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Original Research Article

Effects of Hot Water Combined with UV-C Treatment on Chinese kale (*Brassica oleracea* var. *Alboglabra*) during Storage

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ABSTRACT

Yellowing and wilting are the major postharvest losses of Chinese kale (*Brassica oleracea* var. *Alboglabra*) during storage. This research aimed to investigate the effects of pre-treatments including i) hot water (HW) dipping at 45°C for 30s, ii) ultraviolet C irradiation (UV-C) at dose of 1.82 kJ m^{-2} and iii) a combined treatment between HW and UV-C (HW+UV-C) on the quality of Chinese kale compared with the control treatment during cold storage. After that, all the samples were packed in perforated polyethylene bags before putting into storage at 10°C, 80-85% RH for 7 days. The results showed that leaves of the Chinese kale in the control group become yellowing faster than other treatments. The control samples had a higher trend in L*, b* values and Chroma compared with other treatments during storage periods of 7 days. The control samples had the lowest hue angle (h° = 95.7) after 7 days of storage. However, there was no significant difference in the changes of h° in all treatments during storage periods. The samples pre-treated with HW+UV-C had the highest percentage of weight loss (8.1 and 10.8%) while the control treatment or the samples treated with HW or UV-C alone had significant ($p < 0.05$) less weight loss which was in the ranges between 2.3-3.5% and 3.0-5.1% after 5 and 7 days of storage, respectively. There was no significant difference in the changes in chlorophyll content for all treatments during storage. In conclusion, the UV-C treatment significantly ($p < 0.05$) delayed yellowness (especially, b* value), had less weight loss compared with other treatments. The quality of Chinese kale was maintained by the UV-C treatment during storage periods of 4-5 days.

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INTRODUCTION

Vegetables are important due to their nutritive values such as dietary fiber, minerals, vitamins, phytochemicals, etc. (Pem and Jeewon, 2015). Among those vegetables, Chinese kale or Chinese broccoli, Kailaan, Gai-lan (*Brassica oleracea* var. *Alboglabra*) is one of the most largely grown in many countries. Chinese kale can be grown all year round. It is a good flavoured broccoli relative (Lin and Harnly, 2009; Morgan and Midmore, 2003; Zong et al., 1998). However, the losses of Chinese kale such as weight loss, wilting and yellowing of leaf due to senescence processes and decay still occur after harvest. These losses lead to short shelf life and reduction in marketability (Poochai et al., 1984; Zong et al., 1998; Chairat et al., 2013). Yamauchi, (2015) reported that a loss of green color, due to the degradation of chlorophyll in fresh commodities, is one of the major quality problems occurring during transportation and storage. Chairat et al., (2013) reported that leaf yellowing of Chinese kale was mainly occurred due to degrading of chlorophyll contents after storage. In accordance with Poochai et al., (1984) who reported that leaf yellowing of Chinese kale occurred within a few days after kept them at 20°C or higher.

Different postharvest techniques such as hot water (HW) dipping and ultraviolet C (UV-C) treatment may be used to reduce the losses and extend the storage life of leafy vegetables. For hot water treatments such as the immersion of product in water baths at 40°C for 3.5 min was used to retard leaf senescence and improve storage life of spinach leaves (Gómez et al., 2008), and HW dipping at 50°C, 20-40s delayed yellowing without damaging the leaves of rocket (*Eruca sativa* Mill.) (Koukounaras et al., 2009). For postharvest UV-C treatment, the technique could also be used on a variety of crops for sterilization and disinfection and to extend the shelf life of fruits and vegetables. For example, the UV-C radiation delayed losses of chlorophyll contents and lowered activities of some chlorophyll-degrading enzymes of the Chinese kale leaf (Chairat et al., 2013) and slowed down weight loss in fresh onions (Kasim et al., 2008).

From the previous works, the application of HW and UV-C irradiation showed some positive effects on delaying leaf yellowing, reducing the loss of chlorophyll contents. Furthermore, these pre-treatments are environmentally-friendly techniques suitable for maintaining the storage quality of several fresh products. Therefore, this study aimed to investigate the effect of HW or UV-C applied alone or HW combined with UV-C irradiation (HW+UV-C) on quality parameters of Chinese kale during cold storage.

MATERIALS AND METHODS

Raw materials

Chinese kale was harvested at commercial maturity (50-55 days after planting) from a local farm in Phayao province, the northern part of Thailand. The samples were immediately transported to the postharvest laboratory, Mae Fah Luang University, Chiang Rai within two hours. The stems of the Chinese kale were uniformly cutting in size approximately 35-40 cm. All the samples were washed with tap water (~30°C) before treated. For treatment 1 (T1): control treatment; fresh Chinese kale was dipped into cold water at 2±1°C for 2 min. Treatment 2 (T2): HW dipping; the stems were dipped in HW at 45°C, 30s and immediately dipped in cold water at 2±1°C, 2 min. Treatment 3 (T3): UV-C irradiation (UV-C) the samples were dipped in cold water at 2±1°C for 2 min then dried and treated by UV-C at dose of 1.82 kJ m^{-2}. The last treatment which was combination between HW and UV-C (T4): the samples were dipped in HW at 45°C, 30s then immediately dipped in cold water at 2±1°C, 2 min, dried after that treated by UV-C at the dose of 1.82 kJ m^{-2}. The samples in treatment 1 and 2 were dried by kept at 10°C (1 h) before packing whereas T3 and T4, the samples were dried and also kept at 10°C (1 h) before subjected to the UV-C. The samples in all treatments were packed in perforated polyethylene (PE) bags with 8 holes (6 mm in diameter) with the distance between each hole was 10 cm. All the packed samples were stored at 10°C for 7 days. Each treatment contained three replications and each replication contained three stems. The quality of stored samples was determined at 0, 1, 3, 5 and 7 days of storage.

Ultraviolet C (UV-C) irradiation

UV-C treatments were conducted in a home-made closed corrugated plastic chamber (45 cm (w) X 120 cm (l) X 60 cm (h)) covered with aluminum foil to improve a homogeneous light distribution. The chamber equipped with UV-C lamps (AQUA Ultraviolet TUV 20W/G20 T8, USA) which were attached 25 cm at the top and the bottom of the radiation rack. The UV-C irradiation was carried out in a controlled temperature room at 20±2°C. The UV-C intensity was measured by a UVC light meter (UVC-254SD, Lutron Electronic, USA) to provide a required dose of 1.82 kJ m^{-2}.

Weight loss (%)

The weight of the samples was measured using a digital balance (PA3102, OHAUS Corporation, USA). Weight loss (%) of the Chinese kale was calculated using the following formula: $[(W_i-W_f)/W_i] \times 100$ where W_i was the initial weight and W_f was the final weight at a certain sampling day.

Color measurement

Changes in leaf color of Chinese kale were determined using a color reader (model CR-10, Konica Minolta Inc., Osaka, Japan) and the results expressed as L* (lightness), b* (+b = yellowness and –b = blueness), Chroma and hue angle (h°). The leaf color was measured at a point near the center of the two leaves of each stem.

Total chlorophyll content

Total chlorophyll content was determined according to the modified method of Witham et al., (1971). One gram of Chinese kale leaf was extracted in a mortar with 80% acetone then filtered through Whatman filter paper No.1 and repeated until no color was obtained. Adjusted the final volume of extracted solution to 50 ml with 80% acetone, then determined by a spectrophotometer (model G10S UV-Vis, Thermo Fisher Scientific, Madison, WI USA) at the absorbance of 652 nm. The chlorophyll content was expressed as mg chlorophyll per 100g fresh weight (mg $100g^{-1}$ FW).

Statistical analysis

Data were subjected by analysis of variance (ANOVA) using a completely randomized design (CRD) and means were compared by Duncan's multiple range test at 0.05 level using the statistical software SPSS (version 20). Data are presented as the mean of three replicates ±SE.

RESULTS AND DISCUSSION

Weight loss (%)

The weight loss (%) of Chinese kale tested in this work was shown in Figure 1. There was no significant difference in weight loss between the HW or UV-C samples compared with the control during storage periods of 7 days. Overall, the weight losses of samples in these three treatments gradually increased from about 1.3% on day 1 to about 3.0-5.1% after being stored for 7 days at 10°C. However, the UV-C sample had the lowest weight loss of 3% while the weight losses of the control and HW samples were about 4.0 and 5.1%, respectively during storage periods of 7 days. In contrast, the combined treatment (HW+UV-C) showed a significant ($p < 0.05$) increase in weight loss (8.1 and 10.8% at 5 and 7 days of storage, respectively) compared with other treatments (Figure 1). Lu et al., (2007) reported that improper heat (applied at harmful temperatures or for an excessive period) might cause damage to horticultural products. Escribano and Mitcham, (2014) reported that the main limitation of heat treatment application is the sensitivity of crops to the temperature required for effective condition. Both beneficial and adverse effects of combined heat treatment with other postharvest technique was also reported by Shao et al., (2012) who found that the heat-treated (hot air at 38°C, 4 days) 'Gala' apples before coating with chitosan showed the highest consumer acceptance after storage but, severe heat damage was also found on the fruit treated after coating formation. Some adverse effects on excessive weight loss of fresh products treated with UV-C irradiation before storage were also reported on cucumbers (Kasim and Kasim, 2008) and green onions (Kasim et al., 2008). The authors reported that higher doses of UV-C increased weight loss of onions.

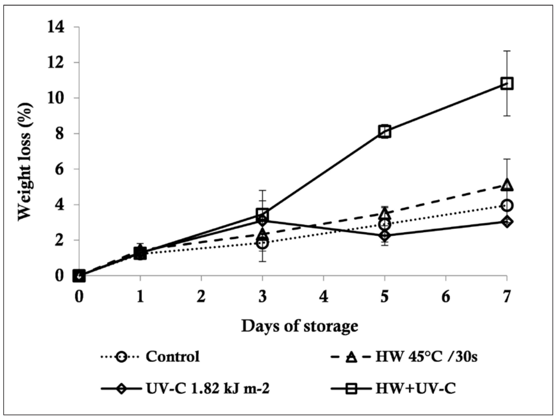

Figure 1. Weight loss (%) of Chinese kale after dipped in hot water (HW at 45°C, 30s), treated with ultraviolet C (UV-C) dose of 1.82 kJ m^{-2}) and a combined treatment of these HW and UV-C conditions (HW+UV-C) compared with control. All samples were packed in perforated polyethylene bags before storage at 10°C, 80-85% RH for 7 days. Vertical bars indicate ±SE (n=9).

In this study, the weight losses of the pre-treated UV-C alone or HW alone on Chinese kale samples were not different compared with the control treatment over storage periods but, the combined treatment had significantly higher in weight loss than the other treatments, which might be due to stress occurrence caused by the combined effects of HW and UV-C application. This stress may exceed the sensitivity of Chinese kale to the applied temperature of HW or the UV-C dose that limited the potential effects of this condition. UV-C is generally injurious, but it can deliver favorable effect on horticultural commodities at low doses, known as hormesis which is stimulation of a plant response by low levels of stress (Luckey, T.D., 1982; Hemmaty, et al., 2007). Therefore, in this study, it is suggested that the use of this combined treatment was not suitable for maintaining the storage quality of Chinese kale.

Leaf Color

Changes in the values of L*, b*, Chroma and h° of Chinese kale leaves are shown in Figure 2A, B, C and D, respectively. The UV-C irradiation seemed to delay the increase in lightness (40.5) at day 3, while the L* values of the other treatments such as the HW+UV-C, control, and HW were 41.9, 42.2 and 42.5, respectively. However, there was no significant difference in lightness changes of Chinese kale leaves in all treatments up to 5 days of storage. The L* value of the stored samples in the control treatment at day 7 was significantly ($p < 0.05$) higher than the L* of the leaves treated by HW+UV-C before storage, while the L* value of the control samples was similar to the leaves pre-treated by HW or UV-C alone (Figure 2A).

Pathare, et al., (2013) noted that the positive b* values represent the yellowish color range while the negative b* values indicate the bluish color range. For the changes in b* values of the Chinese kale samples in this work, overall, the control samples had a higher trend in b* values (become more yellowish colors) compared with the other treatments during storage periods of 7 days. However, the b* value of the samples pre-treated by UV-C alone and stored at 10°C for 3 days was 15.7 which was significantly ($p < 0.05$) lower than the b* values of the control samples which its b* value was 20.1 (Figure 2B). Therefore, the higher in positive b* value reflects the more yellowness of the Chinese kale in the control fruit compared with the UV-C samples. However, there was no significant difference in the b* values between the UV-C samples and the HW or the combined treatment during storage for 7 days.

Chroma is the quantitative aspect of colorfulness which is the attribute of perceived color relating to chromatic intensity. The high Chroma values reflect the more color intensity of samples perceived by humans (Pathare, et al., 2013). In this study, the trends of change in Chroma and b* values were quite similar for Chinese kale in all treatments over storage periods of 7 days (Figure 2B and C). The high Chroma values in the control treatment may reflect the more color intensity of their leaves compared to other treatments. However, there was no significant difference in the changes of Chroma for the Chinese kale in all treatments over the storage period.

Hue angle (h°) is the qualitative trait of color which can be defined as reddish, greenish, and others. A higher value of h° represents a lesser yellow appearance (Pathare, et al., 2013). The average initial h° (122°) of Chinese kale in all treatments slowly decreased to about 117.8° after 3 days of storage and then rapidly decreased to approximately 112.9° and 98° after 5 and 7 days of storage, respectively. There was no significant difference in the changes of h° for the Chinese kale in all treatments over the storage period (Figure 2D).

In this study, the results showed only a small effect of the UV-C treatment on delaying color change, especially b* value of Chinese kale during storage at 10°C within 3 days (Figure 2B). However, some beneficial effects of other UV-C treatments are widely reported for examples, the green color of UV-C treated cucumbers was maintained better during storage than that of the control samples at 5 and 10°C for 10 days (Kasim and Kasim, 2008). The UV-C treatment at the dose of 8 kj m^{-2} delayed yellowing of minimally processed broccoli after stored at 4°C for 21 days (Lemoine et al., 2007). Furthermore, Lemoine et al., (2008) also reported that the combined treatments with hot air at 48°C for 3 hours and UV-C at the dose of 8 kJ m^{-2} caused the higher retention of green color of minimally processed broccoli *(Brassica oleracea* L.) florets when stored in darkness at 20°C for 4 days. Chirat et al., (2013) reported that the UV-C irradiation dose of 3.6 and 5.4 kJ m^{-2} delayed leaf yellowing of Chinese kale described as higher hue values compared with control. However, in this study, no significant difference in the h° values were detected in all treatments (Figure 2D).

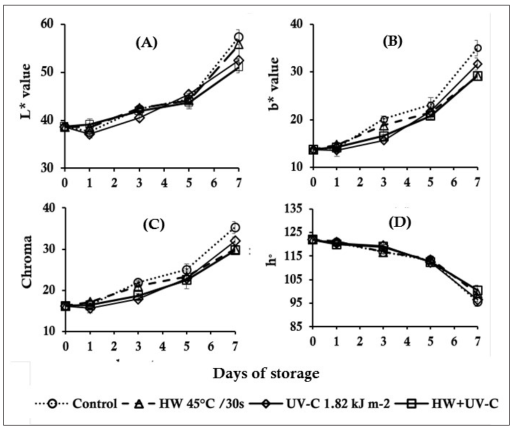

Figure 2. Changes in the values of L* (A), b* (B), Chroma (C) and h° (D) of Chinese kale leaves after dipped in hot water (HW at 45°C, 30s), treated with ultraviolet C (UV-C) dose of 1.82 kJ m^{-2} and a combined treatment of these HW and UV-C conditions (HW+UV-C) compared with control. All samples were packed in perforated polyethylene bags before storage at 10°C, 80-85% RH for 7 days. Vertical bars indicate ±SE (n=9).

Chlorophyll content

Chlorophyll of green leafy vegetable can be used as a visible parameter of determining the quality of vegetables during storage since it gradually deteriorates along with aging (Limantara et al., 2015). In this work, the UV-C treated Chinese kale showed the highest chlorophyll content compared with other treatments. The initial chlorophyll content of Chinese kale samples in all treatment was about 106.5 mg $100g^{-1}$ FW. For the UV-C treated samples, their chlorophyll content increased slightly to 153.1 and 127.3 mg $100g^{-1}$ FW at day 1 and day 3, respectively, after that, a rapid decrease in chlorophyll contents to about 47.9 and 43.9 mg $100g^{-1}$ FW was observed at day 5 and day 7, respectively. The chlorophyll content of UV-C treated samples was higher than other treatments during 3 days of storage. However, there was no significant difference in the change of chlorophyll content among all treatments over storage periods. Therefore, no positive effects on delaying chlorophyll loss by any treatments observed in this work (Figure 3). Poochai et al., (1984) reported that chlorophyll content of Chinese kale at initial day of storage was 127.5 mg $100g^{-1}$ FW and reduced to 81.7 mg $100g^{-1}$ FW after storage at 10°C without bagging for 14 days. Furthermore, Chirat et al., (2013) also reported that the initial chlorophyll content of their Chinese kale samples was 127 mg $100g^{-1}$ FW and rapidly reduced to about 15 mg $100g^{-1}$ FW after 8 days of storage at 20°C. The authors found that the UV-C irradiation dose of 3.6 and 5.4 kJ m^{-2} delayed chlorophyll loss of Chinese kale compared with the control. Overall, all the pre-treatments tested in this study did not help on maintaining chlorophyll content or reducing the loss of chlorophyll compared with control during storage at 10°C for 7 days (Figure 3).

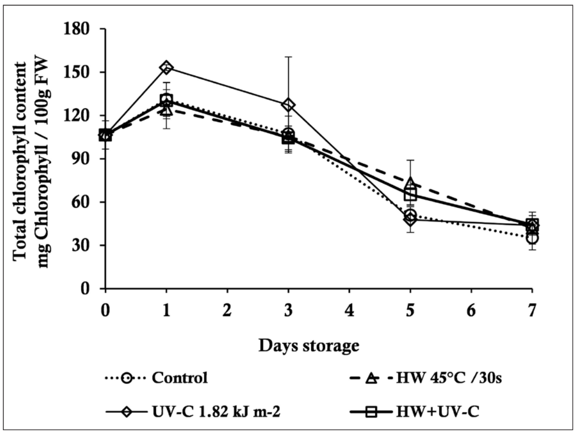

Figure 3. Total chlorophyll content of Chinese kale after dipped in hot water (HW at 45°C, 30s), treated with ultraviolet C (UV-C) dose of 1.82 kJ m^{-2} and a combined treatment of these HW and UV-C conditions (HW+UV-C) compared with control. All samples were packed in perforated polyethylene bags before storage at 10°C, 80-85% RH for 7 days. Vertical bars indicate ±SE (n=9).

CONCLUSIONS

Quality losses of Chinese kale during storage generally due to weight loss, wilting, color change (green to yellow) or reduction of chlorophyll content. Overall, the quality of Chinese kale kept in the control condition was acceptable for only 2 days, while the HW dipping at 45°C for 30s was not effective in maintaining the quality of Chinese kale and could be stored for about 2-3 days. The combined treatment showed significant highest weight loss which led to short storage life of 2-3 days. While the pre-treatment by using UV-C at the dose of 1.82 kJ m^{-2} showed small positive effect on delaying color change, retaining green color and having the lowest weight loss, therefore the UV-C treated samples could be stored for 4-5 days.

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