

## UV-C Irradiation Affects Quality, Antioxidant Compounds and Activity of *Musa* AAA Berangan

(Penyinaran UV-C Mempengaruhi Kualiti, Sebatian dan Aktiviti Antioksidan *Musa* AAA Berangan)

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### ABSTRACT

*A study to determine the effects of ultraviolet-C (UV-C) irradiation on fruit quality, antioxidant compounds and activities of Musa AAA Berangan was carried out. The mature green fruits were exposed to UV-C doses of 0, 0.01, 0.02, 0.03 and 0.04 kJ/m<sup>2</sup> and allowed to ripen at 25±2°C for 5 days. Peel and pulp color, water loss, firmness, soluble solids concentration (SSC), titratable acidity, pH, vitamin C, total phenolic contents (TPC) and antioxidant activity (assay using ferric-reducing antioxidant power (FRAP), 1,1-diphenyl-2-picrylhydrazyl (DPPH) and 2,2'-azino-bis-(3-ethyl-benzothiazoline-6-sulfonic acid) (ABTS) free radical-scavenging) were analyzed at day 0, 1, 3 and 5 after ripening. The peel color (L\*, C\* and h°) of Berangan banana decreased as UV-C irradiation dose increased. UV-C irradiated fruit has lower water loss, firmer pulp and lower SSC than control. The fruit could undergo normal ripening albeit the quality of fruit has been affected by UV-C irradiation. There was significant interaction between UV-C radiation x day after ripening on TPC of Berangan banana. Fruit irradiated with UV-C showed significant higher of TPC as compared with control at later stage of ripening. Antioxidant activities measured with the three assays showed a significant decrease as ripening progressed. The results of this study showed that UV-C radiation as low as 0.01 kJ/m<sup>2</sup> is able to reduce water loss, slow down starch conversion and softening and enhanced TPC of Berangan banana.*

*Keywords: Firmness; peel and pulp color; soluble solids concentration; vitamin C*

### ABSTRAK

*Suatu kajian untuk menentukan kesan iradiasi ultraungu-C (UV-C) ke atas kualiti, sebatian dan aktiviti antioksidan Musa AAA Berangan telah dijalankan. Buah yang hijau matang didedahkan kepada UV-C yang berdos 0, 0.01, 0.02, 0.03 dan 0.04 kJ/m<sup>2</sup> dan dibiarkan ranum pada 25±2°C selama 5 hari. Warna kulit dan isi, kehilangan air, kekerasan isi, kepekatan pepejal terlarut (SSC), keasidan tertitrat, pH, vitamin C, jumlah kandungan fenolik (TPC) dan aktiviti antioksidan (asai menggunakan kuasa antioksidan ferik-penurunan (FRAP), 1,1-difenil-2-pikrihidrazil (DPPH) dan penggarut-radikal bebas asid 2,2'-azinobis-(3-etil-benzotiazolin-6-sulfonik) (ABTS)) dianalisis pada hari 0, 1, 3 dan 5 selepas peranakan. Warna kulit (L\*, C\* and h°) pisang Berangan berkurangan dengan peningkatan dos UV-C. Buah yang diiradiasi UV-C menunjukkan kehilangan air yang lebih rendah, isi yang lebih keras dan SSC yang lebih rendah daripada kawalan. Peranakan buah adalah normal walaupun kualiti buah telah dipengaruhi oleh iradiasi UV-C. Terdapat interaksi bererti antara radiasi UV-C x hari selepas peranakan pada TPC pisang Berangan. Buah yang diiradiasi UV-C menunjukkan pertambahan TPC yang bererti berbanding dengan kawalan pada peringkat akhir peranakan. Aktiviti antioksidan yang diukur dengan ketiga-tiga asai menunjukkan pengurangan yang bererti sepanjang peranakan. Keputusan kajian ini mendedahkan bahawa iradiasi UV-C serendah 0.01 kJ/m<sup>2</sup> mampu mengurangkan kehilangan air, melambatkan pertukaran kanji dan pelembutan, serta meningkatkan TPC pisang Berangan.*

*Kata kunci: Kekerasan; kepekatan pepejal terlarut; vitamin C; warna kulit dan isi*

### INTRODUCTION

Recently, the usage of ultraviolet-C (UV-C) as one of the postharvest treatment has attracted great attention among researchers as it can extend shelf life of several fresh fruits and vegetables. Furthermore, it is safe to use and environmental friendly with no residue exposure issue. Tomatoes treated with UV-C irradiation showed an increase of fruit firmness by inhibiting the activity of cell wall degrading enzymes (Bu et al. 2013). The ripening of strawberry was delayed with longer postharvest life as UV-C treatment caused higher production of polyamines and led

to reduce production of ethylene and action (Pombo et al. 2009). Low ethylene production and action decreased the activity of cell wall-degrading enzymes and thus delay strawberry ripening.

Postharvest treatments given to horticultural produce are a kind of abiotic stress. This stress may affect the levels of secondary metabolites in crop tissues by affecting pathways involved in the biosynthesis of three principal groups: Terpenes, phenolics and nitrogen containing compounds (Cisneros-Zevallos 2003). These compounds are often regarded as an antioxidant, which acts as a

protective mechanism against oxidative compounds. UV-C irradiation increased the total phenols and total flavonoids of Haden mango as compared to control (Gonzalez-Aguilar et al. 2007). In blueberries, UV-C irradiation increased antioxidant activity, phenolics and total anthocyanin of fruit (Wang et al. 2009).

In Europe, UV-C irradiation technology has been used in industry as postharvest treatment. However, there is lack of study on the effects of UV-C irradiation on local fruits. In view of the potential usage of UV-C as postharvest treatments, it is high time to investigate the effects of UV-C on Malaysian's fruit. Banana is one of the most consumed fruits globally while Berangan banana is local variety and most popular among Malaysian. Unfortunately, it has short shelf life with fast starch conversion into sucrose and leads to firmness reduction (Ding 2008). From the literature it is hypothesized that UV-C irradiation could retain fruit quality during ripening. Thus, this study was carried out to examine quality characteristics, antioxidant compounds and activities of Berangan banana after irradiated with UV-C.

## MATERIALS AND METHODS

### FRUIT SOURCES AND UV-C IRRADIATION

Mature green Berangan banana were purchased from a wholesale market. Fruits that free from any form of mechanical injury, insect and pathogen damages were selected for the experiments. Fruits were irradiated with UV-C light (30 watt, 90 cm length) from a distance of 30 cm in an enclosed chamber. The radiation intensity used was 0 (control), 0.01, 0.02, 0.03 and 0.04 kJ/m<sup>2</sup>. Mirrors were fitted to all sides of the chamber to ensure good spreading of the light from the lamp to the fruits. After irradiation, the banana was initiated to ripening by using 5 mL/L of ethylene for 24 h at 25±2°C. After 24 h of ripening initiation, the fruits were placed in 25±2°C/75% relative humidity room for ripening process. Three banana fingers from each irradiation dose at ripening day 0 (before ripening initiation), 1, 3 and 5 (after ripening initiation) were selected randomly for analysis.

### DETERMINATION OF FRUIT QUALITY

Changes in the color of banana peel and pulp were measured using a chroma meter (Minolta CR-400, Japan). The values of *L\**, *C\** and *h<sup>o</sup>* were taken randomly at the stem end, mid region and floral end of a fruit face. After peel color determination, the peel was removed and pulp color of the banana was measured at the spots as peel. The *L\** values indicate lightness of the color, which range from 0 (dark) to 100 (white). The *C\** values indicate the saturation of the color. The *h<sup>o</sup>* values of 0°, 90°, 180° and 270° is corresponding to the red, yellow, green and blue color, respectively.

The water loss during ripening was determined by the weight differences at days 0, 1, 3 and 5, which were then compared with day 0. The reading was expressed

in percentage (fresh weight basis). Pulp firmness was evaluated using a computer-controlled Instron 5543 Material Testing Machine (Canton, MA, USA). The Instron was used simultaneously with an Instron Merlin software version M12-13664-EN. Banana pulp was subjected to a puncture test at a constant speed of 20 mm/min, using a 6 mm diameter plunger probe. Force formation curves were recorded and firmness (as represented by the slope newton (N)/mm of the linear section of the force-deformation curve) was used as the indicator of textural property.

For soluble solids concentration (SSC), 10 g of fruit was macerated and the tissue was homogenized with 40 mL of distilled water by using a kitchen blender. After filtering with cotton wool, the filtrate was measured using a refractometer (Model N1, Atago Co., Japan) to obtain the %SSC. The readings were corrected to a standard temperature of 20°C by adding 0.28% to obtain %SSC at 27°C.

The remainder of the filtrate from the SSC determination was used to determine titratable acidity (TA) and pH. TA was determined by titrating with 0.1 mol/L NaOH using 1% phenolphthalein as an indicator. The results were calculated as a percentage malic acid. pH of filtrate was measured using a glass electrode (Crison Micro pH 2000, Spain).

As for vitamin C content, 10 g banana pulp was homogenized with 3% cold HPO<sub>3</sub> using a kitchen blender. The volume was made up to 50 mL and filtered with cotton wool. Then, 5 mL of the filtrate was titrated with 2, 6-dichlorophenol-indophenol solution to a pink color. The vitamin C content was determined according to Ranganna (1977) method.

### DETERMINATION OF TOTAL PHENOLIC CONTENTS (TPC) AND ANTIOXIDANT ACTIVITY

At each analysis days, fresh fruit pulp sample was cut into small pieces and frozen with liquid nitrogen. Then, the sample was freeze-dried with a freeze dryer (Martin Christ BETA 1-8 LD, Germany) for two days. The dried samples were pounded using a pebble and pestle into fine powder and stored in a dark container at -20°C prior to analysis. One gram of the ground sample was extracted with 50 mL 80% methanol solution at room temperature on an orbital shaker set at 180 rpm. The mixture was centrifuged at 2000 rpm for 30 min. After that, the extract was used for TPC and antioxidant activity determination.

TPC of the crude extract was determined by using Folin-Ciocalteu assay method described by Allothman et al. (2009) with some modifications. 1.5 mL of 10% Folin-Ciocalteu assay and 1.2 mL 6% sodium bicarbonate were mixed with 300 µL crude extract. The solution was allowed to stand for 1 h in the dark at 25±2°C. The absorbance was measured at 765 nm using a spectrophotometer (S1200, England) in triplicates. A calibration curve was prepared using a standard solution of gallic acid (0.01-0.11 mg/mL, R<sup>2</sup>=0.9774) in 80% methanol, giving an absorbance range of 0.123-1.118. The results were expressed as mg gallic acid equivalents (GAE)/g banana dry weight.

The antioxidant activity of UV-C treated banana was studied by performing ferric reducing antioxidant power (FRAP) assay, a method adopted from Alothman et al. (2009) with some modifications. The FRAP reagent was prepared by mixing 2.5 mL TPTZ (2, 4, 6-tripyridyl-s-triazine) solution, 2.5 mL ferric chloride and 25 mL acetate buffer (pH3.6). The FRAP reagent was pre-warmed at 37°C for 4 min before being added to 40 µL aliquots of extract sample. The mixture was then incubated at 37°C for 1 h. The absorbance was determined at 593 nm, using a spectrophotometer (S1200, England) over three times. A calibration curve was prepared using a standard solution of Trolox (6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid) (400-2000 µmol/L,  $R^2=0.9077$ ) in 80% methanol giving an absorbance range of 0.245-0.742. FRAP values were expressed as µmol Trolox/g banana dry weight.

The antioxidant activity of the fruit extracts was also studied by evaluating the free-radical-scavenging effect on 1,1-diphenyl-2-picrylhydrazyl (DPPH) radical, a method adopted from Alothman et al. (2009) with some modifications. 100 µL extract was mixed with 250 µL methanolic DPPH solution and 2 mL of 80% methanol. The mixture was shaken and allowed to stand for 30 min at 25±2°C. The absorbance readings were taken at 517 nm using a spectrophotometer (S1200, England). A calibration curve was prepared using a standard solution of Trolox (160-800 µmol/L,  $R^2= 0.906$ ) in 80% methanol giving an absorbance range of 0.648-0.267. The results were expressed in µmol Trolox/g banana dry weight.

The antioxidant activity of UV-C treated banana was also determined by using 2,2-azinobis (3-ethyl-benzothiazoline-6-sulfonic acid) (ABTS<sup>+</sup>) free-radical-scavenging following the procedure described by Shan et al. (2005) with some modification. Seven mM of ABTS and 2.45 mM of K<sub>2</sub>O<sub>8</sub>S<sub>2</sub> were mixed and incubated for 16 h in

the dark at 25±2°C before use to generate ABTS<sup>+</sup> radical cation. The ABTS<sup>+</sup> solution was diluted with distilled water to give an absorbance at 734 nm of 0.700±0.005. Then, 3.9 mL of the ABTS<sup>+</sup> solution was mixed thoroughly with 100 µL extract sample and left to stand for 6 min at 25±2°C in the dark. The absorbance was measured at 734 nm by using a spectrophotometer (S1200, England). A calibration curve was prepared using a standard solution of Trolox (200-1000 µmol/L,  $R^2= 0.961$ ) in 80% methanol giving an absorbance range of 0.565-0.051. The results were expressed as µmol Trolox/g fruit dry weight.

#### STATISTICAL ANALYSIS

The experimental design was a randomized complete block design with a factorial arrangement of treatments (5 levels of radiation dose × 4 days of ripening) and replicated thrice. Data were analyzed using analysis of variance while means was separated using least significant difference (LSD) at  $p\leq 0.05$ . The Pearson's correlation analysis was performed to correlate the fruit quality characteristics, as well as antioxidant compounds and activities of the fruit. All statistical analysis was carried out using SAS 9.1.

#### RESULTS

The  $L^*$ ,  $C^*$  and  $h^\circ$  values of Berangan banana peel decreased as UV-C irradiation dose increased (Table 1). In contrast to peel, the pulp color of fruit was generally not affected by UV-C irradiation, except the  $L^*$  values. As ripening progressed, both banana peel and pulp showed increases in  $L^*$  and  $C^*$  values while peel  $h^\circ$  values decreased significantly from green (119.69) to yellow (88.20). The pulp  $h^\circ$  values did not show any changes as the fruit ripened from Day 0 to 5.

TABLE 1. Main and interaction effects of UV-C radiation and day after ripening on peel and pulp color ( $L^*$ ,  $C^*$ , and  $h^\circ$ ) of Berangan banana

Factors	Peel color			Pulp color		
	$L^*$	$C^*$	$h^\circ$	$L^*$	$C^*$	$h^\circ$
UV-C radiation dose (U), kJ/m <sup>2</sup>						
0.00	63.65 a <sup>2</sup>	36.99 a	115.08 a	71.02 a	30.65 a	94.38 a
0.01	63.26 a	37.02 a	116.47 a	69.51 abc	30.54 a	93.43 a
0.02	62.68 ab	36.70 a	115.26 a	70.42 ab	30.60 a	93.17 a
0.03	61.69 b	33.25 b	106.36 b	68.99 bc	30.36 a	92.78 a
0.04	60.27 c	32.94 b	106.08 b	68.09 c	30.10 a	90.51 a
Day after ripening (D)						
0	56.38 b	29.03 c	119.69 a	66.89 b	25.86 c	93.60 a
1	56.34 b	30.32 c	118.51 a	67.62 b	26.77 c	94.84 a
3	66.57 a	41.26 b	96.70 b	72.03 a	33.47 b	92.76 a
5	68.34 a	45.70 a	88.20 c	71.89 a	35.69 a	90.22 a
Interaction						
U x D	NS	NS	NS	NS	NS	NS

<sup>2</sup> Different letters within columns and factors denote significant differences by LSD at  $p\leq 0.05$   
NS Non-significant at  $p\leq 0.05$

UV-C irradiation affected Berangan banana water loss with irradiated fruit showed significant lower water loss than the control (Table 2). Fruit irradiated with 0.01 kJ/m<sup>2</sup> UV-C showed a lower water loss as compared to 0.02, 0.03 and 0.04 kJ/m<sup>2</sup> dose. As expected, Berangan banana showed 7.37% of water loss as the fruit ripened from day 0 to 5. The firmness of control fruit was much lower than UV-C irradiated fruit by about 25% (Table 2). SSC of Berangan banana was affected significantly by interaction between the radiation dose x day after ripening (Table 2). At ripening Day 1 and 3, the SSC of control fruit exceeds UV-C irradiated fruit (Figure 1). By ripening Day 5, fruit irradiated with 0.02 kJ/m<sup>2</sup> UV-C has lower SSC than other treatment of fruit. Dose of 0.01 kJ/m<sup>2</sup> UV-C caused lower TA in Berangan banana as compared with control (Table

2). For pH, 0.02 and 0.03 kJ/m<sup>2</sup> UV-C dose irradiated fruit exhibited higher pH than control (Table 2). Both TA and pH showed a contradictory trend during ripening.

Among UV-C radiation dose, 0.01 kJ/m<sup>2</sup> enhanced vitamin C content in Berangan banana (Table 3). Unlike vitamin C, there was significant interaction between UV-C radiation dose x day after ripening on TPC of Berangan banana (Table 3). However, no significant interaction was found in antioxidant activity of Berangan banana as evaluated using FRAP, DPPH and ABTS assays. Figure 2 shows the interaction effect of UV-C radiation dose on TPC of Berangan banana during fruit ripening. At ripening Day 0, generally there was no significant difference in TPC among control and UV-C irradiated fruit. After a day of ripening, 0, 0.01 and 0.02 kJ/m<sup>2</sup> UV-C irradiated fruit has higher TPC

TABLE 2. Main and interaction effects of UV-C radiation and day after ripening on water loss, firmness, soluble solids concentration (SSC), titratable acidity (TA) and pH of Berangan banana

Factors	Water loss (%)	Firmness (N)	SSC (% SSC)	TA (% malic acid)	pH
UV-C radiation dose (U), kJ/m <sup>2</sup>					
0	4.30 a <sup>2</sup>	9.68 b	11.63 a	0.37 a	4.99 b
0.01	2.48 c	12.85 a	10.85 b	0.34 b	5.06 ab
0.02	3.29 b	11.94 a	11.07 b	0.36 ab	5.01 a
0.03	3.39 b	11.88 a	10.95 b	0.35 ab	5.12 a
0.04	3.49 b	11.87 a	10.91 b	0.35 ab	5.08 ab
Day after ripening (D)					
0	0.00 d	24.87 a	3.11 d	0.21 d	5.63 a
1	0.92 c	17.77 b	4.93 c	0.25 c	5.31 b
3	5.27 b	2.20 c	15.43 b	0.52 a	4.61 c
5	7.37 a	1.73 c	20.86 a	0.44 b	4.66 c
Interaction					
U x D	NS	NS	*	NS	NS

<sup>2</sup> Different letters within columns and factors denote significant differences by LSD at  $p \leq 0.05$   
NS, \* Non- significant or significant at  $p \leq 0.05$

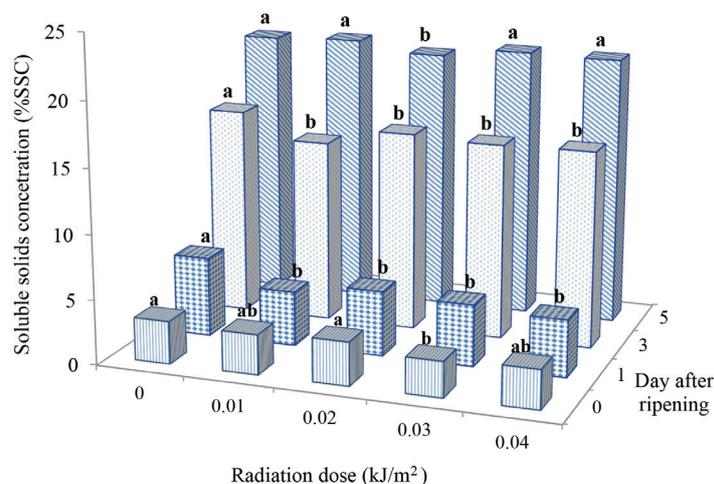


FIGURE 1. Effects of UV-C radiation x day after ripening on soluble solids concentration of Berangan banana. Means separations pertaining to each day after ripening followed by the same letters are not significantly different by LSD at  $p \leq 0.05$

TABLE 3. Main and interaction effects of UV-C radiation and day after ripening on vitamin C content, total phenolic contents (TPC) and antioxidant activity (FRAP, DPPH and ABTS) of Berangan banana

Factors	Vitamin C (mg 100/g fruit FW)	TPC (mg GAE/g fruit DW)	FRAP ( $\mu$ mol Trolox/g fruit DW)	DPPH ( $\mu$ mol Trolox/g fruit DW)	ABTS ( $\mu$ mol Trolox/g fruit DW)
UV-C radiation dose (U), kJ/m <sup>2</sup>					
0	3.77 b <sup>c</sup>	2.88 bc	35.75 bc	28.31 a	20.50 ab
0.01	4.51 a	3.39 a	39.93 a	31.79 a	22.47 a
0.02	3.87 b	3.14 ab	38.94 ab	28.12 b	21.96 a
0.03	3.85 b	3.16 ab	38.32 ab	29.13 ab	21.54 a
0.04	3.67 b	2.79 c	33.90 c	25.62 b	19.23 b
Day after ripening (D)					
0	4.46 a	3.88 a	46.34 a	36.48 a	27.41 a
1	4.48 a	3.83 a	45.69 a	35.22 a	27.00 a
3	3.99 b	3.16 b	35.33 b	23.17 b	20.12 b
5	2.81 c	1.42 c	22.12 c	19.51 c	10.02 c
Interaction					
U x D	NS	*	NS	NS	NS

<sup>a</sup>Different letters within columns and factors denote significant differences by LSD at  $p \leq 0.05$

NS, \* Non-significant or significant at  $p \leq 0.05$

FW = Fresh weight

DW = Dry weight

FRAP = Ferric reducing antioxidant power

DPPH = 1,1-Diphenyl-2-picrylhydrazyl radical-scavenging activity

ABTS = 2,2',-Azino(bis-3-ethyl-benzothiazoline-6-sulfonic acid) radical-scavenging activity

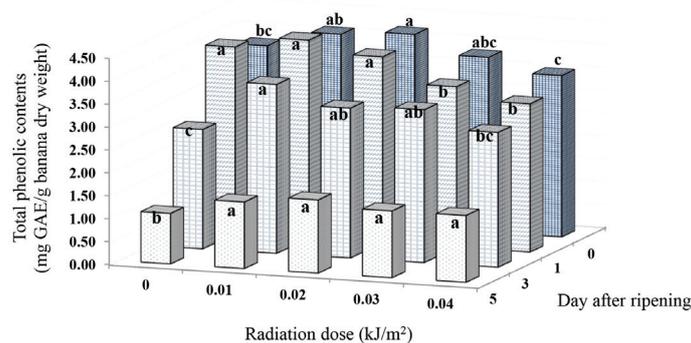


FIGURE 2. Effects of UV-C radiation x day after ripening on total phenolic contents of Berangan banana. Means separations pertaining to each day after ripening followed by the same letters are not significantly different by LSD at  $p \leq 0.05$

than fruit exposed to 0.03 and 0.04 kJ/m<sup>2</sup>. By ripening Day 3, it is obvious that the TPC of control fruit was lower than fruit irradiated with 0.01, 0.02 and 0.03 kJ/m<sup>2</sup> of UV-C. By ripening Day 5 where the fruit is suitable for consumption, the TPC of control fruit was significant lower than fruit irradiated with UV-C. This indicated that fruit irradiated with UV-C has higher TPC although the content decreased as ripening day progressed. Or in other words, the TPC of Berangan banana was preserved by UV-C radiation.

After exposing to 0.01 kJ/m<sup>2</sup> UV-C, the antioxidant activity of Berangan banana as evaluated using FRAP showed significant higher activity than control (Table 3). This followed by significant decrease when fruit irradiated with 0.04 kJ/m<sup>2</sup> UV-C. When antioxidant activity

of Berangan banana evaluated using DPPH, fruit irradiated with 0.02 and 0.04 kJ/m<sup>2</sup> UV-C showed significant lower activity than control and 0.01 kJ/m<sup>2</sup> UV-C (Table 3). A quite similar finding was also found in ABTS with lower activity when fruit irradiated with 0.04 kJ/m<sup>2</sup> UV-C as compared to other dosage (Table 3). Regardless of irradiation dose, antioxidant activities as assayed using FRAP, DPPH and ABTS decreased with ripening (Table 3).

## DISCUSSION

In the present study, as ripening day progressed Berangan banana showed substantial changes in peel color (Table 1), firmness and SSC (Table 2). These changes are in

TABLE 4. Correlation coefficients of vitamin C, total phenolic contents (TPC) and antioxidant activity (FRAP, DPPH and ABTS assays) of Berangan banana treated with different intensity of UV-C and allow ripening for 5 days

	Vitamin C	TPC	FRAP	DPPH	ABTS
Vitamin C	-				
TPC	0.107 <sup>ns</sup>	-			
FRAP	-0.005 <sup>ns</sup>	0.909**	-		
DPPH	-0.080 <sup>ns</sup>	0.613**	0.674**	-	
ABTS	0.002 <sup>ns</sup>	0.921**	0.930**	0.717**	-

NS, \*\* Non- significant or highly significant at  $P \leq 0.05$

FRAP = Ferric reducing antioxidant power

DPPH = 1,1-Diphenyl-2-picrylhydrazyl radical-scavenging activity

ABTS = 2,2',-Azino(bis-3-ethyl-benzothiozoline-6-sulfonic acid) radical-scavenging activity

accordance to the findings reported by Ding et al. (2006) and Ding (2008) in Berangan banana. As compared to control, UV-C irradiated fruit has lower water loss, higher pulp firmness and lower SSC than control fruit (Table 2). Reducing water loss in UV-C irradiated fruit is beneficial where besides directly reduce financial loss due to weight loss, it also maintains fruit composition and metabolism of detached fruit (Rizzini et al. 2009). Firmness of Berangan banana was retained in UV-C treated fruit (Table 2). Similar finding was also found in tomato (Bu et al. 2013) and strawberry (Pombo et al. 2009). The firmer tomato after UV-C irradiation was due to higher content of cellulose and acid-soluble pectin than control (Bu et al. 2013). UV-C irradiation also retarded cell wall disassembly of tomato pericarp and suppressed the transcription expression of *PME2.1*, *Cell*, *PGcat* and *Exp1* genes and thus inhibited pectin methylesterase (PME), polygalacturonase (PG) and cellulose activities during storage. The literature on the effect of UV-C irradiation on enzymes associated with banana peel cell wall modification is lacking. However, the PME and PG activities of Berangan banana that dipped in 50°C hot water was lower than control fruit (Ding & Amin 2013). This indicated PME and PG activities of Berangan banana is affected by postharvest treatment.

The effect of UV-C irradiation on SSC varied with fruit species. UV-C irradiation did not affect SSC of apple (Hagen et al. 2007) and tomato (Liu et al. 2009) but induced SSC accumulation in strawberry (Li et al. 2014). In present study, the effect of UV-C on SSC of Berangan banana differed from these researchers. The interaction results indicated that the SSC of control fruit was higher than UV-C irradiated fruit during initial of ripening. As ripening progressed to Day 5, fruit irradiated with 0.02 kJ/m<sup>2</sup> UV-C exhibited lower SSC. This indicated 0.02 kJ/m<sup>2</sup> UV-C radiation is able to slow down Berangan banana fruit metabolism. The increase of SSC is a common metabolic response in Berangan banana towards ripening where starch hydrolyzed to sucrose (Ding 2008).

In the present study, UV-C irradiation has caused TPC accumulation in Berangan banana as shown in Figure 2. The increase in TPC is a common response of the plant to stresses. The accumulation of TPC could be due to excessive lignification in response to the phytotoxic effect of the high UV-C dose. Phenolic compounds are the most important

compound and major contributors to the antioxidant property in the fruits (Scalzo et al. 2005). This can be proven in this study where TPC correlated strongly with FRAP ( $r=0.909$ ) and ABTS ( $r=0.921$ ) and moderately with DPPH ( $r=0.613$ ) (Table 4). However, vitamin C did not correlate with TPC and antioxidant activities indicating vitamin C did not contribute to antioxidant activity in Berangan banana. This could probably due to low content of vitamin C in Berangan banana. Antioxidant compounds and antioxidant activities of UV-C irradiated Berangan banana decreased as day after ripening progressed and showed lowest contents and activities by ripening Day 5 (Table 3). In terms of nutritional quality, this is not a good change as banana is eaten when it is fully ripen by ripening Day 5. However, from Figure 2, it is clear that fruit irradiated with UV-C contains higher TPC as compared to control fruit.

In conclusion, UV-C irradiation is a potential treatment to retain fruit quality. The only drawback in using UV-C irradiation is peel browning which affects visual quality of fruit. From Ding and Yap (2014) study, it was found that the lethal dose causing Berangan banana peel browning is 0.03 kJ/m<sup>2</sup> UV-C. Thus, 0.01 kJ/m<sup>2</sup> UV-C irradiation is recommended to retain fruit quality and enhance TPC of Berangan banana. For further study, the effects of UV-C irradiation on pathogen disease will be carried out as UV-C has germicidal property which could replace the usage of agrochemicals in postharvest treatment.

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Received: 15 July 2014

Accepted: 1 April 2015