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Original Research Article

Effect of Pre-treatment by Ultraviolet-C (UV-C) Irradiation Incorporated with Hydro-cooling on Postharvest Quality of Red Hot Chili (*Capsicum annuum* L.)

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ABSTRACT

Red hot chili (*Capsicum annuum* L.) cv. Superhot is an important commercial vegetable crop with high export potential of Thailand. The main quality changes during storage were the rapid in weight loss and spoilage. The objective of this research was to investigate the effect of pre-treatment on the qualities of red hot chili by using ultra-violet-C (UV-C) irradiation incorporated with hydro-cooling before storage. The chili fruits were irradiated with 0, 4.4 and 6.6 $KJ.m^{-2}$, respectively before hydro-cooling at 0 ˚C for 15 minutes and then stored at 5˚C for 21 days in plastic tray wrapped with PVC film. Non-hydro-cooled and non-illuminated chili served as control. The results showed that all the UV-C dosages incorporated with hydro-cooling were highly effective in maintaining fresh weight and firmness. Green appearance of calyx or pedicel and redness in chili as expressed by acceptable quality score were also maintained. Chili fruit treated by UV-C irradiation at dose of 4.4 $KJ.m^{-2}$ incorporated with hydro-cooling resulted in significantly ($P \le 0.05$) reduction of 7.02 % weight loss at 21 days of storage and fruit rot as well as enhancing antioxidant capacity (DPPH) and total carotenoid content of chili. This combined treatment could prolong the storage life of chili to 21 days whereas the control could keep for only 12 days. The data suggested that the UV-C incorporated with hydro-cooling could maintain quality and extend the shelf life of red hot chili.

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INTRODUCTION

Red hot chili (*Capsicum annuum* L.) cv. Superhot is an important commercial vegetable crop of Thailand and very high potential for exported. Chili is a large source of vitamins which contains amounts of vitamins A, B, C and small amounts of carotenoids (Kim *et al*., 2007). However, the exportation of chili has gradually decreased due to many problems during transport and distribution of produce. One major problem in the distribution of fresh chili in Thailand is loss of postharvest quality mainly caused from heat of respiration or vital heat and temperature fluctuation during transport resulting in high damage and spoilage on the fruit. Fresh chili should rapidly reach the temperature for short-term storage or shipping in order to maintain the highest quality and ensure that produce will arrive at its destination in good condition. Pre-cooling (cooling) depends on the temperature of the produce at harvest, the physiology of the produce and the desired postharvest life. Hydro cooling is usually used to pre-cooled method because of its simplicity and effectiveness to removed field heat. UV-C light has already been pre-treatment in many fruit after harvested mainly to control fruit decay (González-Aguilar *et al*., 2007). Moreover, it also delays some ripening associated processes (D'hallewin et al., 2000) and induced antioxidant capacity by inducing phenylpropanoids biosynthesis (Korkina, 2007). Luis *et al*., (2012) investigated UV-C irradiation (0 KJm^{-2} to 20 KJm^{-2}) on fresh-cut bell pepper that high dose (20 KJm^{-2}) reduced the deterioration rate and extended shelf life without causing changes in sugars, acids, antioxidants contents. The appropriate dose of UV-C irradiation is depended on commodity and it's ripening stage. Although there were many researches UV-C combined with postharvest technologies with encouraging results, the pre-treatment by UV-C illumination incorporated with hydrocooling has not been investigated in chili fruit. Thus, present research was carried out to study the effect of UV-C irradiation incorporated with hydro-cooling on postharvest quality and physicochemical changes of red hot chili during storage at 5˚C for 21 days in plastic tray wrapped with PVC film.

MATERIALS AND METHODS

Plant materials and UV-C irradiation incorporated with hydro-cooling

Red hot chili cv. Superhot produced under the GAP system was harvested from a commercial farm in Sakonnakhon province, Thailand. The chili fruits were graded followed the standards of an export company (the fruit length of 5-8 cm long and 100% red color). The fruits were randomly packed in polyethylene (PE) basket each basket contained 300 grams per replications. Then the chili fruit were exposed into a box containing two germicidal UV-C lamps (TUV 30W, Salvania, Japan) with the exposure distance of 70 cm for 0, 60 and 90 min to obtain dosages of 0, 4.4 and 6.6 $KJ·m^{-2}$ respectively. After UV-C treatments, chili fruits were immersed in cold water with 200 μL·L-1 sodium hypochlorite at 0 ⍰C for 15 min or until the internal heat of chili fruits reached to 5⍰C then allowed to air-dried. Non-hydro cooled and non UV-C irradiation was considered as control. The samples were kept at 5˚C and 80-85% RH for evaluation in term of postharvest quality every 3 days. Postharvest qualities including visual appearance and acceptable quality were evaluated on a relative scale of 1 (wilting) to 5 (fresh), weight loss (%), firmness, total antioxidant capacity by DPPH assay, total carotenoids content, fruit rot and storage life were determined. The experiment design was Completely Randomized Design (CRD) with 3 replications.

Determination of Weight loss Firmness and Acceptable quality

Fresh weight loss of the yellow bell pepper fruit was measured before storage and in every 3 days until the end of storage. The percentage of weight loss during storage was calculated compared to the initial weight. Firmness of the fruit was determined using Effegi fruit firmness tester with the probe size of 2 mm and expressed as newton (N). The acceptable quality of Red Hot chili was evaluated by visual appearance on a relative scale of 1 (wilting) to 5 (fresh) depend on green appearance of calyx or pedicel, redness of chili and freshness.

Determination of DPPH radical scavenging activity (DPPH assay)

Total antioxidant capacity of chili was determined by the method described by Loypimai *et al*., (2009). One gram of chili was homogenized with 20 ml of distilled water and filtered with what man No.1. The samples were centrifuged at 8,000 × g for 15 minutes. The supernatant was kept in refrigerator before used. A 0.2 mM of 80 % ethanol DPPH solution was prepared. An aliquot (0.1 ml) of each sample with appropriate dilution was added to 0.3 ml of ethanolic DPPH solution. The samples were measured in triplicate at 517 nm by spectrophotometer (Labmed inc) after incubation for 30 minutes at room temperature in dark. Antioxidant capacity was expressed as µmole Trolox equivalents (TE) per 100g FW. The percent of DPPH radical scavenging activity was calculated as follows.

$$\% \text{ of DPPH radical scavenging} = [A_{blank} - A_1] / A_{blank} \times 100$$

Where: A blank = the absorbance of ethanolic DPPH solution.

A 1 = the absorbance of sample.

All the tests were analysed in triplicates and the analyses of samples were averaged from triplicates.

Total carotenoid content

The total carotenoid content of chili was analysed according to the method described by Hornero-Mendez and Miguez-mosquera (2001). Ten grams of chilli fruit was extracted with acetone by homogenizer and filtered with what man No.1. The samples were centrifuged at 12,000 x g for 10 minutes at 4 ˚C. The pellet was extracted again untill no color. The supernatants were collected and brought to 100 ml acetone. The three replicates of extracted sample were measured absorbance at 472 nm and expressed as OD_{427} Kg^{-1} of fruit.

Statistical analysis

Statistical analysis was carried out using the analysis of variances (ANOVA). The treatment means were separated using the least significant difference (LSD) method at a significance level of $P < 0.05$. Data are shown as mean ± standard error (S.E.).

RESULTS AND DISCUSSION

Fruit rot and storage life

Table 1 shows percentage of fruit rot and storage life of hot chili irradiated with UV-C before hydro-cooling. The highest fruit rot at 21 days of was 25.25% in non-hydrocooled fruit and the lowest fruit rot was 10.11% in chili fruit irradiated with 4.4 $KJ·m^{-2}$. Moreover, UV-C irradiated with 4.4 $KJ·m^{-2}$ incorporated with hydro-cooling treatment had the longest storage life (21 days) when compared with the control (12 days).Similarly, the result had been reported that UV-C treatments reduced decay and retained quality of pepper at 7 $KJ·m^{-2}$ (Vincente et al, 2005), yellow bell pepper at 6.6 $KJ·m^{-2}$ (Promyou and

Supapvanich, 2012). A reasonable explanation for the different in dosage might be the different types of product that could receive the effective dose in those cases (Civello et al., 2006).

Table 1. Fruit rot and storage life of red hot chili irradiated with 0 4.4 and 6.6 KJ·m^{-2} before hydro cooling then stored at 5°C for 21 days in plastic tray wrapped with PVC film.

Treatments	Fruit rot (%)	Storage life
Control	25.25^{a}	12^{c}
UV-C 0 KJ.m^{-2} +hydro cooling	20.16^{b}	15^{b}
UV-C 4.4 KJ.m^{-2} +hydro cooling	10.11^{d}	21^{a}
UV-C 6.6. KJ.m^{-2} +hydro cooling	13.39^{c}	20^{a}
F-test	P=0.01	P=0.01
$LSD_{0.05}$	3.10	7.20

Different letters in the same column indicate significant difference at P< 0.05.

Weight loss, Texture and acceptable quality

Figure 1 presents the change in weight loss of red hot chili; UV-C irradiation incorporate with hydro cooling retarded the increase in the percentage of weight loss in chili fruit throughout storage rather than control treatment. The highest efficiency to reduce weight loss was found in chili fruit treated with 4.4 KJ·m^{-2} UV-C before hydro cooling which agree with Cuvi *et al*. (2011) finding was reported that UV-C treated red pepper fruit was inhibited the increase level of weight loss during storage. Promyou and Supapvanich (2012) also reported ultraviolet-C (UV-C) illumination in 'Kaew Kamin' mango fruit which shown that UV-C with cold storage not only led to reduce weight loss but also maintained nutritional values for 16 days. In addition the same authors found that UV-C illumination (6.6 KJ.m^{-2}) in yellow bell pepper prevented the loss of firmness, weight loss and enhanced biologically active compounds.

UV-C irradiation incorporate with hydro cooling maintained the firmness of chili fruit during storage for 21 days depended on the doses of UV-C. The red hot chili fruit illuminated with 4.4 and 6.6 KJ·m^{-2} UV-C showed a slight decrease in firmness over storage while a marked loss of firmness was show in the control fruit (Figure 2). Barka *et al*., (2000) reported that UV-C treatments could reduce the activity of cell wall degrading enzymes and delay softening by affecting the cell wall disassembly rate and this could explain the higher levels of firmness found in UV-C-treated pepper.

Figure 3 shows acceptable quality score of red hot chili fruit treated with UV-C irradiation then hydro cooling before storage. Chili fruit treated with 4.4 KJ·m^{-2}. UV-C incorporated with hydro cooling had higher acceptable quality score than that of other three treatments. The lowest score of the control obviously associated with the highest level of wilting and drying of fruit stem. Consistent with the research of Boonyaritthongchai *et al*., (2013) reported that hydro cooling and modified atmosphere had the effect to the quality of red hot chili by delaying fruit stem browning and received higher acceptance scores from the consumer than control treatments.

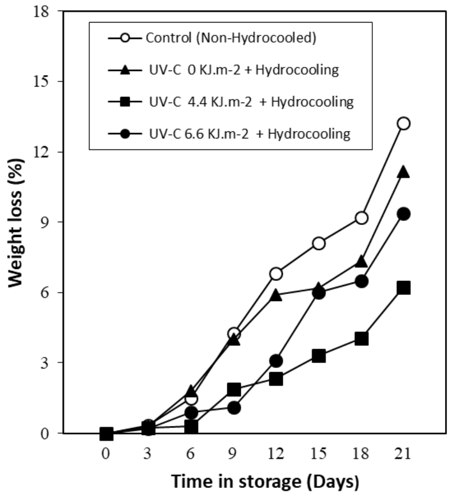

Figure 1 weight loss of red hot chili irradiated with 0, 4.4 and 6.6 KJ·m^{-2} before hydro cooling then stored at 5°C for 21 days in plastic tray wrapped with PVC film. The error bar indicates the least significant difference (LSD) at $P \leq 0.05$.

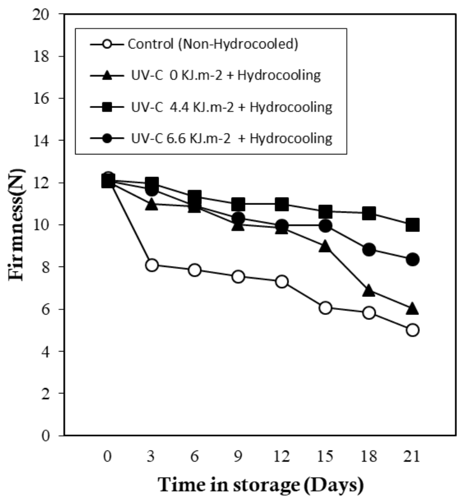

Figure 2 Firmness of red hot chili irradiated with 0, 4.4 and 6.6 KJ·m^{-2} before hydrocooling then stored at 5 °C for 21 days in plastic tray wrapped with PVC film. The error bar indicates the least significant difference (LSD) at $P < 0.05$.

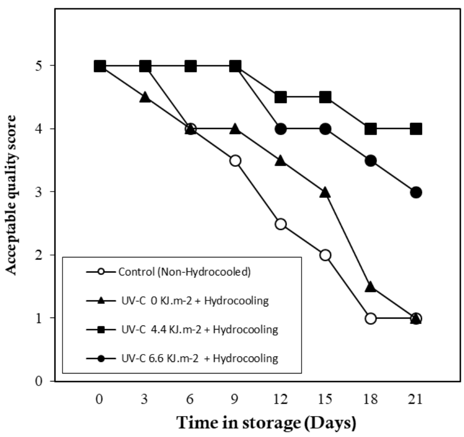

Figure 3 Acceptable quality score of red hot chili irradiated with 0, 4.4 and 6.6 KJ·m^{-2} before hydro cooling then stored at 5°C for 21 days in plastic tray wrapped with PVC film. The error bar indicates the least significant difference (LSD) at $P < 0.05$.

Total antioxidant capacity and total carotenoids content

Total antioxidant capacity (TC) and carotenoids content of the chili fruit were enhanced by UV-C which 4.4 KJ·m^{-2} doses had the highest enhancing than three others as shown in Figure 4A and 4B, respectively. Whereas, non- hydro cooling and hydro cooling without irradiation with UV-C remained constant in total antioxidant capacity during 12 days and slightly increased over storage which was similar to the result in Promyou and Supapvanich (2012) described that the sweet pepper fruit exposure to UV-C capable activation of antioxidant enzymes (catalase and superoxide dismutase) resulting in maintained the quality of sweet pepper during low temperature storage.

The total carotenoid content of 4.4 KJ·m^{-2} UV-C incorporated with hydro cooled chili fruit was dramatically increased during 6 days of storage and showed significantly higher than those of 0, 6.6 KJ·m^{-2} UV-C incorporated with hydro cooling and the non-hydrocooled. In this case increase in total carotenoid content in UV-C treated with 4.4 KJ·m^{-2} with hydro cooling might be part of antioxidant system against the physiologically stress mechanism. The decreasing of total carotenoid content in 6.6 KJ·m-^{2} with hydro cooling might be due to photobleaching or photoinhibition at this dose. The result was similar to our previous work in which TC content of UV-C treated yellow bell pepper fruit held at 12°C was higher than that of untreated fruit (Promyou and Supapvanich, 2012). Moreover, Lui et al (2009) also reported that TC content in 'Red ruby' tomato fruit was enhanced by UV-C illumination.

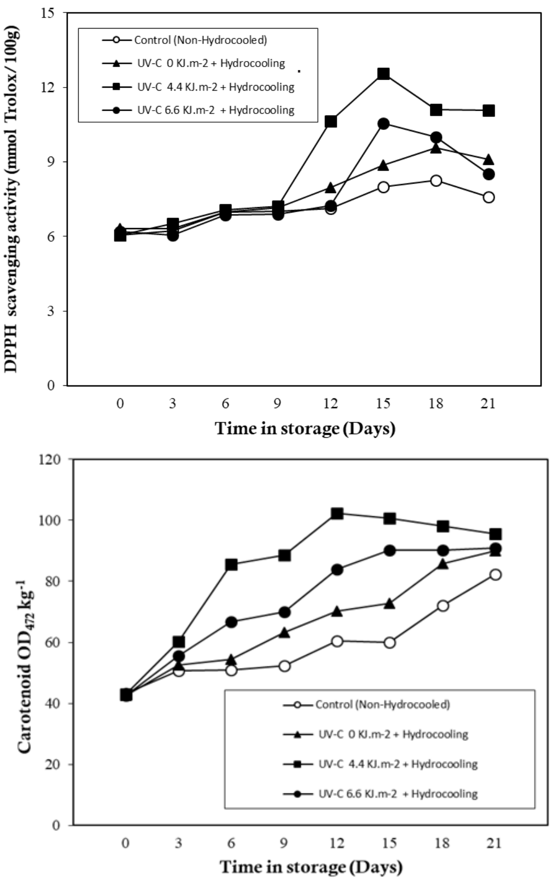

Figure 4. Total antioxidant capacity (A) and carotenoid content (B) of red hot chili irradiated with 0, 4.4 and 6.6 KJ·m^{-2} before hydrocooling then stored at 5°C for 21 days in plastic tray wrapped with PVC film. The error bar indicates the least significant difference (LSD) at $P \leq 0.05$.

CONCLUSIONS

UV-C treatments reduced decay in red hot chili cv. Superhot. UV-C doses incorporated with hydro-cooling were highly effective in maintaining fresh weight and firmness. UV-C irradiated at dose of 4.4 KJ·m^{-2} showed the positive results including significantly reduced the percentage of weight loss and fruit rot as well as enhanced antioxidant capacity and total carotenoid content of chili fruit Moreover, 4.4 KJ·m^{-2} UV-C incorporated with hydro-cooling treatment had the longest storage life (21 days) when compared with the control (12 days). Thus, UV-C will be suggested to be an efficiency method to reducing fruit decay and maintaining red hot chili quality during cool storage.

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