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Original Research Article

Effect of ultraviolet-C (UV-C) irradiation on physicochemical changes of fresh-cut baby corn during storage

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ABSTRACT

Baby corn (*Zea mays* L.) is an important vegetable crop of Thailand. The demand for fresh-cut baby corn in the market has increased substantially as containing high nutritional values including fibers, minerals, β carotene and ascorbic acid. The postharvest problem of this product is weight loss during storage and wholesale which lead to quantitative and nutritional quality losses. This research investigated the effect of ultraviolet-C (UV-C) irradiation on physiochemical changes of fresh-cut baby corn during storage. The fresh-cut baby corns were irradiated with 2.2, 4.4, and 6.6 $KJ.m^{-2}$ UV-C, respectively, and the untreated baby corn was assumed as control. The fresh-cut baby corns were then kept in plastic tray wrapped with PVC film and stored at 5°c for 7 days. The results showed that treatment of 4.4 $KJ.m^{-2}$ UV-C gave the best results on retaining fresh weight, electrolyte leakage, firmness and delaying the decreased of antioxidant capacity (DPPH) in fresh-cut baby corn. However, UV-C irradiation had no effect on the changes in color values (L* a* b*) and ascorbic acid content throughout storage time.

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INTRODUCTION

Baby corn is the ear of maize plant (*Zea Mays* L.) harvested young, especially before or after the silks had emerged but fertilization hasn't taken place (Rattanachai and Kanlayanarat, 2015). Baby corn is a popular asia vegetable which can be eaten cooked or raw because of its sweetness and succulent taste including rich in carbohydrates, protein, vitamins, minerals, amino acid, fibres, β carotene and ascorbic acid (Kaiser and Ernst, 2017; Hooda and Kawatra, 2013). Baby corn is an important vegetable crop in Thailand and it has been exported annually about 40 million USD from 2014 to 2017 (OAE, 2017). In Table 1, slightly decreased exported tons and values were observed from 2014 to 2017. This was due to the quality losses during exportation. The quality deteriorations of postharvest baby corn are fresh weight loss during transportation, high respiration rate, rapid loss of sweetness and browning (Bakry *et al*., 2015; Somboonsarn, 1993). Therefore, delaying postharvest losses and maintaining the product qualities by postharvest treatment have been recently explored. Concerning on the human health, the quality of fruits and vegetables are becoming an important factor. Therefore, the changes in nutrients composition of vegetables after harvest have been currently interested by the consumers. UV-C irradiation is an alternative postharvest handling replacing chemical treatments for maintaining the qualities of fresh commodities. It also maintains fruit firmness and retards softening by reducing the activity of cell wall degradation enzymes, enhancing the polyamine levels and consequently delaying ripening and senescence of tomato (Barka *et al*., 2000). Moreover UV-C treatment induced antioxidant capacity and antioxidant enzymes activities, in strawberry (Erkan *et al*., 2008) and fresh-cut mango (Gonzalez-Aguilar *et al*., 2008). Vincente *et al*. (2005) reported that UV-C treatment has been used to extend the shelf life and reduce the increased level of total phenol, respiration rate and electrolyte leakage of red pepper. Also, UV-C not only could induce phytoalexins that play an important role in diseases resistance (Shama *et al*., 2007) but also could activate genes encoding pathogenesis related proteins caused by abiotic stress (Calabrese et al., 1987: Obande *et al*., 2007). Thus, we were interested in the investigation of UV-C irradiation for maintaining postharvest quality and physicochemical changes of fresh-cut baby corn during storage. The objectives of this study were to: (1) investigate physiochemical changes of fresh-cut baby corn treated by UV-C irradiation during storage; (2) find out the suitable dosage for UV-C irradiation for fresh-cut baby corn.

Table 1. Export Situation of Baby corn in Thailand from 2014 to 2017. (Source: Offices of Agricultural Economics, 2017)

Year	2014	2015	2016	2017
Export (Tons)	37,651	33,126	33,050	33,326
Value (million USD)	45	39	40	40

MATERIALS AND METHODS

Plant materials and UV-C irradiation

The baby corn (*Zea Mays* L.) was harvested at 45-50 days after planning or baby corn silk came out 1-2 cm from the top end of ears. Baby corn samples were obtained from the farm where baby corn is commercially grown in Sakon Nakon province, Thailand. The samples were husked and selected as uniformity without physical damages, diseases and insect attack. The fresh-cut baby corn (15 cm length and 3 cm diameter) were randomly placed into a box (1.32 m long, 1.85 m wide and 0.8 m deep) containing two germicidal UV lamps (TUV, 30W, Salvania, Japan) and were irradiated at distance of 70 cm for 30, 60 and 90 min to obtain dosages of 2.2, 4.4 and 6.6 $KJ.m^{-2}$, respectively. Each fresh-cut baby corn was rotated manually two times to ensure uniform surface exposure to UV light. Non UV-C irradiated fresh-cut baby corn served as the control. After treated with UV-C, the samples were packed in the foam tray and wrapped with PVC cling film then stored at 5 ±1°C. On each sampling day, fresh-cut baby corn was analyzed immediately or otherwise cut, frozen and stored at -80°C until use. Three replications (a tray contained 300 g of fresh-cut baby corn) of samples were used in this experiment.

Determination of weight loss, color change, firmness and electrolyte leakages (EL)

The weight loss of fresh-cut baby corn was measured before storage and everyday till the end of storage. The percentage of weight loss was calculated by comparing with initial weight. The color change was interpreted by using Hunter Lab Mini Scan @ XE Plus (Hunter Associates Laboratory Inc., USA). The color change was recorded as greenness (a* value), yellowness (b* value) and brightness (L* value). Firmness of fresh-cut baby corn was measured with a TA-XT II texture analyser (Stable Micro System, Surrey, England). The data was expressed in Newton (N). The electrolyte leakage (EL) was determined using the method described by Ergun *et al* (2007). The fresh-cut baby corn was sliced into 2 mm thick and 5 grams of fresh-cut baby corn were soaked in distilled water. The sample was put in 30 ml of deionized water and shaken for 30 minutes. The conductivity of the solution was measured before and after boiling in autoclave for 15 minutes at 121°C by using conductivity meter. The EL was expressed as percentage of tissue EL.

Determination of ascorbic acid content

The ascorbic acid of fresh-cut baby corn was measured following the method of AOAC (1980). Two grams of sample was homogenized with 16 ml of metaphosporic acid-acetatic acid (HPO_3-HOAC) for 2 minutes and then filtered with Whatman No 1. Ten ml of sample solution was added to a conical flask mixed with 2 ml of metaphosporic acid-acetatic acid (HPO_3-HOAC). The solution was titrated against with indophenol solution till pink to red color persisted for 5 seconds. The titration was repeated three times. The data was calculated with the following formula and expressed as mg $100\ g^{-1}$ FW.

Calculation:

$Z\ mg.g^{-1} = \{X-B\}\times\{F\div E\}\times\{V\div Y\}$ (AOAC, 1980)

where :

X = Average titre value obtained from the sample titration.

B = Average titre value obtained from the blank titration.

F = Mg of ascorbic acid equivalent to 1 ml of indophenols solution.

E = No. of grams of fruit sample assayed.

V = Volume of initial assay solution.

Y = Volume of sample aliquot titrated.

Determination of DPPH radical scavenging activity (DPPH assay)

Total antioxidant capacity of fresh-cut baby corn was determined by the method described by Loypimai *et al*. (2009). One gram of baby corn was homogenized with 20 ml of distilled water and filtered with Whatman No.1. The samples were centrifuged at 8,000 × g for 15 min. 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 by spectrophotometer (Labomed, inc) in triplicate at 517 nm after incubation for 30 minutes at room temperature in dark. Antioxidant capacity was expressed as percent of DPPH radical scavenging. The percent of DPPH radical scavenging activity was calculated as follows.

% 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.

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 $P \leq 0.05$. Data were shown as mean ± standard error (S.E.).

RESULTS AND DISCUSSION

Weight loss, firmness and electrolyte leakages (EL)

Fresh weight and firmness were recognized as the main factors affecting quality attributes of fresh commodities. The results in Figure 1 showed that the weight loss of fresh-cut baby corn increased continuously after being stored for 7 days at 5°C in all treatments. UV-C irradiation delayed the increase of weight loss compared to control. The weight loss of untreated fresh-cut baby corn dramatically increased while UV-C treated fresh-cut baby corn slightly increased. At the end of storage time, the highest weight loss was found in control (3.51%) and then followed by UV-C treated with 2.2 KJ.m^{-2} and 6.6 KJ.m^{-2} and 4.4 KJ.m^{-2} (3.11, 3.06 and 1.77%), respectively. Therefore, we suggested that UV-C treated with 4.4 KJ.m^{-2} had high efficiency to maintain weight loss in fresh-cut baby corn during storage.

Similarly trend found in fresh-cut baby corn irradiated with UV-C had higher firmness when compared to control as shown in figure 2. A marked decrease of firmness was found in control while a slight decrease was found in 2.2 and 6.6KJ.m^{-2}. The firmness of UV-C treated with 4.4 KJ.m^{-2} was significantly higher than control and remained constant throughout storage at 5°C for 7 days.

The weight loss of fresh-cut baby corn was retarded by UV-C irradiation at 4.4 KJ.m^{-2} during storage. UV-C irradiated at this dosage might be stimulated the activities of lignifying enzymes and phenyl alanine ammonialyase (Lu et al., 1991). Moreover, UV-C induced polyamine levels by positively or negatively charged to molecules as membrane phospholipid that can prevent loss of moisture from cell membrane (Civello *et al*., 2006). Cuvi et al (2011) also reported that UV-C treated red pepper fruit inhibited the increased level of weight loss during storage. The higher firmness of UV-C irradiated fresh-cut baby corn compared to control might be associated to the reduction of the activities of cell wall degrading enzymes (Barka et al., 2000). The higher weight loss, EL and decreasing of firmness in UV-C 6.6 KJ.m^{-2} might be excessive UV-C dose and cause oxidative stress and resultant in cellular damage (Civello *et al*., 2006). The proper dose of UV-C irradiation is largely depending on the product and it's ripening stage. In fresh-cut baby corn UV-C dose at 4.4 KJ.m^{-2} suggested the effective dose which was below the threshold for damage. Therefore we suggested that UV-C irradiation effectively maintained fresh weight and firmness of fresh-cut baby corn during storage.

The higher electrolyte leakage (EL) was found in all treatments as showed in Figure 3. However, fresh-cut baby corn irradiated with UV-C had lower EL than control throughout storage. Fresh-cut baby corn irradiated with 4.4 KJ.m^{-2} UV-C was the least EL. The result showed that the least EL may be related to the remained firmer of fresh-cut baby corn and reduction of weight loss at UV-C 4.4 KJ.m^{-2}. Regarding to the accumulation of polyamine in plant cell as a response to stress might prevent cell wall degradation (Civello *et al*., 2006). As a result, UV-C irradiation reduced the increase in EL of fresh-cut baby corn during storage. As previous reported UV-C irradiation could be reduced the increase in EL in yellow bell pepper (Promyou and Supavanich, 2012) and red pepper (Vicente *et al*., 2005).

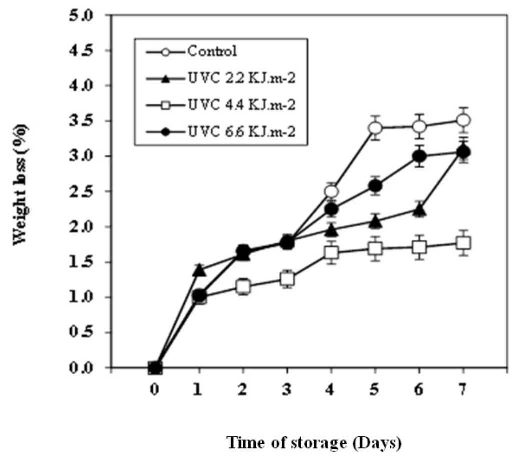

Figure 1. Weight loss of fresh-cut baby corn irradiated with 2.2 (▲), 4.4 (□), 6.6 (●) KJ.m^{-2} UV-C and without UV-C (○) stored at 5°C for 7 days. The error bar indicates the least significant difference (LSD) at $P \leq 0.05$.

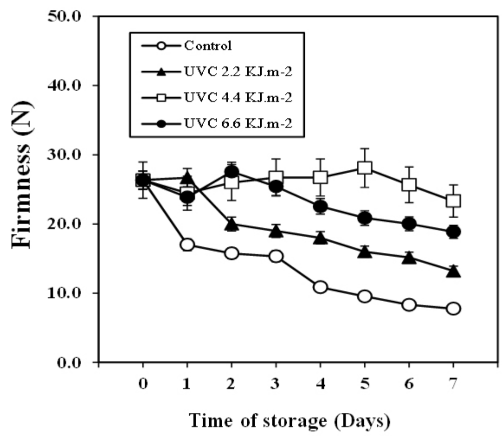

Figure 2. Firmness of fresh-cut baby corn irradiated with 2.2 (▲), 4.4 (□), 6.6 (●) KJ.m^{-2} UV-C and without UV-C (○) stored at 5°C for 7 days. The error bar indicates the least significant difference (LSD) at $P \leq 0.05$.

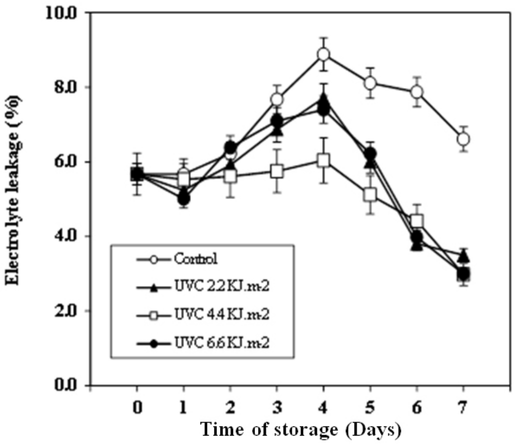

Figure 3. Electrolyte leakage of fresh-cut baby corn irradiated with 2.2 (▲), 4.4 (□), 6.6 (●) KJ.m^{-2} UV-C and without UV-C (◯) stored at 5°C for 7 days. The error bar indicates the least significant difference (LSD) at *P ≤ 0.05*.

Superficial tristimulus color

There were no significantly differences in lightness (L*), greenness (a*) and yellowness (b*) in all treatments, (Figure 4). The L* value of all treatments slightly decreased in day 3 and 5 but no significantly differences during storage. The greenness of fresh-cut baby corn remained constant throughout the storage. Although a slight decrease of b* value was found in control, 2.2 and 4.4 KJ.m^{-2} on day 2 and 5 it remained constant at the end of storage. Therefore, the result suggested that UV-C treatment had no effect on the color of fresh-cut baby corn during storage. Similar researches have been reported that UV-C irradiation had no effect in color changes of red pepper cv. Zafiro (Vicente *et al*., 2005), tomato cv. Red Ruby (Liu *et al*., 2009) and fresh-cut watermelon (Artes-Hernandez *et al*., 2010).

Ascorbic acid content (AsA)

As shown in Figure 5, AsA content of fresh-cut baby corn irradiated with UV-C remained constant during 2 days storage while the AsA content of control significantly decreased thereafter. Although there were no significantly differences in day 3, afterward a marked decrease was observed in control within day 2 and then gradually decreased at the end of storage. Nevertheless, the AsA content of UV-C treated with 4.4 KJm^{-2} remained constant from day 5 to the end of storage, while other treatments continued to decrease till the end of storage. The decrease in AsA content of fresh-cut baby corn after UV-C treatment might be related to the decline activities of ascorbate oxidase and ascorbic acid catabolic enzymes (Barka 2001; Maccarrone *et al*., 1993). A slightly higher AsA content in fresh-cut baby corn irradiated with UV-C were found only 4 days of storage after that no significantly differences in UV-C treatments and control until at the end of storage. Similar results have also been reported that UV-C application inhibited the decreasing of AsA content in fresh-cut water melon (Artes-Hernandez *et al*., 2010) kiwi fruit (Bal and Kok, 2010) and yellow bell pepper (Promyou and Supavanich, 2012).

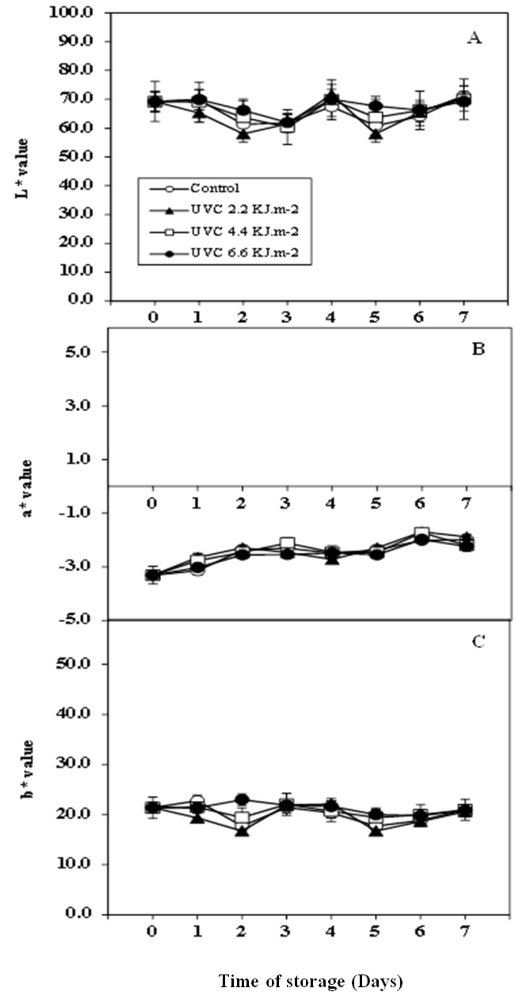

Figure 4. Changes in lightness (L*value) (A), greenness (a*value) (B) and yellowness (b*value) (C) of fresh-cut baby corn irradiated with 2.2 (▲), 4.4 (□), 6.6 (●) KJ.m^{-2} UV-C and without UV-C (◯) stored at 5°C for 7 days. The error bar indicates the least significant difference (LSD) at *P ≤ 0.05*.

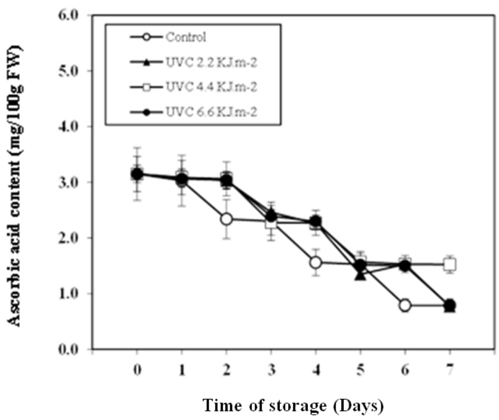

Figure 5. Ascorbic acid contents of fresh-cut baby corn irradiated with 2.2 (▲), 4.4 (□), 6.6 (●) KJ.m^{-2} UV-C and without UV-C (◯) stored at 5°C for 7 days. The error bar indicates the least significant difference (LSD) at *P ≤ 0.05*.

DPPH radical scavenging activity

Antioxidants are a major role in the prevention of oxidative damage in the plant cells. The results showed that DPPH value in all treatments of fresh-cut baby corn continuously decreased during storage. In day 2, fresh-cut baby corn irradiated with 4.4 and 6.6 KJ.m^{-2} UV-C were significantly higher than 2.2 KJ.m^{-2} and control. Afterward a marked decreased in anitioxidant capacity was observed in the control, 2.2, 6.6 KJ.m^{-2} while 4.4KJ.m^{-2} kept significantly higher than others throughout the storage (Figure 6). A dramatically decreased of antioxidant capacity in UV-C irradiated with 6.6 KJm^{-2} might be due to too much stessed for fresh-cut baby corn and possibly resulted in injury. This have been reported by that high dose of UV treatment caused decline in antioxidant capacity in strawberry (Baka *et al*., 1999) and blue berries (Wang *et al*.,2009).

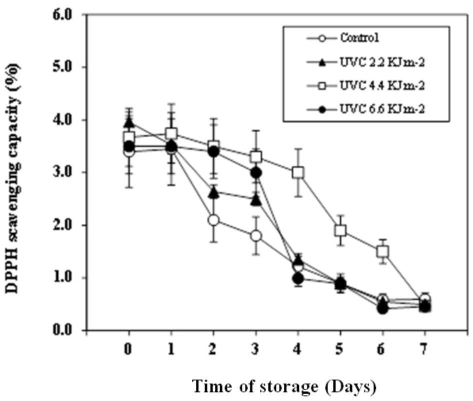

Figure 6. DPPH scavenging capacity of fresh-cut baby corn irradiated with 2.2 (▲), 4.4 (□), 6.6 (●) KJ.m^{-2} UV-C and without UV-C (◯) stored at 5°C for 7 days. The error bar indicates the least significant difference (LSD) at $P \leq 0.05$.

As a result, we suggest that UV-C irradiated with 4.4 KJ.m^{-2} delayed the decreasing of antioxidant capacity of fresh-cut baby corn compared to others treatments during stroage. A decrease in antioxidant capacity have also been addressed by some authors in minimally process citrus fruit during storage (Del caro *et al*., 2004; Piga *et al*., 2002).This could be allied with the relationship between antioxidant (carotenoid) and ascorbic acid, as the ascorbic acid was not affected by the UV-C irradiation (Shen *et al*.,2013).

CONCLUSIONS

In conclusion, UV-C irradiation maintained postharvest qualities of fresh-cut baby corn by remaining firmness and fresh weight when compared with control and there was no effect on colour change of fresh-cut baby corn during storage. UV-C irradiated at dose of 4.4 KJ.m^{-2} showed the positive results among all treatments. Although there were no significant differences in ascorbic acid content, fresh-cut baby corn irradiated with 4.4 KJ.m^{-2} UV-C had a slightly higher than those of other treatments during storage. Moreover, a dose of UV-C at 4.4 KJ.m^{-2} showed the highest efficiency to delay the decreased of antioxidant capacity of fresh-cut baby corn compared to other treatments. It seems that UV-C treatment in 4.4 KJ.m^{-2} is a proper dose to maintain postharvest quality of fresh-cut baby corn during storage.

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