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Short Communication

Effect of sequential UV-C irradiation on microbial reduction and quality of fresh-cut dragon fruit

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Abstract

This study investigated the effect of UV-C sequential treatment (pre-, post- and both pre/post-cutting) on microorganism and quality of fresh-cut dragon fruit [*Hylocereus undatus* (Haw) Britt. and Rose]. Dragon fruit was irradiated by UV-C at 3.2 kJ/m^2 pre-cutting, post- cutting and both pre/post-cutting compared with the control (no UV-C treatment). Fresh-cut dragon fruit were packed in foam tray, wrapped with polyvinylchloride film and stored for 6 days at 5±1ºC and 95% RH. Results showed that UV-C irradiation reduced microbial contamination compared to the control. Treatment with UV-C post-cutting, dragon fruit significantly lower total aerobic bacteria, coliforms, yeast and mold during storage than other UV-C treatments ($p<0.05$). Physical properties i.e. weight loss, firmness, flesh color difference and sensory attributes of fresh-cut dragon fruit was unaffected by UV-C treated post-cutting and maintained better quality than other treatments. However, UV-C treatment slightly effected on total soluble solid and ascorbic acid content, regardless of sequential application. In summary, UV-C irradiation post-cutting could potentially apply as a sanitizing method for fresh-cut dragon fruit without quality alternation.

Introduction

Dragon fruit [*Hylocereus undatus* (Haw) Britt. and Rose], native to Mexico, was transplanted to other parts of the World including Southeast Asian such as Vietnam, Malaysia, Philippines, Indonesia and Thailand. The flesh of dragon fruit is mildly sweet, low in calories and contain high amount of vitamin C and antioxidant. Dragon fruit has gained more attention due to its health benefit.

Fresh-cut fruit and vegetable industry in Thailand has been rapidly growing in recent years in response to an increased in consumer demand of fresh and healthy food. Fresh-cut produce prepared by minimally processes including washing, cutting, packaging and distributing. However, fresh-cut produce are more susceptible to microbial contamination and has a shorter shelf-life than the intact ones since they have been subjected to physical stress after peeling and/or cutting.

In order to decrease microbial contamination of fresh-cut produce, several washing treatments including ozone, organic acids and sodium hypochlorite have been used as disinfection agents (Yuk *et al.*, 2007). However, sodium hypochlorite which is widely used in food industry may cause product tainting (Izumi, 2007) and chlorine may reacts with natural organic products in food to form mutagenic trihalomethans (THM) which potentially carcinogenic (Artés *et al.*, 2007). In addition, washing step might cause the mechanical damage that leads to the promotion of increased microbial growth.

Ultraviolet (UV-C) irradiation, range of 240-260 nm, is used as an alternative to chemical sanitizer and has been approved for use as a surface disinfectant treatment for food product in USA (US-FDA, 2002). The use of UV-C treatment has been reported on microbial inhibition in fresh produce such as tomato (Liu *et al.*, 2000), mushroom (Guan *et al.*, 2012) and fresh-cut watermelon (Artés-Hernández *et al.*, 2010). However, in some cases, high doses of UV-C may damage to the treated tissue (Artés *et al.*, 2007). Therefore, the possibility of reducing the treatment intensity by sequential UV-C treatment to preserve fruit quality appears very promising (Allende *et al.*, 2006). Moreover, little information is available on the effects of sequential UV-C treatment for fresh-cut produce. This could be potentially used for sanitizing fresh-cut dragon fruit in practice. The objective of this work was to evaluate the effects of sequential UV-C irradiation (pre-cutting, post-cutting and both pre-/post-cutting) on microbial reduction and overall quality of fresh-cut dragon fruit during storage.

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Materials and Methods

Plant material

Dragon fruit [*Hylocereus undatus* (Haw) Britt. and Rose] were picked at the commercial maturity stage (color-break) from a local commercial grower in Phayao province, Thailand. Healthy fruit (350 g) were washed with running tap water and air-dried at room temperature. Whole dragon fruit was longitudinally cut into six sections using a sterile knife, and the peels were removed. Dragon fruit cubes were placed in polystyrene foam tray before UV-C irradiation.

UV-C radiation

The UV-C doses applied were selected based on our preliminary experiments, which determined the maximum UV-C radiation dose without detrimental effects on sensory quality of dragon fruit fresh. A germicidal UV-C irradiator containing two UV-C emitting bulbs was used. The UV-C radiation intensity was determined by Solarmeter model 8.0 UV meter (Solartech inc., USA). Sample were placed 30 cm of distance from UV-C lamps. The applied UV-C intensity was calculated from a mean of 10 readings and the applied doses varied by altering the exposure time at the fixed distance and light intensity.

To determine the effect of UV-C irradiation, different application methods were introduced in terms of without UV-C irradiation (control), applying UV-C at doses of 3.2 kJ/m^2 to whole dragon fruit (pre-cutting), applying UV-C at doses of 3.2 kJ/m^2 to fresh-cut dragon fruit (post-cutting), and applying UV-C at dose of 3.2 kJ/m^2 to whole and fresh-cut dragon fruit (pre-post cutting). Three replicates of fresh-cut dragon fruit from each foam tray were wrapping with polyvinylchloride film. The packaged fresh-cut cubes were then stored at 5±1ºC and 95% RH for 6 days.

Microbiological quality

Microbial counts were made from a 10-g macerated sample in 90 ml of 0.85% NaCl as previous described by Izumi (1999). Total aerobic bacteria was determined using serial dilutions on plate count agar (Himedia Laboratories Pvt. Ltd., India). The duplicate plates were incubated at 37ºC for 48 h. Coliform bacteria and yeast and mold count with same dilutions were also carried out on deoxycholate agar (Himedia Laboratories Pvt. Ltd., India) and potato dextrose agar (Himedia Laboratories Pvt. Ltd., India), respectively. Microbial populations were expressed as $\log_{10}$ colony forming units per g of sample (log CFU/g).

Physicochemical quality

Weight loss of each sample was determined by weighing the same samples from the beginning of storage until the end of the experiment and calculated a percentage of the initial weight. Fruit firmness was measured using a Texture analyzer model TA.XT. plus with a stainless knife blade of 7 x 12 cm in size and 3 mm of thickness. Shear force was expressed as a maximum force in newton (N).

Color of dragon fruit flesh was measured randomly from the two sides of the cubes using a colorimeter (model CR-100; Minolta Corp., Japan). Values were expressed as Hunter color indexes L^* (lightness), a^* (green-red) and b^* (blue-yellow). The color difference (ΔE) from the initial day was calculated from the equation $\Delta E = [(L^*-L_0^*)^2 + (a^*-a_0^*)^2 + (b^*-b_0^*)^2]^{1/2}$.

Total soluble solids content of the juice extracted from dragon fruit was measured using a refractometer (Atago Co., Japan) at 25ºC and expressed as ºBrix values. Ascorbic acid content was measured by indophenols method according to Nielsen (2010). Two mL of fruit juice in 5 mL metaphosphoric-acetic acid solution were titrated with 2,6-dichloroindolphenol (dye solution) until the end point. The result was expressed as mg/g fresh weight of fruit sample.

Sensory evaluation

Sensory evaluation was carried out on the same day of microbial and quality analysis by a six-member trained panel group. The evaluate parameters were the color and overall visual quality using a nine-point hedonic scale (1: extremely poor, 3: poor, 5: acceptable and limit of usability, 7: good and 9: excellent).

Statistical analysis

The experiments were conducted using a completely randomized design (CRD). Analysis of variance (ANOVA) to evaluate treatment effects was performed using SPSS version 18. Means were tested for significance at $p<0.05$ using the Duncan's multiple range test (DMRT). Figures represent mean values (n = 3) ±SD.

Results and Discussion

Effect of sequential UV-C on microbial quality

Microbial population on the control samples at day 0 averaged 2.92, 2.51 and 2.78 log CFU/g for total aerobic bacteria, coliforms, yeast and mold, respectively (Figure 1). It was found that, UV-C treatment reduced counts of total aerobic bacteria and coliform group (coliforms) on initial day as compared

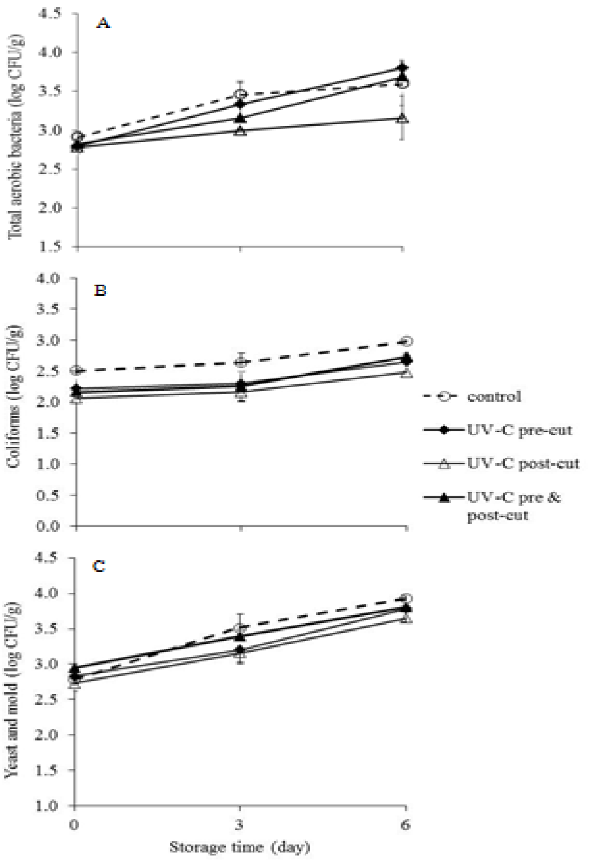

Figure 1. Total aerobic bacteria (A), coliforms (B) and yeast/mold (C) of fresh-cut dragon fruit sequential treated with UV-C pre-cutting, post-cutting and both pre/post-cutting before storage at 5±1°C for 6 days

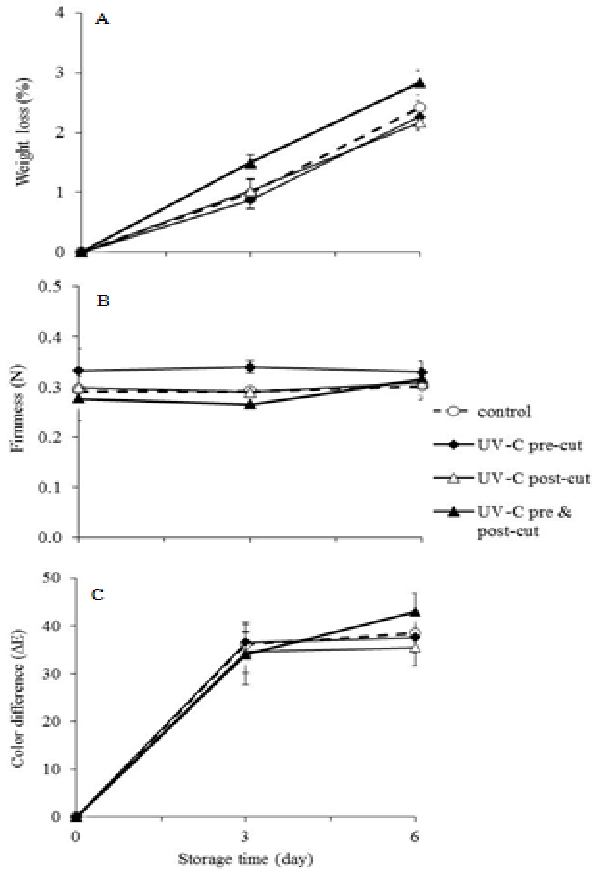

Figure 2. Weight loss (A), firmness (B) and color difference (C) of fresh-cut dragon fruit sequential treated with UV-C pre-cutting, post-cutting and both pre/post-cutting before storage at 5±1°C for 6 days

to the control. However, UV-C did not affect counts of yeast and mold on fresh-cut dragon fruit. The inconsistent result was also found on the effect of UV-C on the microbial growth in pomegranate arils that yeast and molds were unaffected (López-Rubira *et al*., 2005).

After 6 days, microbial counts markedly increased, mainly in control samples. Counts of total aerobic bacteria, coliforms, yeast and mold in UV-C treated samples were significantly lower than the control and post-cutting treatment was the most effective (Figure 1B and 1C). UV-C caused a substantial reduction in microbial growth by mostly absorbed by the DNA molecule of microorganisms causing cross linking between neighboring pyrimidine bases on the same strand of DNA, preventing reproduction of the microorganisms (Pala and Toklucu, 2013).

It has been reported that effectiveness of UV-C on microbial inactivation depends on radiation dose (Guan *et al*., 2012; Pala *et al*., 2013). However, no significant differences were found among the number of total aerobic bacteria of the control and sequential UV-C treated pre-cutting and both pre/post-cutting after 6 days in storage. The lack of UV-C application time response in our study may be due to the cell permeability change after twice UV-C treatment increasing electrolyzed, amino acids and carbohydrate leakage which can stimulate bacterial growth (Artés *et al*., 2007). Additionally, the aril surface composition of dragon fruit skin could protect the microorganisms from the UV-C radiation in whole fruit. It should be considered that the effect of UV-C on the inactivation of microorganisms not only depend on the dose but also the surface area exposure.

Effect of sequential UV-C on physicochemical quality

In control sample the weight loss reached 2.4% after 6 days of storage (Figure 2A). Weight loss increased with time and the maximum weight loss was observed with UV-C treated both pre/post-cutting (2.8%). However, there was no significant difference in weight loss of fresh-cut dragon fruit treated with UV-C pre-cutting, post-cutting and the untreated control. The effect of sequential UV-C treatments on firmness during storage at 5ºC is shown in Figure 2B. Firmness of fresh-cut dragon fruit in all treatments remained largely unchanged during

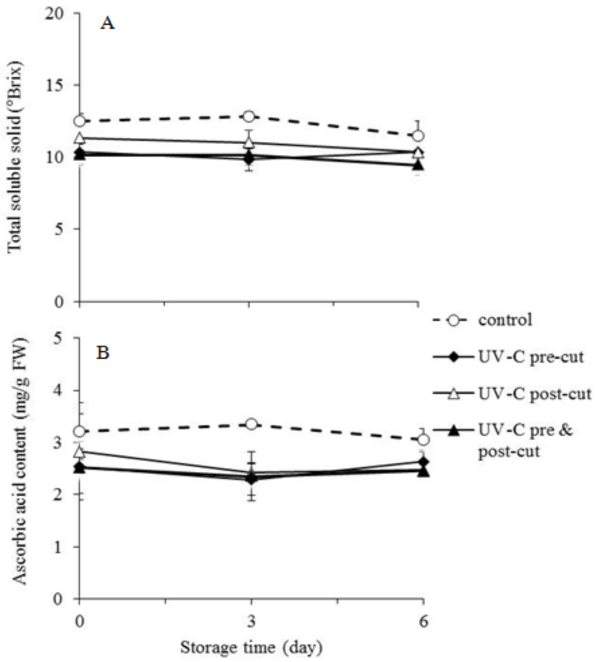

Figure 3. Total soluble solid (A) and ascorbic acid content (B) of fresh-cut dragon fruit sequential treated with UV-C pre-cutting, post-cutting and both pre/post-cutting before storage at 5±1°C for 6 days

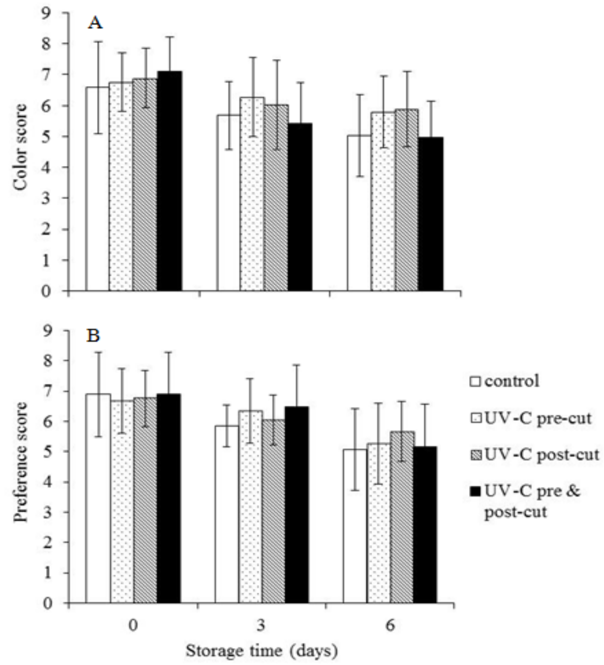

Figure 4. Color score (A) and preference score (B) of fresh-cut dragon fruit sequential treated with UV-C pre-cutting, post-cutting and both pre/post-cutting before storage at 5±1°C for 6 days

storage indicating that sequential UV-C treatment generally had no significant impact on slice firmness.

Color difference value (ΔE) increased during storage indicated the difference of color from the initial day (Figure 2C). Compared to the control and other UV-C treatments, that treated with twice UV-C had higher color difference value after 6 days in storage. We found the water soaked area in dragon fruit flesh after twice UV-C treatment (data not shown). It is possible that the use of UV-C both pre/post-cutting caused slight damage to the surface tissue. These results agree with previous reports on button mushrooms (Guan *et al*., 2012) and baby spinach (Escalona *et al*., 2010) that higher UV-C doses caused cell damage and respiratory stress.

Total soluble solids (TSS) of untreated and UV-C treated sample, averaging 11°Brix for all treatments, are shown in Figure 3A. TSS for all treatment generally declined after storage, although the control sample tented to maintain slightly higher TSS during storage. There were no significant differences in these values after UV-C treatments compared to the untreated sample after storage for 6 days. Similarly, no significant effect of UV-C treatment was found in soluble solid of orange juice (Pala and Toklucu, 2013).

Ascorbic acid content in fresh-cut dragon fruit range from 2.29 ± 0.3 and 3.35 ± 0.1 mg/g FW without differences among the UV-C treatments (Figure 3B). Control samples showed a slight decrease from the initial content. Higher decreases were monitored for UV-C treated samples, with the twice UV-C treatment (both pre/post-cutting) showed the lowest ascorbic acid content after 6 days of storage. This indicated that ascorbic acid losses increased in line with the UV-C application time. Pala and Toklucu (2013) reported a 9.25% reduction of ascorbic acid in orange juice treated with high UV-C dose (48.12 kJ/L). On the other hand, UV-C did not significantly affect the vitamin C content in fresh-cut watermelon (Artés-Hernández *et al*., 2010) and button mushrooms (Guan *et al*., 2012).

Results from the above physicochemical quality showed that the use of sequential UV-C both pre/post-cutting treatment reduced the ascorbic acid content in fresh-cut dragon fruit possibly related to the tissue damage, which would contribute to the antioxidant activity. In addition, UV-C light acts indirectly against microorganism by stimulating plant defense mechanism (Artés *et al*., 2007). Therefore, further study need to investigate the effect of UV-C on defense response and antioxidant activity of fresh-cut fruit.

Effect of sequential UV-C on sensorial quality

Initially, the overall visual quality and color score of fresh-cut dragon fruit were excellent immediately after UV-C treatment (Figure 4). At the end of the storage, post-cutting UV-C treated samples were significantly more liked than the control and other sequential UV-C treated sample. By contrast, sensorial characteristics of fresh-cut dragon fruit changed unfavorably after the twice UV-C treatment (both pre/post-cutting). Therefore, post-cutting UV-C treatment could inactivate spoilage microorganism without considerably affecting sensory quality of fresh-cut dragon fruit.

Conclusion

This study showed that sequential UV-C radiation at 3.2 kJ/m^2 potentially reduced microbial growth and maintains quality of fresh-cut dragon fruit. It appears that twice UV-C treatment (both pre/post-cutting) caused tissue damage to the fresh-cut dragon fruit, as indicated by changes in weight loss, microbial counts and sensory evaluation. Therefore, this study indicated that UV-C radiation applied post-cutting was effective in reducing microbial loads and may potentially extend storage periods without quality deterioration of fresh-cut dragon fruit.

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