits pulp remained constant over storage at both storage temperatures. The b^* value of the both banana fruits pulp held at 25°C decreased during storage whilst that of the both fruits pulp held at 13°C

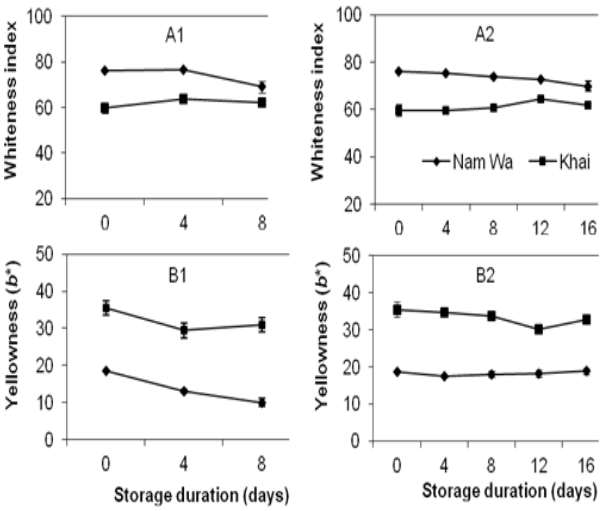

Figure 2. Whiteness index (WI) (A) and yellowness (b^* value) (B) of the bananas pulp stored at 25°C (1) and at 13°C (2) during storage. Data represent the mean of ten replications ± SD

remained constant throughout storage. This indicates that low storage temperature retained the yellowness of banana fruits pulp during storage. This might be related to the maintenance of total carotenoids content in the fruit pulp during storage. Facundo *et al*. (2015) reported that cold storage induced the accumulation of carotenoids in banana fruit during storage. Newilah *et al.* (2009) also reported that the yellowness of banana flesh was associated with the amount of carotenoids content and the increase or decrease of this compound accorded to the banana genome. Similarly, Englberger *et al.* (2006) reported that yellow-fleshed bananas, such as 'Kluai Khai', had significant carotenoids level whilst the cream-fleshed bananas like 'Kluai Nam Wa' had minimal carotenoid levels.

Texture

Firmness of the both banana fruits during storage is presented in Figure 3. The firmness of all banana fruits held at 25°C decreased throughout storage. The firmness of 'Kluai Nam Wa' banana fruit reduced more than that of 'Kluai Khai throughout storage. Imsabai *et al.* (2006) reported a significant increased softening in 'Kluai Nam Wa' fruit during stored at 25°C for 4 days. At 13°C, the firmness of both 'Kluai Nam Wa' and 'Kluai Khai' banana fruits remained constant for 8 days and then markedly decreased. The firmness reduction of 'Kluai Nam Wa' banana fruits was also more than that of 'Kluai Khai' banana fruit. In the similar vein, the softening of 'Goldfinger' banana fruit was delayed during storage at 10°C for 22 days whilst a rapid decrease in firmness was found in the fruit held at 20°C after day 4 of storage (Nunes

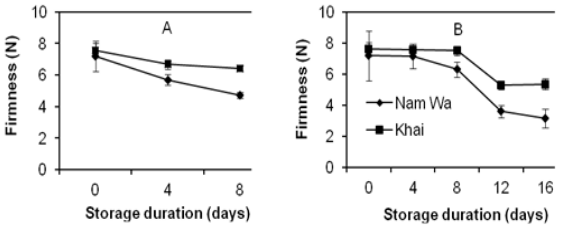

Figure 3. Firmness of the bananas stored at 25°C (A) and at 13°C (B) during storage. Data represent the mean of ten replications ± SD

et al., 2013). It is widely recognized that softening of banana fruit is associated with cell wall degradation due to the action of cell wall hydrolases such as pectate lyase, β-glucosidase and polygalacturonase (Medina-Suárez *et al*., 1997; Pathak and Sanwal, 1998) and starch degradation (Shiga *et al*., 2011) which cold storage retards these degradations.

Total antioxidant capacity, total phenolics and total flavonoids content

It is widely recognized that banana fruit is a tropical fruit has high nutritional value including antioxidants and health beneficial bioactive compounds such as polyphenols and flavonoids (Bennett *et al*., 2010). Figure 4 shows the changes in TAC, TP and TF contents of the both banana fruits during storage. At 25°C, TAC content of 'Kluai Khai' banana fruit increased significantly during storage ($P<0.05$) (Figure 4A1) whilst that of 'Kluai Nam Wa' banana fruit increased slightly. The changes in TAC content of 'Kluai Khai' and 'Kluai Nam Wa' banana fruits were similar to the results reported by Fernando *et al.* (2014) and Kondo *et al.* (2005), respectively. At 13°C, an increase in TAC content of 'Kluai Khai' banana fruit was found after 4 days of storage whilst that of 'Kluai Nam Wa' markedly decreased over storage for 16 days (Figure 4A2). TP and TF contents of 'Kluai Khai' banana fruit were obviously higher than those of 'Kluai Nam Wa' banana fruit. Compared to 'Kluai Hom Thong' banana fruit, 'Kluai Khai' banana fruit had higher bioactive compounds involving TAC, TP and and ascorbic acid content (Fernando *et al*., 2014). This shows that *Musa* AA Group banana fruit might have bioactive compounds higher than *Musa* ABB Group and *Musa* AAA Group banana fruits. During storage at 25°C, TP content of 'Kluai Khai' banana fruit decreased on day 4 and then markedly increased on day 8 of storage (Figure 4B1). At 13°C, TP content of both banana fruits decreased significantly on the first 4 days from 0.63 to 0.46 mg GA /g FW for 'Kluai Nam Wa' fruit and from 0.74 to 0.43 mg GA / g FW

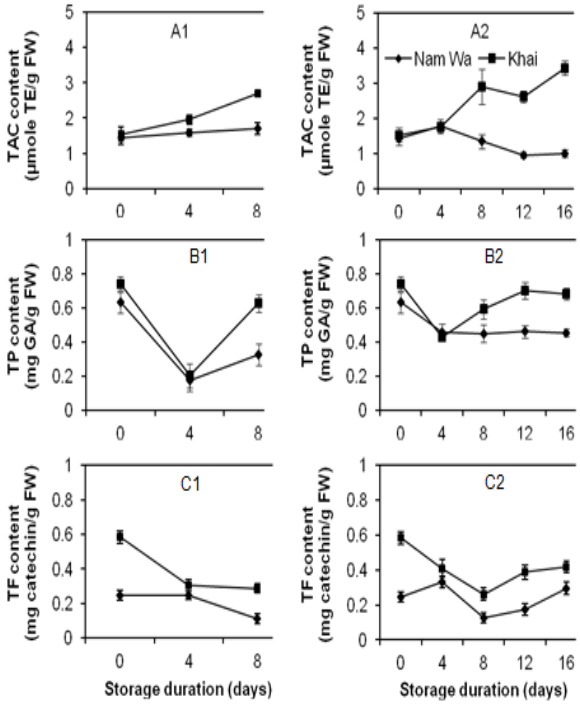

Figure 4. Total antioxidant capacity (TAC) (A), total phenols (TP) (B) and total flavonoids (TF) (C) content of the ripe banana fruits stored at 25°C (1) and at 13°C (2) during storage. Data represent the mean of ten replications ± S

for 'Kluai Khai' fruit ($P<0.05$), after that TP content of 'Kluai Khai' banana fruit increased markedly whilst that of 'Kluai Nam Wa' remained constant throughout storage (Figure 4B2). An increase in TP content of 'Kluai Khai' banana fruit during storage had also been reported by Fernando *et al*. (2014). TF content of the both banana fruit held at 25°C and 13°C decreased over 8 days of storage (Figure 4C1 and 4C2). After 8 days of storage, TF content of both banana fruits held at 13°C increased continuously until the end of storage period. In 'Kluai Hom Thong' banana fruit (*Musa* AAA Group), an increase in TF content had also been reported during storage at 25oC for 10 days (Ummarat *et al*., 2011). These suggest that the changes in bioactive compounds of banana fruits depended upon genome. Similarly, Sulaiman *et al.* (2011) addressed that the amount of bioactive compounds and their changes in Malaysian bananas varied with maturity and cultivars.

Conclusion

Skin blackening and senescence spots were key factors affecting visual appearance and superficial skin colour of both 'Kluai Nam Wa' and 'Kluai Khai' banana fruits during storage. Storage at 25°C induced both skin blackening and senescence spots of the banana fruits whilst storage at 13°C delayed the both symptoms. 'Kluai Nam Wa' banana fruit had both skin blackening and senescence spots faster than 'Kluai Khai' banana fruit. The reduction of L^* and b^* values of the both banana fruits skin were concomitant with skin blackening and senescence spots. Storage at 13°C retained pulp colour and firmness of the both banana fruits and induced bioactive compounds of 'Kluai Khai' banana fruits. We suggest that 13°C is a proper storage temperature for ripe 'Kluai Khai' banana fruit which the both visual quality and certain eating qualities were retained for more than 16 days.

Acknowledgements

Authors thank King Mongkut's Institute of Technology Ladkrabang (KMITL) for financial support. We are also grateful to Faculty of Industrial Education and Horticultural program, Prince of Chompon campus for all facility supports in this work.

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