Use of UV-C Treatments to Maintain Quality and Extend the Shelf Life of Green Fresh-cut Bell Pepper (*Capsicum annuum* L.)

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Abstract: The objective of this work was to select a Ultraviolet-C (UV-C) treatment for fresh-cut mature green bell pepper, and to evaluate the effect of its combination with refrigeration on quality maintenance. Bell pepper sticks were treated with 0, 3, 10, or 20 kJ/m^2 UV-C in the outer (O), inner (I), or both sides of the pericarp (I/O) and stored for 8 d at 10 °C. During the first 5 d of storage, all UV-C treatments reduced deterioration as compared to the control. The treatment with 20 kJ/m^2 I/O was the most effective to reduce deterioration, and was used for further evaluations. In a second group of experiments, mature green bell pepper sticks were treated with 20 kJ/m^2 I/O, stored at 5 °C for 7 or 12 d and assessed for physical and chemical analysis, and microbiological quality. UV-C-treated fruit showed lower exudates and shriveling than the control. UV exposure also reduced decay, tissue damage, and electrolyte leakage. After 12 d at 5 °C, UV-C irradiated peppers remained firmer and had higher resistance to deformation than the control. The UV-C treatments also reduced weight loss and pectin solubilization. UV-C exposure decreased the counts of mesophile bacteria and molds, and did not affect acidity or sugars. UV-C-treated fruit stored for 0 or 7 d at 5 °C did not show major differences in antioxidants from the control as measured against DPPH$^{\bullet}$ or ABTS$^{\bullet+}$ radicals. Results suggest that UV-C exposure is useful to maintain quality of refrigerated fresh-cut green pepper.

Keywords: irradiation, postharvest, shelf life, storage, vegetables

Practical Application: Exposure to UV-C radiation before packing and refrigeration could be a useful nonchemical alternative to maintain quality and reduce postharvest losses in the fresh-cut industry.

Introduction

Production of fresh-cut fruits and vegetables has rapidly increased in the last decade, probably associated with changes in habits (Oms-Oliu and others 2010), and has become an appealing alternative for produce commercialization. Fresh-cut products may increase the chances of consuming fresh vegetables, due to their reduced time of preparation, ease of use, and lower generation of wastage, and may also improve presentation and serving size. However, they are usually more perishable than the corresponding unprocessed counterparts (Gonzalez-Aguilar and others 2010).

The main causes of whole bell pepper postharvest deterioration are weight loss, shriveling, bacterial spoilage, and fungal decay. Refrigeration is recommended to maintain quality, but given that peppers are chilling sensitive, storage below 7 °C for long periods is not recommended for whole fruits (Cantwell 2009). Consequently, there is interest in the search for nonchemical treatments able to complement low-temperature storage. The combination of storage at 5 °C and modified atmosphere packaging (MAP) is useful to maintain the quality of pepper stripes (Gonzalez-Aguilar and others 2004). However, the benefits of modified atmospheres for bell pepper are moderate compared to other commodities. Storage at CO_2 partial pressures over 10 kPa or O_2 below 3 kPa and vacuum-packaging can increase electrolyte leakage, ethanol, and acetaldehyde (Gonzalez-Aguilar and others 2004; Conesa and others 2007a,b). Other methods such as mild hot water treatments (55 to 60 °C, 180 s) have shown to maintain visual appearance of fresh-cut peppers and to reduce losses of ascorbic acid and phenolics, but did not prevent, and even favored microorganism growth (Sgroppo and Pereyra 2009).

UV radiation has been used for a long time in medicine and in the food industry for water and surface disinfection (Gil and others 2009), and interest in extending its use for direct application on produce has risen (Artés and others 2009). Treatments with ultraviolet energy offer several advantages to food processors, since they are effective against a wide range of microorganisms, are simple, do not require great investment, do not leave residues, and generally lack legal restrictions (González-Aguilar and others 2010). The optimal UV-C doses are highly dependent on the commodity and ripening stage (Civello and others 2006; Beaulieu 2007). Besides

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the well-known germicidal effect of UV-C radiation, several studies have reported that it can modulate ripening and senescence, maintain quality, and extend the shelf life of fruits and vegetables (Baka and others 1999). UV-C treatments delay the ethylene peak in tomato (Maharaj and others 1999) and reduce chlorophyll degradation and softening in various commodities (Civello and others 2006). It has also been shown that they may increase antioxidant accumulation (Cantos and others 2001; González Aguilar and others 2007) and prevent physiological disorders such as chilling injury (Vicente and others 2005). The aims of our work were to select an appropriate UV-C dose for fresh-cut mature green pepper, and to evaluate the effect on physical, chemical analysis, and microbiological quality under low-temperature storage.

Materials and Methods

Plant material and UV-C treatments

Bell pepper fruits (*Capsicum annuum* L.) cv. Jaen grown in greenhouses in La Plata, Buenos Aires, Argentina, were harvested at the mature green stage and transported to the laboratory. Fruits were washed with chlorinated water (100 mg/L NaClO, pH 7.0) for 3 min, the peduncle and seeds were removed, and the pericarp was cut into 5 cm × 1 cm sticks. The pepper sticks were cooled to 10 °C, and irradiated under a bank of 4 UV-C lamps (UV-C peak emission at 254 nm, TUV G30T8, 30W, Philips, Argentina) at a distance of 30 cm (radiation intensity 15 W/m^2).

Experimental settings

Selection of UV-C dose. Fresh-cut peppers were treated in the outer (O), inner (I), or both sides of the pericarp (I/O) with different UV-C doses as follows:

i) 0 kJ/m^2 (control);
ii) 3.0 kJ/m^2 (I);
iii) 3.0 kJ/m^2 (O);
iv) 3.0 kJ/m^2 (I/O) (1.5 kJ/m^2 on each side);
v) 10 kJ/m^2 (I);
vi) 10 kJ/m^2 (O);
vii) 10 kJ/m^2 (I/O);
viii) 20 kJ/m^2 (I);
ix) 20 kJ/m^2 (O);
x) 20 kJ/m^2 (I/O);

The effective dose was measured with a radiometer (Cole-Palmer Instrument Company, Vernon Hills, Ill., U.S.A.). Plastic trays (12 cm × 10 cm × 4 cm) containing 20 pepper sticks, covered with perforated polyvinyl chloride (PVC) were prepared, stored at 10 °C and evaluated after 5 or 8 d. Ten trays were prepared for each treatment.

The most effective UV-C dose was determined by evaluating fruit appearance with an intensity scale. A scale ranging from 0 to 3 was used: 0 = excellent; 1 = good; 2 = acceptable; 3 = poor. The deterioration index (DI) was calculated for individual pepper sticks (n = 200) as follows:

$$\mathrm{DI} = \frac{\sum (\text{injury level} \times \text{number of fruit sticks in this level})}{\text{total number of fruit sticks in the treatment}}$$

All the samples were evaluated by the same analyst. The trays were coded with a number, and the order for visual inspection was randomly selected

Effect of the selected UV-C dose on quality maintenance. Fresh-cut green bell peppers were UV-C treated as follows:

i) 0 kJ/m^2 or control
ii) 20 kJ/m^2 (I/O)

Pepper sticks were put into plastic trays and covered with perforated PVC. In order to test whether or not the treatments were also beneficial at lower temperatures, the fruit was stored at 5 °C for 12 d. Twelve trays containing 20 pepper sticks were prepared for each treatment and storage time. The whole experiment was repeated twice using fruits from different harvests. All quality measurements were done immediately after sampling or otherwise fruit tissue was frozen in liquid N_2 and stored at −80 °C until analysis.

Decay and dehydration

The percentage of sticks showing shriveling, soft rots, or fungal decay during storage at 5 °C for 12 d was determined. Pepper sticks were individually evaluated (n = 240) for each treatment and storage time.

Weight loss

Weight loss was determined by weighing groups of 5 pepper sticks from different trays during storage. Twelve replicates were evaluated for each treatment and storage time. Results were calculated as percentage of weight loss.

Extractable juice

Five pepper sticks, randomly selected from different trays, were compressed against a weighed filter paper (W_i) by a weight of 2 kg, for 30 s. After that the sticks were removed and the filter paper was weighed (W_f). The extrated juice was calculated by determining the weight gain of the filter paper ($W_f - W_i$), and expressed in mg per kg of fresh weight. Three replicates were done for each treatment and storage time.

Respiration rate

Pepper sticks randomly selected from different trays, weighing approximately 150 g were put into a hermetic flask and held for 20 min at 5 °C. The CO_2 generated was measured with an infrared sensor (Alnor Compu-flow, Model 8650, Alnor, IL, U.S.A.) and used to calculate fruit respiration rate. Results were expressed in mg of CO_2 produced per kg of fresh fruit in an hour. Three replicates were evaluated for each treatment and storage time.

Electrolyte leakage

Measurements were performed as reported by Concellón and others (2005) with modifications. Two pepper sticks were weighed and immerged in plastic tubes with 20 mL water for 5 min. The tissue was removed, and the conductivity of the solution was measured with a conductimeter (Model 510, Oakton, Vernon Hills, Ill., U.S.A.). To evaluate the total amount of electrolytes in the tissue, the pepper sticks were placed back in the plastic tubes and ground with an Omnimixer (Sorvall Inc., Norwalk, Conn., U.S.A.). The suspension was centrifuged at 10000 × g for 10 min and the conductivity of the supernatant was measured as previously described. The linearity of the response was determined with a KCl standard. Results were expressed as the percentage of electrolytes that leaked out of the tissues in 5 min. Three replicates were evaluated for each treatment and storage time.

Texture

The texture of the bell pepper sticks was determined by 2 different assays in a texture analyzer (Model TA.XT2, Stable Micro Systems Texture Technologies, Scarsdale, N.Y., U.S.A.). For bending tests, bell pepper sticks (5 cm × 1 cm and 4 mm thick) were horizontally held (1 cm from each end). A dented probe with rectangular section (10 mm × 1 mm) was used to displace the center of the sticks at a speed of 0.5 mm/s and the force required to bend them 6 mm by applying a normal force on the cuticle side was determined. The resistance to deformation was calculated as the slope of the force/time curve recorded during the tests. Results were expressed in N/s. Puncture tests were performed in the inner side of the pepper sticks by compressing the fruit tissue 2 mm in the equatorial zone, at a rate of 0.5 mm/s with a 3-mm-dia probe and recording the maximum force developed during the test. Results were expressed in Newton (N). For both assays, five pepper sticks were randomly selected from each tray and evaluated for each treatment and storage time ($n = 60$).

Color

Surface color was measured with a colorimeter (Model CR-400, Minolta, Osaka, Japan) to obtain L*, a*, and b* values. The hue angle was calculated as 180 tg^{-1} b*/a*. Thirty measurements were done, on the outer side of the sticks, for each treatment and storage time.

Sugars and acidity

For sugar determinations, frozen tissue was processed in a mill (Model A11, IKA Works Inc., Sao Paulo, Brazil), and 1 g of the resulting powder was extracted with 5 mL ethanol. The mixture was vortexed, centrifuged at 17000 × *g* for 10 min at 4 °C, and the supernatant was brought to 100 mL with water. Sugars were measured with the anthrone reagent (Yemm and Willis 1954). Aliquots of the ethanolic extracts were brought to 500 μL with water. One mL of 2 g/L anthrone, prepared in 98% (w/w) H_2SO_4, was added to the test tubes in a water-ice bath. The samples were heated at 100 °C for 10 min, cooled in water, and the absorbance at 620 nm was measured in a spectrophotometer (Model UV Mini-1240, Beckman, Calif., U.S.A.). Results were expressed as g of glucose equivalents per kg of fresh weight. Four replicates were analyzed for each treatment and storage time.

For acidity measurements, fruit pulp was frozen in liquid nitrogen, ground in a mill, and 10 g of the resulting powder was added to 100 mL water. Samples were titrated with 0.1 mol/L NaOH to pH 8.2 (AOAC 1980). Four replicates were analyzed for each treatment and storage time. Results were expressed as $[H^+]$ moles/L of fresh weight.

Antioxidant capacity against DPPH$^\bullet$ and ABTS$^{\bullet+}$ radicals

Frozen fruit tissue was ground in a mill and approximately 1 g of the powder was vortexed for 1 min in 5 mL cold ethanol and centrifuged at 15000 × *g* for 10 min at 4 °C. The supernatant was used for antioxidant determinations. The DPPH$^\bullet$ assay was done according to Brand-Williams and others (1995) with minor modifications. Different aliquots (0 to 50 μL) of fruit ethanolic extracts were pippetted and taken to a final volume of 80 μL with water. After that, 500 μL of a 60 mg/L solution of the radical DPPH$^\bullet$ in ethanol was added. Samples were vortexed and held at 20 °C for 90 min in darkness. The absorbance at 515 nm was measured and the amount of extract required to consume 50% of the initial DPPH$^\bullet$ was calculated (EC_{50}). To avoid this inverse relationship between antioxidant content and EC_{50}, results were expressed as $1/EC_{50}$. Three replicates were done for each treatment and storage time.

The ABTS$^{\bullet+}$ assay was performed as previously described (Arnao and others 2001). Ten μL of ethanolic fruit extracts was added to 1 mL of ABTS$^{\bullet+}$ working solution, vortexed, incubated for 7 min and the absorbance at 734 nm was measured. Results were expressed as mg of Trolox equivalents per kg of fresh tissue. Three replicates were done for each treatment and storage time.

Molds and bacteria

Approximately 50 g of pepper sticks were put into two sterilized beakers containing 225 mL 0.1% w/v peptone. Samples were

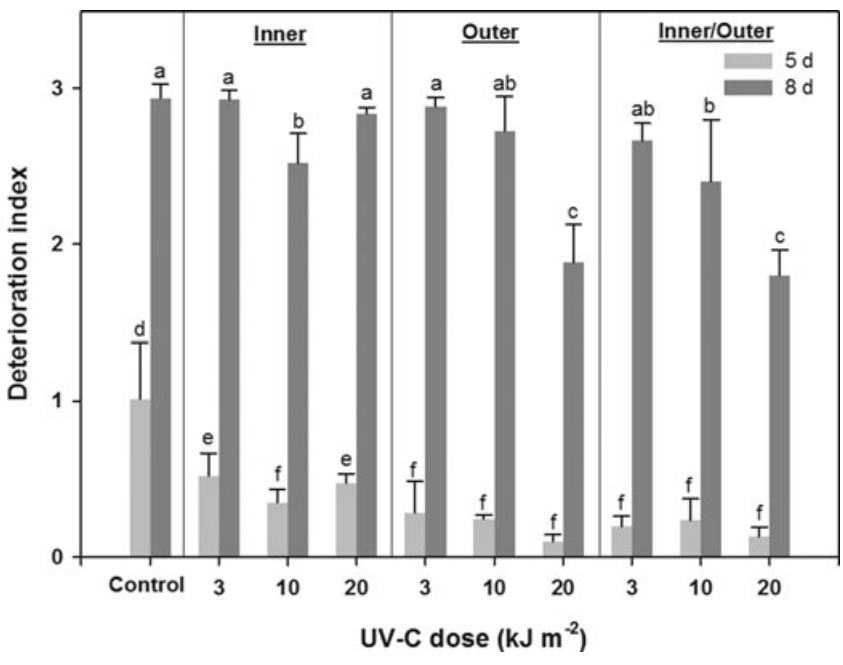


Figure 1–Deterioration index in mature green bell pepper sticks treated with 0, 3, 10, or 20 kJ/m² of UV-C radiation in the inner, outer, or both sides of the pericarp, and subsequently stored at 10 °C for 5 or 8 d. The vertical bars represent the standard deviations, and values followed by different letters are significantly different based on a Fisher test, at a level of significance of $P < 0.05$.

stirred for 15 min and from each beaker a series of decimal dilutions was prepared. One mL samples from different dilutions (10^{-2} to 10^{-5}) were poured in triplicate into the appropriate culture medium (Petrifilm^{TM} plates 6400 and 6407, 3M, St. Paul, Minn., U.S.A.). Plates were incubated at 30 °C for aerobic mesophile bacteria and at 20 °C for molds. Results were expressed as log of colony forming units (CFUs) per kg of fresh fruit.

Water-soluble pectin (WSP)

Pepper sticks weighing approximately 7 g were ground in 20 mL water with an Omnimixer. The suspension was vortexed and then centrifuged at 10000 × *g* for 10 min at 4 °C. The supernatant was precipitated by adding 3 volumes of cold ethanol. Samples were then centrifuged at 17000 × *g* for 10 min at 4 °C and the pellet was saved and dissolved in HAc/NaAc buffer (pH 5.0, 50 mM) to obtain the WSP. Three replicates were evaluated for each treatment and storage time. The concentration of uronic acids was determined as previously reported (Blumenkrantz and Asboe-Hansen 1973). Results were expressed as g of galacturonic acid per kg of fresh fruit.

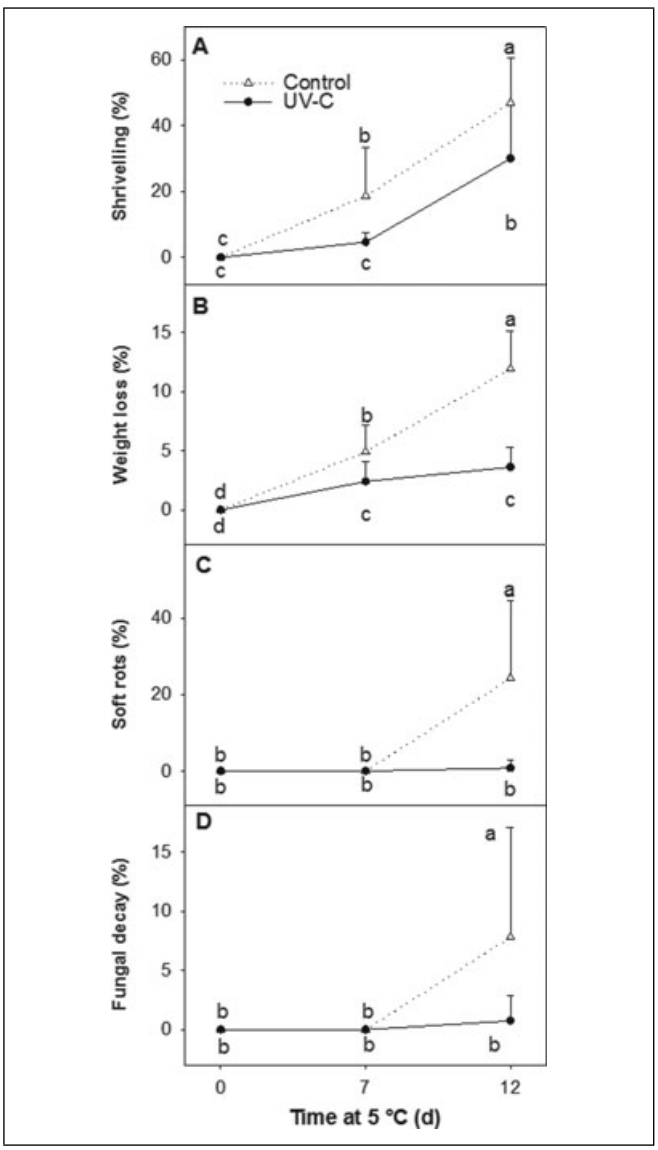


Figure 2–(A) Shriveling, (B) weight loss, (C) soft rots, and (D) fungal decay in control and UV-C-treated (20 kJ/m^2, I/O) mature green pepper sticks during storage at 5 °C for 0, 7, or 12 d. The vertical bars represent the standard deviations. Values followed by different letters are significantly different based on a Fisher test, at a level of significance of $P < 0.05$.

Statistical analysis

Experiments were performed according to a factorial design with time at 5 °C and treatments as factors. Data was analyzed by ANOVA. The main effects and the interactions were analyzed and the means were compared by the Fisher test at a significance level of 0.05.

Results and Discussion

Treatment selection

After 5 d at 10 °C all UV-C-treated pepper sticks showed lower deterioration than the control (Figure 1). At the end of the storage period, nontreated fruit had clear signs of spoilage, such as tissue maceration, softening, dehydration, and juice leakage. It is worth noting that, while treatments with a dose of 20 kJ/m^2 in the outer side or in both surfaces were the most effective in terms of quality maintenance, exposure to the same dose in the inner surface alone did not cause any improvement. This might have resulted from some tissue damage caused by excessive UV-radiation in the latter (Piga and others 1997; Allende and others 2006). High radiation doses can result oxidative stress and cellular damage (Civello and others 2006). The lack of injuries in the treatment with 20 kJ/m^2 I/O suggests that the effective dose received in this case by the inner side (10 kJ/m^2), was below the threshold for damage. In contrast, in the treatment 20 kJ/m^2 I, all the radiation was received in the inner side of the pericarp, and tissue damage could have occurred. The lack of damage in the fruit exposed to the highest dose only in the outer side, suggests that this surface has higher resistance to UV-C radiation. This could be related to the presence of phenolics in the cuticle, which have been shown to protect against UV radiation (Solovchenko and Merzlyak 2003). UV-C treatments have been useful to maintain the quality of several fruits and vegetables (Shama and Alderson 2005). The appropriate doses are highly variable depending on the commodity and ripening stage (Civello and others 2006). In red peppers, UV-C exposure (7 kJ/m^2) reduced decay and chilling injury (Vicente and others 2005), but no previous studies have evaluated the influence of these treatments on green peppers either whole or processed. Our results show that brief UV-C exposure might be useful to prevent deterioration. The treatment with a dose of 20 kJ/m^2 in both sides of the pericarp was selected for further evaluations.

Combination of UV-C Treatments and Refrigerated Storage

Weight loss, dehydration, and decay. Weight loss increased during storage in both control and treated fruit. After 7 d of storage, 20% of the control, and only 3% of UV-C-treated sticks showed dehydrated borders (Figure 2A). Weight loss was also lower in the irradiated samples. After 12 d at 5 °C, the weight loss was 11.8% in the control and 3.6% in UV-C-treated fruit (Figure 2B).

The recommended temperatures for storing whole pepper are 7 to 10 °C because they are chilling sensitive (Cantwell 2009). However, fresh-cut products usually are less sensitive than the intact crops to chilling temperature (Watada and others 1996). Kang

and Lee (1997) observed that the shelf life of sliced peppers at 5 °C was determined by chilling injury. In contrast, González-Aguilar and others (2004) reported that the main factor governing fruit deterioration was microbial growth, and concluded that storage at a temperature of 5 °C is more beneficial. In this work, we did not observe symptoms of chilling injury during the 12 d storage at 5 °C. The shelf life of the product was limited mainly by shriveling, soft rot, fungal decay, and softening. No soft rots were detected after 7 d at 5 °C in any of the treatments, but after 12 d of storage, the incidence of soft rots increased rapidly in the control (Figure 2C).

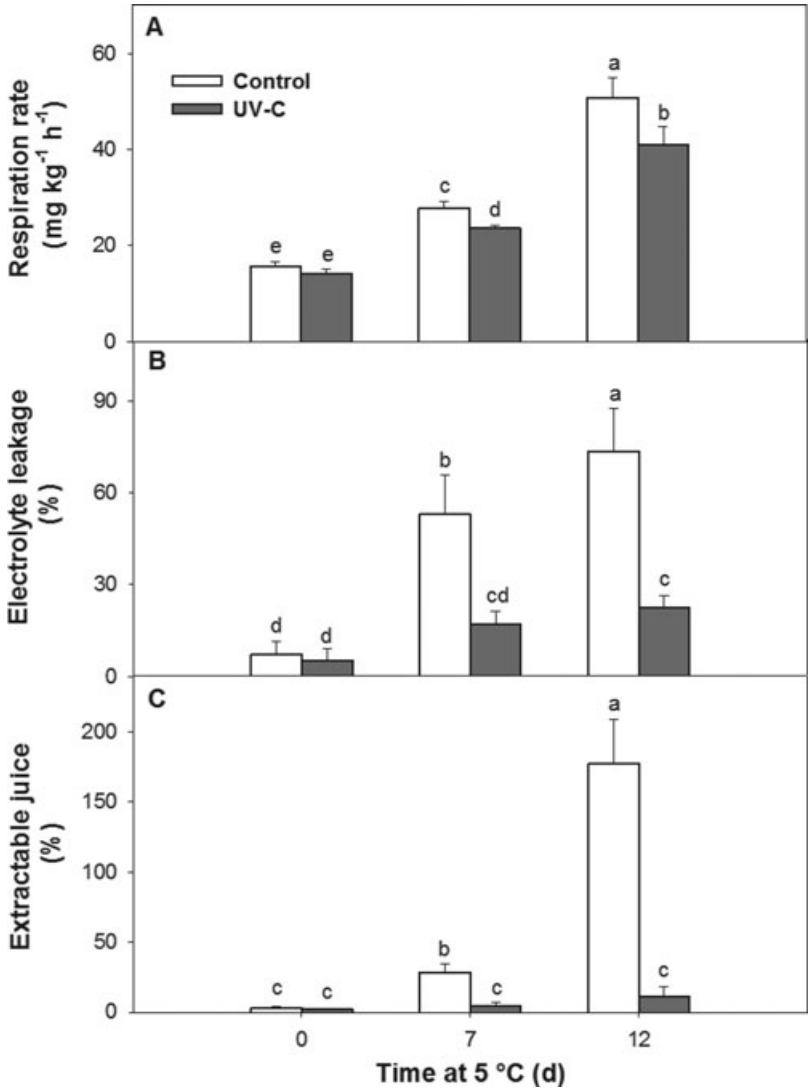
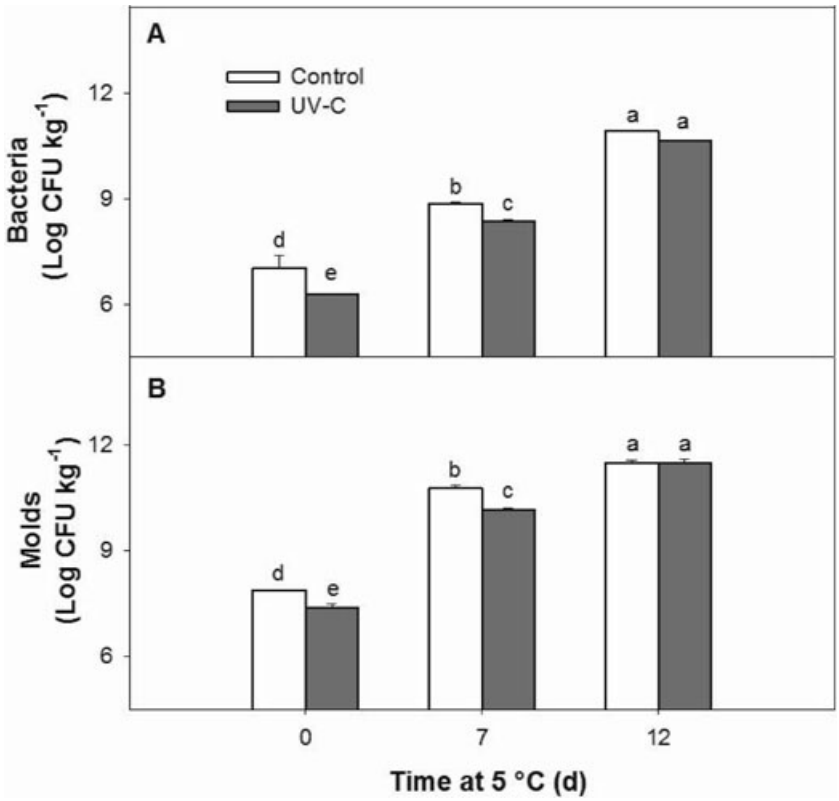


Figure 3–(A) Respiration rate, (B) electrolyte leakage, and (C) exudates in control and UV-C-treated (20 kJ/m^2, I/O) mature green pepper sticks during storage at 5 °C for 0, 7, or 12 d. The vertical bars represent the standard deviations. Values followed by different letters are significantly different based on a Fisher test, at a level of significance of $P < 0.05$.

Table 1–Surface color (hue), sugars, acidity, antioxidant capacity measured against the radicals DPPH$^\bullet$ or ABTS$^{\bullet+}$, and water-soluble pectins (WSP) in control and UV-C-treated (20 kJ/m^2, I/O) green pepper sticks during storage at 5 °C for 7 or 12 d. The standard deviations are shown.[a]

		Time at 5 °C (d)		
		0	7	12
Hue	Control	124.4 ± 1.5^a	124.6 ± 1.4^a	124.0 ± 1.8^a
	UV-C	124.5 ± 1.9^a	124.8 ± 1.8^a	123.8 ± 1.8^a
Sugars	Control	30 ± 0.6^a	32 ± 0.3^a	29 ± 3.1^a
(g/kg)	UV-C	33 ± 0.4^a	31 ± 1.8^a	28 ± 3.6^a
Acidity	Control	0.014 ± 0.001^a	0.012 ± 0.002^{ab}	0.011 ± 0.001^b
([H$^+$]mol/L)	UV-C	0.011 ± 0.001^b	0.011 ± 0.001^b	0.012 ± 0.001^{ab}
Antioxidants with DPPH$^\bullet$	Control	1.80 ± 0.23^{ab}	1.29 ± 0.04^c	2.15 ± 0.25^a
(kg^{-1}) × 10^{-2}	UV-C	1.83 ± 0.09^{ab}	1.72 ± 0.13^b	1.45 ± 0.18^{bc}
Antioxidants with ABTS$^{\bullet+}$	Control	536 ± 24^{ab}	468 ± 26^b	628 ± 98^a
(mg/kg)	UV-C	544 ± 10^{ab}	502 ± 27^b	475 ± 36^b
WSP	Control	0.374 ± 0.07^c	1.269 ± 0.06^b	1.792 ± 0.29^a
(g/kg)	UV-C	0.396 ± 0.13^c	0.429 ± 0.25^c	1.126 ± 0.25^b

[a]Values followed by different letters are significantly different based on a Fisher test at a level of significance of $P < 0.05$.



Figuer 4–Counts of (A) mesophylic bacteria and (B) molds in control and UV-C-treated (20 kJ/m^2, I/O) mature green pepper sticks during storage at 5 °C for 0, 7, or 12 d. The vertical bars represent the standard deviations. Values followed by different letters are significantly different based on a Fisher test, at a level of significance of $P <$ 0.05.

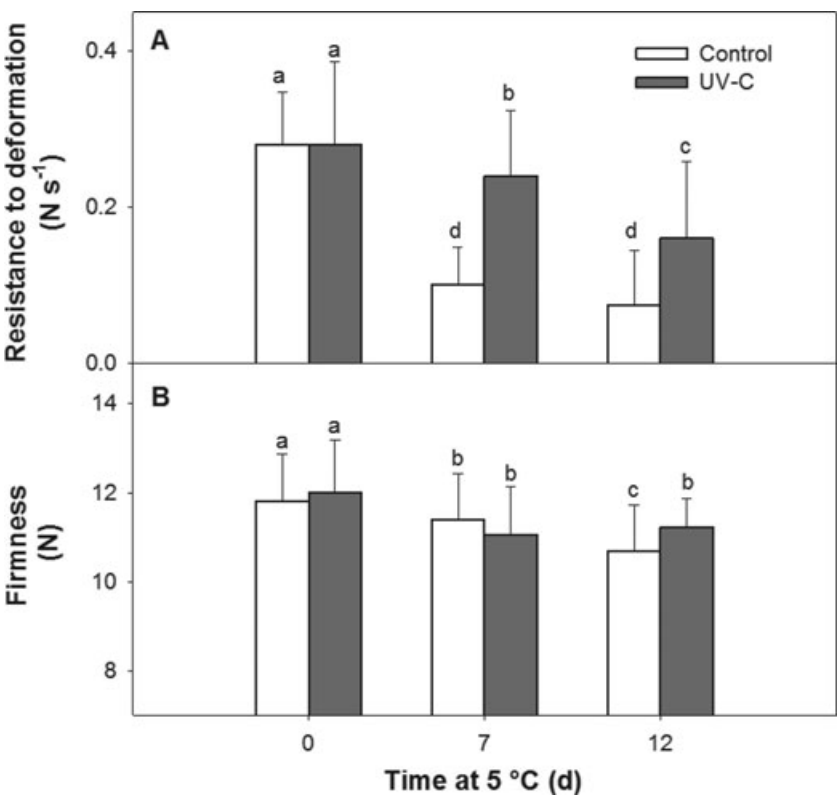


Figure 5–(A) Resistance to deformation and (B) firmness in control and UV-C-treated (20 kJ/m^2, I/O) mature green pepper sticks during storage at 5 °C for 0, 7, or 12 d. The vertical bars represent the standard deviations. Values followed by different letters are significantly different based on a Fisher test, at a level of significance of $P <$ 0.05.

Fungal decay was less prevalent than soft rots, and UV-C treatments also reduced its incidence significantly (Figure 2D).

Fruit respiration, extractable juice, and electrolyte leakage

Before storage no differences in respiration rate were found between control and UV-C-treated sticks (Figure 3A). After 7 d at 5 °C, the controls showed higher CO_2 production than the irradiated peppers. At the end of the storage period, nontreated peppers also showed a respiration rate 20% higher than that of UV-C-treated fruit (Figure 3A). Similar results were reported by Lamikanra and others (2005) in fresh-cut melon. Given that peppers are nonclimacteric fruit, the rise in CO_2 production seems more likely related to damage, as the fruit is approaching senescence. In this scenario, the lower respiration of UV-C-treated peppers could be interpreted as a delay in tissue disruption. Electrolyte leakage and juice exudates were also higher in control fruit after 7 or 12 d of storage at 5 °C supporting this (Figure 3B and 3C).

Color, sugars, acidity, and antioxidants

No changes in surface color were found during storage (Table 1). Sugar content was around 3% and no differences were found between control and treated fruit (Table 1). The UV-C treatments caused a slight reduction in fruit acidity. However, at the end of the storage period control and treated fruit reached similar values. This is coincident with previous works in whole red peppers, showing that sugars and acids were not markedly affected by UV-C treatments (Vicente and others 2005). Some studies have shown that physical stresses could be useful to reduce losses or even induce the accumulation of antioxidants (Cantos and others 2001; Cisneros-Zevallos 2003). In the work presented here, the antioxidant capacity of UV-C-treated fruit did not change during storage, but showed a slight increase in the control. The main hydrophilic antioxidant in pepper is ascorbic acid, and its content greatly increases during ripening (Kumar and Subba-Tatta 2009). It has been reported that UV-C treatments can delay ripening, by affecting the expression of genes and the activity of enzymes required for this process (Civello and others 2006). The lack of variation in antioxidants of UV-C-treated fruit during storage might be associated with arrested biosynthesis of ascorbic acid, but this would require a more detailed evaluation. After 12 d of storage, the antioxidants were lower in treated fruit. However, at that point, marked deterioration was already evident in the controls, making this difference of little technological interest, if any.

Microbiological counts

Immediately after UV-C exposure, reductions in fungal and bacterial counts were found (Figure 4A and 4B). Subsequently, the microbial populations increased in both control and treated peppers, but irradiated fruit still had lower counts after 7 d at 5 °C. The reduction of postharvest diseases by UV-C treatments has been associated in some cases with the germicidal effect of the radiation treatment (Civello and others 2006). At the end of the storage period, the log CFU/kg for molds and mesophilic bacteria were similar in control and UV-C-treated peppers, despite the great difference of decay Figure 4A and 4B). This suggests that at least part of the decrease of decay found in treated peppers is not related to the germicidal effect of UV-C radiation, but to an indirect mechanism mediated by the fruit. Applying a potentially harmful agent such as UV-C radiation, at appropriate intensities and doses, has been reported to induce some beneficial physiological responses (Shama and Alderson 2005). Accumulation of the phytoalexins scopoletin and scoparone has been found in UV-C-treated citrus fruit (D'Hallewin and others 1999). Increases in the activity of enzymes associated with the metabolism of phenolic compounds, such as phenylalanine ammonia-lyase (PAL) and polyphenol oxidase (POD), may also contribute to reduce the susceptibility against pathogens in irradiated fruits (Pombo and others 2011). The induction of genes coding for β-1,3-glucanase y chitinase by UV-C has also been reported (El Ghaouth and others 2003).

Texture and WSP

Fruit flex resistance decreased in both control and treated peppers during storage, but UV-C exposure significantly delayed the loss of rigidity. After 7 and 12 d at 5 °C, the irradiated fruits showed higher flex resistance than the controls (Figure 5A). UV-C-treated fruit were also firmer than the control after 12 d of storage (Figure 5B). As fruit was held at 5 °C, WSP increased rapidly in the control, whereas in UV-C-treated tissue pectin solubilization was delayed (Table 1). Maintenance of firmness in UV-C-treated fruits has been associated with reduced activity of cell wall degrading enzymes (Maharaj and others 1999). The delay in ripening caused by UV-C treatments could also, without any direct activation of defensive responses, maintain the fruit in a maturity stage with lower susceptibility against postharvest pathogens. The delay in softening and the higher resistance to deformation, together with the lower solubilization of pectin, juice extractability, and electrolyte leakage in UV-C-exposed fruit, suggest a better maintenance of tissue integrity. This would reduce nutrient availability and keep tougher barriers to pathogens.

Conclusion

Results show that UV-C treatments (20 kJ/m^2 I/O) reduce deterioration and extend the postharvest life of fresh-cut mature green pepper. The treatments did not cause major changes in sugars, acids, or antioxidants, minimized desiccation, and reduced pectin solubilization, softening, and decay and could be considered as an effective complementary technology to cold storage. Future studies might be useful to evaluate the benefits of the photochemical treatment under MAP.

Acknowledgments

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