Effect of Trichome Removal and UV-C on Populations of *E. coli* O157:H7 and Quality of Peach Fruit

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Abstract. **The objective of the study was to evaluate the effect of trichome (fuzz) removal on the efficacy of ultraviolet-C in inactivating *Escherichia coli* O157:H7 on peach fruit, and quality of peach [*Prunus persica* (L.) Batsch, cv. PF25] fruit as affected by fuzz removal and ultraviolet-C. Peach (cultivar PF25) fruit, with and without fuzz removal, were inoculated with a five-strain cocktail of *E. coli* O157:H7 and treated with ultraviolet-C at doses of 0, 221, and 442 mJ/cm^2. Fuzz was rubbed off using damped cloths. Survival of *E. coli* populations was determined at days 1, 4, and 7 at 20 °C. To study fruit quality, noninoculated fruit with and without fuzz removal were treated with ultraviolet-C at the same doses. Results demonstrated that ultraviolet-C at 442 mJ/cm^2 reduced the population of *E. coli* by 1.2 to 1.4 log colony-forming units (CFU)/fruit on peach with fuzz, and 0.9 to 1.1 log CFU/fruit on fruit without fuzz 1 day after ultraviolet-C treatment. However, *E. coli* populations of all samples were similar with additional storage time, resulting in no significant difference among the treatments after 7 days of storage at 20 °C. Ultraviolet-C at doses up to 442 mJ/cm^2 did not have any significant effect on the surface color of peaches during 7 days of storage, although fruit with fuzz removal increased L*, hue, and chroma values. In addition, fuzz removal promoted the loss of firmness during storage. Furthermore, ultraviolet-C at 442 mJ/cm^2 increased antioxidant capacity of peach skin with fuzz. Overall, our results suggested that fuzz removal had marginal effects on the efficacy of ultraviolet-C, and ultraviolet-C did not negatively affect the quality of peaches.**

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Fresh and fresh-cut produce are often washed with chemical sanitizers such as chlorine to minimize cross contamination and improve microbial safety. However, soft stone fruits, such as tree-ripened peaches, cannot tolerate washes due to their advanced ripeness and tenderness. Therefore, tree-ripened fruits are often packed under dry conditions (Crisosto and Valero, 2008; Crisosto et al., 1995). Although the chances of tree fruits being contaminated with human pathogens is low, there have been reports of foodborne disease outbreaks and recalls associated with the fruit (Bennett et al., 2018; Jackson et al., 2015). Therefore, producers and packers of tree-ripe stone fruits are in need of nonaqueous measures to sanitize fruit.

Ultraviolet-C radiation at short wavelengths (100–280 nm) has germicidal effects, resulting in damage to DNA (Sinha and Häder, 2002). The U.S. Food and Drug Administration (FDA) has approved the use of ultraviolet light for disinfection of liquid (water and juices), and decontamination of food preparation surfaces and food containers (Koutchma et al., 2009; U.S. FDA, 2000). Earlier studies have demonstrated that ultraviolet-C is able to reduce pathogens on the surface of various fruits (Bialka and Demirci, 2007; Yaun et al., 2004). However, there are several challenges for the commercial application of ultraviolet technology (Fan et al., 2017; Yan et al., 2014). First, some fruit may develop discoloration after ultraviolet-C treatment, particularly during post-ultraviolet storage. Second, bacterial pathogens injured by exposure to ultraviolet light may later be repaired by dark and/or by enzymatic mechanisms, leading to potential cell survival and re-growth (Fernández Zenoff et al., 2006). In addition, high doses of ultraviolet-C may potentially damage and weaken fruit tissues, which could increase the growth of surviving pathogens. For these reasons, possible re-growth of human pathogens and impact on fruit quality must be evaluated following ultraviolet treatments. In our previous study (Yun et al., 2013), we found that, even though ultraviolet-C at 442 mJ/cm^2 produced limited reductions (1.2–1.9 log CFU/fruit) of *E. coli* and *Salmonella* on inoculated apricot (*Prunus armeniaca* L.) fruit, the differences in bacterial population between treated and control fruits increased during storage. It is unclear whether the rapid decline in inoculated bacterial populations would occur on other stone fruits, such as peaches.

In addition, many types of fruit, such as peaches, have a layer of nonsecreting trichomes (fuzz). Commercially, peaches are often wet-brushed to remove the trichomes (fuzz) for consumer appeal (Taylor and Rushing, 2012). The fuzz, which is single-cell extensions of epidermal cells, may contribute to protective ultraviolet-shielding of bacteria during treatment (Crisosto and Valero, 2008; Kays and Paull, 2004).

The objective of the present study was to study the changes in *E. coli* O157:H7 populations and fruit quality following ultraviolet-C exposure, as affected by the removal of fuzz during post-ultraviolet-C storage of peaches.

Materials and Methods

Source of fruit and other materials. Peach [*P. persica* (L.) Batsch, cv. PF25] was harvested from a Central Pennsylvania orchard at commercial maturity (light green ground color). PF25 is a freestone, yellow peach. Rifampicin was purchased from Sigma-Aldrich Chemical Co. (St. Louis, MO). Tryptic soy broth (TSB), tryptic soy agar (TSA), Sorbitol MacConkey Agar (SMAC), and peptone water were from Difco (Becton Dickinson, Sparks, MD).

Removal of fuzz. To study the effect of fuzz removal on peaches, each piece of fruit was wiped (rubbed) gently with water-dampened microfiber cloths (12 × 12 inches, MicroFiber Cleaning Cloths; A&H Branded

Products LLC, Rochester Hills, MI) as suggested by Dr. T. Suslow of University of California (personal communication).

E. coli *O157:H7 study.* Five strains of *E. coli* O157:H7, including RM 6535 (lettuce), RM 7386 (Romaine lettuce), O6FOO475 (spinach outbreak), RM 1484 (apple juice), and Sakai (sprouts) were used to inoculate peach fruit with or without fuzz removal as described earlier (Yun et al., 2013). All strains were from the ARS Eastern Regional Research Center collection. The *E. coli* strains were made resistant to 100 µg/mL rifampicin by successive transfers of the bacteria in TSB with increasing concentrations of the antibiotic. The strains of *E. coli* O157:H7 were grown in 10 mL of TSB at 37 °C with 100 µg/mL rifampicin for 18 h. After centrifuging (2182 g_n, 10 min), the pellets were suspended with 0.1% peptone water and combined to obtain a five-strain cocktail of *E. coli* O157:H7. Peaches (with or without fuzz) were spot-inoculated onto the cheek area of the fruit with 100-µL aliquots (≈6 droplets) of the *E. coli* O157:H7 cocktail using a micropipette. The area (≈1 cm^2) of fruit with the inocula was marked with an indelible ink pen for easy recovery of the pathogens following treatments. Fruit were dried for 2 to 3 h in a laminar flow biohood. There were three pieces of fruit for each treatment, and experiments were repeated four times.

The inoculated fruit were treated with ultraviolet-C in a custom-built ultraviolet-C chamber for 0, 30, and 60 s at an intensity of ≈7.4 mW/cm^2 with inoculated skin areas facing the ultraviolet-C light, resulting in ultraviolet doses of 0, 221, and 442 mJ/cm^2, respectively. An ultraviolet treatment chamber containing two ultraviolet-C fixtures was used to provide the required irradiation wavelength (254 nm). Each fixture had one 0.61-m-long 55W ultraviolet-C emitting bulb (SaniLIGHTTM; Atlantic Ultraviolet, White Plains, NY). A UVX Radiometer (model UVX; UVP Inc., Upland, CA) was used to measure the intensity of ultraviolet light from the lamp. After ultraviolet treatment, fruit were stored at 20 °C for 7 d, and *E. coli* O157:H7 was recovered from fruit on days 1, 4, and 7. To recover bacteria, the fruit skin with the inoculum was excised using a pair of surface-sterilized scissors, combined, and placed into 80-mL stomacher bags. Twenty milliliters of buffered peptone water (0.1%) (pH 7.2) was added to each bag and homogenized using a stomacher circulator (Panoramic; Neutec Group Inc., Farmingdale, NY) for 1.5 min. The recovered bacteria, after proper serial dilutions, were plated onto two TSA plates containing 100 µg/mL rifampicin (TSAR) and two SMAC plates for *E. coli* O157:H7. Colonies on plates were counted after 24 h of incubation at 37 °C.

Effect of ultraviolet-C treatment on peach quality. Peach fruit (both with and without fuzz, but not inoculated with *E. coli*) were treated similarly with ultraviolet-C as described earlier for the *E. coli* study. Only shaded sides of peaches were exposed to ultraviolet-C, because our preliminary study suggested that the shaded sides were more sensitive to skin damage. The shade side was distinguished from the sun side, as it had less redness. After treatment with 0, 221, and 442 mJ/cm^2 ultraviolet-C as described earlier, fruit were stored at 20 °C for 7 d. Color, firmness, and oxygen radical reducing capacity (ORAC) were measured on 0, 1, 4, and 7 d after treatment. There were six fruits for each replicate and four replicates (a total of 24 fruit) for each sampling day per type of fruit per ultraviolet dose.

Quality analysis. Texture was measured on the shaded side of each nonpeeled fruit with a texture analyzer (Model TA-XT2i; Texture Technologies Corp., Scarsdale, NY) equipped with a cylindrical plunger (11 mm in diameter). The plunger traveled to the depth of 10 mm at a speed of 10 mm/s. The maximum force required to penetrate the fruit was used to indicate firmness. Color (L*, a*, and b*) was measured on the shaded side of each fruit with Hunter UltraScan VIS colorimeter (Hunter Associates Laboratory, Reston, VA) using a 1.3-cm measuring aperture. D65/10° was used as the illuminant-viewing geometry. Hue and chroma were calculated from a* and b* values (McGuire, 1992).

ORAC assay. After ultraviolet-C treatment, shaded side of skin was removed with a cork borer (diameter: 22 mm). The flesh was removed by trimming with a razor blade, resulting in ≈1-mm-thick discs. The discs were weighed (2.2 ± 0.6 g) and stored at –80 °C before extraction. There were four replicates of samples, with each sample consisting of three discs from three fruits forming a composite sample. To extract antioxidants, the discs were homogenized in 20 mL of 20% ethanol using a homogenizer (Virtishear; Virtis, Gardiner, NY) at a speed setting of 70 for 1 min. The homogenate was then filtered through a four-layer cheesecloth and then centrifuged at 17,217 rpm for 10 min using a Sorvall Lynx 4000 centrifuge (Thermo Scientific, Grand Island, NY). The supernatant was used for ORAC assay after proper dilution. For the ORAC assay, a BioTek Synergy HT Multimode Microplate Reader (Winooski, VT) was used. After 25-µL samples were loaded into the wells of a 96-well microplate, the reaction mode of the instrument automatically pipetted and transferred fluorescein (150 µL, 40 nM) into the wells. The plate was incubated at 37 °C for 30 min before 2,2′-azobis(2-amidinopropane) dihydrochloride (AAPH) (25 µL, 153 mM) was injected into each well to start the reaction. Readings were taken at an emission wavelength of 528 nm every minute for a duration of 30 min. The final results were calculated by comparison with Trolox standard curve using the differences of areas under the decay curves between the blank and a sample, and antioxidant concentrations were expressed as micromole Trolox equivalents (TE) per gram or per cm^2 skin (µmol TE/g or µmol TE/cm^2).

Scanning electron microscopy (SEM). Peaches with and without fuzz removal were inoculated with a cocktail of five strains of *E. coli* O157:H7, and then treated with ultraviolet-C as described earlier. After ultraviolet-C treatment, fruit skins (≈1 cm^2 in area and 1 mm in thickness for surface and 0.5 cm^2 in area and 5 mm in thickness for cross section) were removed and immersed in ≈20 mL of a 2.5% glutaraldehyde–0.1 M imidazole buffer solution (pH 7.2). The skin samples were washed in 0.1 M imidazole, and dehydrated by immersing in 20 mL

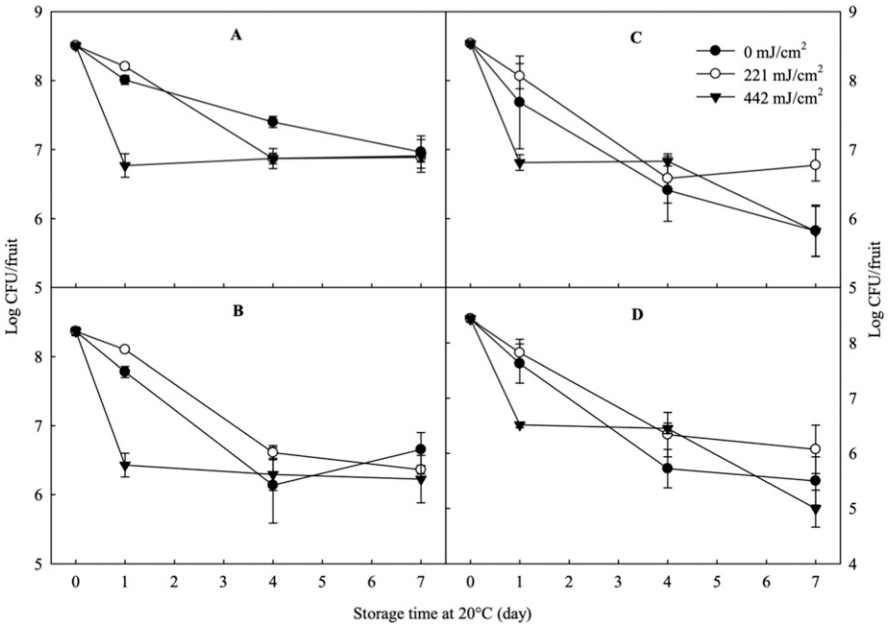

Fig. 1. Changes in population of *E. coli* O157:H7 on peach skin with natural fuzz (**A**, **B**) and with fuzz removed (**C**, **D**) during post–ultraviolet-C storage at 20 °C. Peaches were inoculated with a cocktail of five strains of *E. coli* O157:H7 and treated with ultraviolet-C at doses of 0, 221, and 442 mJ/cm^2. *E. coli* was enumerated on TSAR (**A**, **C**) and SMAC (**B**, **D**), respectively. Vertical bars represent SDS (n = 4).

ethanol solutions (50%, 80%, and absolute ethanol in consequent order). The samples were then fractured in liquid nitrogen, sputter-coated with gold using a Scancoat Six Sputter Coater (BOC Edwards, Wilmington, MA) and digitally imaged using a model Quanta 200 FEG scanning electron microscope (FEI Co., Inc., Hillsboro, OR) operated in the high vacuum and secondary electron imaging mode.

Experimental design and statistical analysis. The experiments were conducted using a factorial design accounting for ultraviolet dose, storage duration, and fuzz removal. Data were subjected to General Linear Model procedures using SAS version 9.4 (SAS Institute, Raleigh, NC). The effects of ultraviolet dose, storage duration, and fuzz removal were analyzed using the Bonferroni pairwise means comparisons. The analysis of variance (ANOVA) model was a "3-way ANOVA" as indicated by the number of factors (ultraviolet dose, storage duration, and fuzz removal).

Results and Discussion

Reduction of E. coli *O157:H7 populations on peaches.* When *E. coli* O157:H7 populations were assessed 1 d after ultraviolet-C treatment, ultraviolet-C treatment at the low dose (221 mJ/cm^2) did not affect the population of *E. coli* O157:H7 regardless of fuzz removal (Fig. 1). At 442 mJ/cm^2, ultraviolet-C significantly ($P < 0.05$) reduced *E. coli* populations on peaches with fuzz by 1.2 and 1.4 log CFU/fruit as assessed on TSA and SMAC, respectively. On fuzz-removed peaches, the reductions were 0.9 and 1.1 log CFU/fruit on TSA and SMAC, respectively. The differences in *E. coli* populations between the nontreated and ultraviolet-C-treated (442 mJ/cm^2) samples become smaller with increasing storage time. After 7 d of storage, there was no significant difference in populations of *E. coli* among the three treatments on fruit either with or without trichomes removed. Even though statistical analysis indicated that fuzz removal significantly reduced the efficacy of ultraviolet-C in inactivating *E. coli* O157:H7, the differences were minimal (only ≈0.3 logs). The removal of fuzz may create microwounds, bacterial niches, and prevent ultraviolet-C from reaching the protected sites, reducing *E. coli* cell exposure to ultraviolet-C. Our earlier results (Yun et al., 2013) showed that ultraviolet-C treatment at a dose range of 74 to 442 mJ/cm^2 achieved 1.2 to 1.9 log CFU/fruit reduction of *E. coli* on apricot surfaces. Higher ultraviolet-C doses achieved very limited additional increase in *E. coli* inactivation.

Our earlier results on apricots showed that the difference in *E. coli* populations between samples treated with ultraviolet-C at 442 mJ/cm^2 and nontreated fruit became larger during storage. After 8 d of storage at 20 °C, *E. coli* O157:H7 populations on the apricot fruit treated with 442 mJ/cm^2 ultraviolet-C were 3.3 and 4.2 log CFU/fruit lower than the nontreated fruit when enumerated on TSA and SMAC, respectively. Results from our present study showed that *E. coli* O157:H7 populations of all samples decreased during storage. After 7 d of storage, all fruits attained similar populations of *E. coli* O157:H7. It seems that there were differences between peach and apricot in response to ultraviolet-C in terms of changes in *E. coli* populations during post-ultraviolet storage. It is possible that ultraviolet-C at higher doses induced damage on fruit skins leading to cellular leakage. The pH of juice from apricots was 3.0 or lower with an acidity of 0.5% or higher, being much lower pH and higher acidity than those of peaches. Therefore, low pH as a result of cellular leakage from apricots could be bacteriostatic or bactericidal to *E. coli*. It is also possible that high doses of ultraviolet-C stimulated synthesis of antimicrobial compounds on apricots, but not on peaches. It is known that ultraviolet-C elicits a range of biochemical responses (the hormesis phenomenon) in fresh produce (Shama, 2007; Stevens et al., 1998).

Bialka and Demirci (2007) found that 60 s of pulsed ultraviolet treatment achieved maximum reductions of 4.3 and 2.9 log CFU/g for *Salmonella* and *E. coli*, respectively, on blueberries (*Vaccinium corymbosum)*. Yaun et al. (2004) showed that ultraviolet-C at an ambiguous dose resulted in 3.3 and 2.8 log reductions of *E. coli* O157:H7 on apples (*Malus ×domestica* Borkh.) and green leaf lettuce (*Lactuca graminifolia* Michx.), respectively, and 2.2 log reduction of *Salmonella* spp. on tomatoes (*Solanum lycopersicum* L.). The reductions of *E. coli* on peaches and apricots were smaller compared with those demonstrated on other fruits, suggesting that the surface structures, such as trichome, may have an influence on the efficacy of

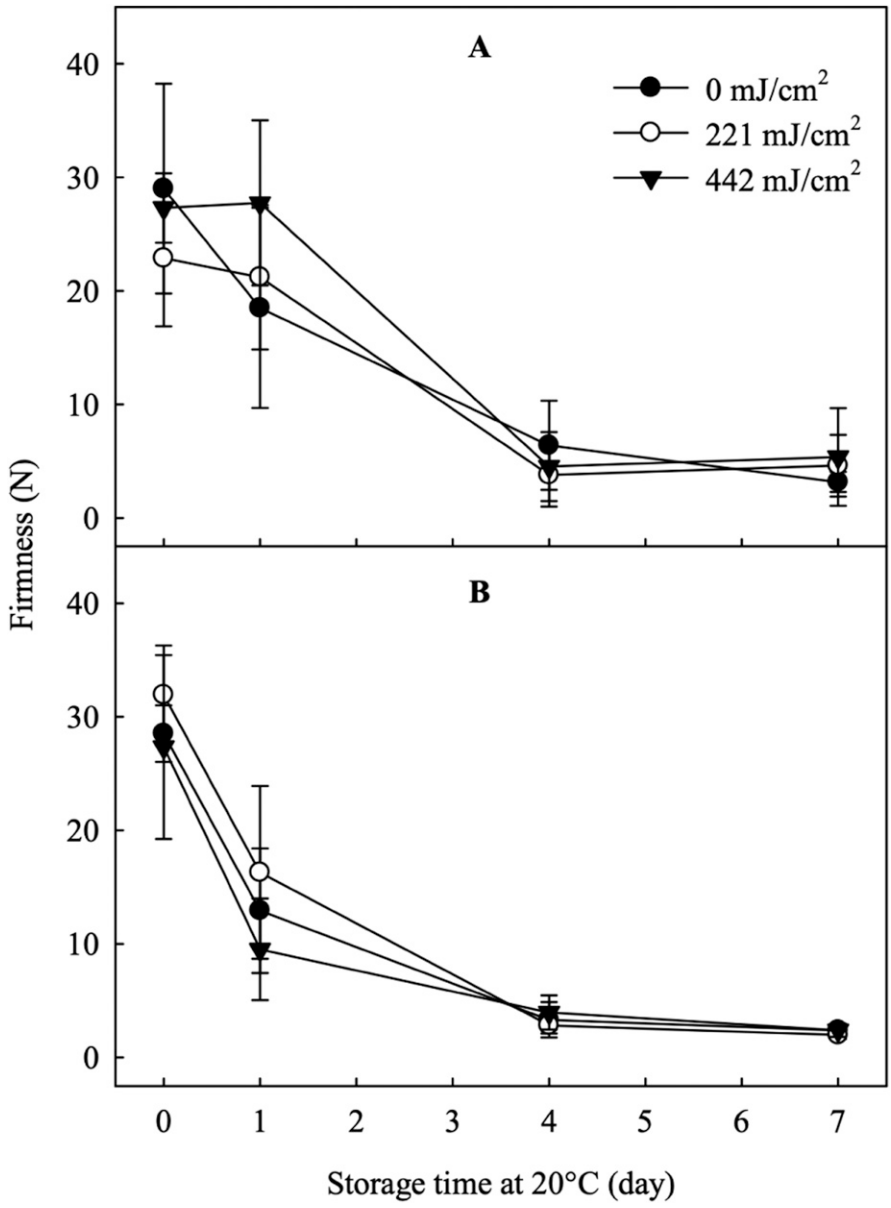

Fig. 2. Changes in firmness of peaches during post–ultraviolet-C storage at 20 °C. Peaches with natural fuzz (**A**) or fuzz removed (**B**) were treated with ultraviolet-C at doses of 0, 221, and 442 mJ/cm^2 and then stored at 20 °C for 7 d. Vertical bars represent SDS (n = 4).

ultraviolet-C. It is known that surface characteristics of fruit influence the efficacy of ultraviolet-C light (Adhikari et al., 2015).

Our results demonstrated that ultraviolet-C reduced populations of *E. coli* O157:H7 by less than 2 log CFU/fruit, observed at day 1 of storage. During additional storage time, the difference in bacterial populations between ultraviolet-C–treated and nontreated fruit disappeared. Similar results have been reported earlier. For example, Escalona et al. (2010) showed that populations of *Listeria* and *Salmonella* on spinach (*Spinacia oleracea* L.) leaves became similar after 14 d of storage at 5 °C, even though ultraviolet-C initially reduced bacterial population by up to 2.9 log CFU/g. Results from the present study and others demonstrate the limitation of ultraviolet-C technology in enhancing microbial safety of fresh produce.

Effect on peach quality. Fruit firmness decreased rapidly during the first 4 d of storage in both peaches with and without fuzz (Fig. 2). At day 1, fruit with removed fuzz had significantly lower firmness (12.9 vs. 22.2 N) than those with fuzz. There was relatively little change in firmness during storage from day 4 to day 7, compared with the changes occurring during the first day. Our results indicate that removal of fuzz significantly ($P < 0.05$) accelerated the loss of firmness during storage at 20 °C. On average, fruit without fuzz removal had significantly higher firmness than those with fuzz removal at day 1 (22.2 vs. 12.9 N) and day 7 (4.4 vs. 2.3 N). There was no significant difference in firmness between fuzzed and de-fuzzed fruit at day 1 or 4. Ultraviolet-C at any dose or sampling day did not have any significant effect on firmness. During the fuzz removal, fruit may have been physically damaged even though there was no visible change in the surface of the fruit. As a result of mechanical injury, ethylene production and the ripening process may be accelerated. In addition, fruit after fuzz removal may have higher weight loss than the fruit without fuzz removal.

Removal of fuzz from peach surface significantly ($P < 0.05$) increased L*, hue, and chroma values (Table 1), indicating fuzz removal made the fruit appear greener, lighter, and brighter. During storage, the L* and hue values of the shaded side of peaches decreased in both peaches with and without fuzz, suggesting the darkening and yellowing of the peaches. Much fewer changes in chroma values were observed during storage. For the non–ultraviolet-C–treated fruit, the loss of hue values in peaches with fuzz removed was more rapid than that of fruit with fuzz. Ultraviolet-C had no significant effect on any of the color parameters at days 1 and 4 except that after 7 d of storage, the chroma values of peaches treated with the higher dose of ultraviolet-C were significantly lower than the non–ultraviolet-C–treated fruit in both fuzz and de-fuzzed peaches, suggesting high doses of ultraviolet-C treatment may result in skin browning. Skin browning during storage after ultraviolet-C treatment was also

Table 1. Effect of ultraviolet-C and fuzz removal on color parameters of peach fruit during storage. Peaches were treated with ultraviolet-C at doses of 0, 221, and 442 mJ/cm^2. Fruit color on the shaded side was measured after 1, 4, and 7 d of storage at 20 °C.

	L* values			Hue values			Chroma values		
Storage time (d)	0 mJ/cm^2	221 mJ/cm^2	442 mJ/cm^2	0 mJ/cm^2	221 mJ/cm^2	442 mJ/cm^2	0 mJ/cm^2	221 mJ/cm^2	442 mJ/cm^2
Peach with fuzz									
0	68.4 ± 1.8 aAB[z]	68.4 ± 1.2 aAB	69.1 ± 1.8 aAB	72.4 ± 4.3 aA	73.5 ± 3.2 aABC	78.0 ± 4.1 aAB	44.4 ± 1.2 aC	45.4 ± 2.0 aBC	46.2 ± 1.5 aCDE
1	67.6 ± 1.3 aAB	66.4 ± 1.1 aAB	67.8 ± 1.5 aABC	72.8 ± 3.5 aA	72.5 ± 2.7 aABCD	77.5 ± 4.1 aAB	43.9 ± 1.4 aC	44.4 ± 2.0 aC	46.8 ± 1.3 aBCDE
4	65.3 ± 3.3 aB	62.9 ± 4.0 aB	64.5 ± 2.6 aBC	71.7 ± 5.3 aA	63.3 ± 6.3 bD	68.9 ± 4.9 aBC	46.2 ± 2.9 aBC	43.3 ± 3.0 aC	45.8 ± 2.5 aDE
7	66.7 ± 3.3 aAB	62.9 ± 2.8 aB	63.0 ± 3.2 aC	69.7 ± 4.8 aA	65.9 ± 3.9 aCD	68.1 ± 3.7 aC	49.8 ± 2.0 aAB	45.7 ± 2.2 abBC	44.3 ± 3.4 bE
Peach with fuzz removal									
0	71.4 ± 1.9 aA	71.3 ± 1.2 aA	72.3 ± 1.3 aA	78.9 ± 4.3 aA	80.5 ± 3.2 aA	79.6 ± 2.8 aAB	49.6 ± 1.4 aAB	50.5 ± 1.4 aAB	51.0 ± 1.2 aABC
1	67.9 ± 2.7 aAB	69.0 ± 1.5 aA	70.4 ± 1.5 aA	77.2 ± 4.3 aA	78.5 ± 3.2 aAB	78.0 ± 3.1 aA	50.1 ± 1.7 aAB	51.7 ± 1.4 aA	51.5 ± 1.6 aAB
4	68.7 ± 1.6 aAB	65.5 ± 4.1 aAB	67.2 ± 2.5 aABC	76.2 ± 3.4 aA	72.5 ± 4.9 aABCD	74.7 ± 3.7 aABC	53.0 ± 2.8 aA	48.5 ± 3.3bABC	52.5 ± 2.2 aA
7	67.5 ± 3.2 aAB	66.0 ± 1.9 aAB	63.6 ± 1.6 aC	71.1 ± 4.5 aA	70.2 ± 2.4 aBCD	70.5 ± 2.2 aABC	54.6 ± 2.9 aA	52.4 ± 2.3 abA	49.7 ± 1.4 bABCD
Fuzz removal		***			***			***	
Ultraviolet		NS			*			NS	
Storage		***			***			*	
Ultraviolet × storage		NS			NS			***	
Ultraviolet × fuzz		NS			NS			NS	
Fuzz × storage		NS			NS			NS	

[z]The numbers are averages ± SDS (n = 4). Means followed by a common lower case letters (a–c) in a row or upper case letters (A–E) in a column are not significantly different ($P < 0.05$).
NS, *, ***Nonsignificant or significant at 0.05 or 0.001, respectively.

observed in pears (*Pyrus communis* L.), peaches (*P. persica*), and mushroom (*Agaricus bisporus*) (Gonzalez-Aguilar et al., 2004; Guan et al., 2012; Syamaladevi et al., 2014). Peaches developed significant amounts of decay after 7 d of storage, and ultraviolet-C had no apparent effect on the decay rate (data not shown).

In general, ultraviolet-C exposure increased ORAC values of peels from peach fruit with fuzz, and ORAC values increased with increasing ultraviolet-C dose (Fig. 3). Significant increases in ORAC values were observed on day 1 at ultraviolet-C dose of 442 mJ/cm^2; however, ultraviolet-C did not increase ORAC values of skins from de-fuzzed peaches. In fact, at day 7, ORAC values of samples from ultraviolet-C–treated fruits were less than those of nontreated samples. In addition, ORAC values of de-fuzzed peaches decreased during storage, whereas no decrease in ORAC values was observed in peaches with fuzz. It is known that ultraviolet-C increases antioxidants of fruits and vegetables. For example, Erkan et al. (2008) found that postharvest ultraviolet-C treatments for 5 and 10 min (2.15 and 4.30 kJ/m^2) enhanced antioxidant capacity (ORAC values) of strawberries (*Fragaria* L.) after 15 d of storage at 10 °C. Fresh-cut mango (*Mangifera indica* L.) treated with ultraviolet-C for 10 min (dose not provided) induced a hypersensitive defense response resulting in phenol and flavonoid accumulation, which was positively correlated with ORAC values during storage at 5 °C (González-Aguilar et al., 2007). Similarly, ultraviolet-C treatment resulted in higher antioxidant activity in fresh-cut bananas (*Musa* L.) (Alothman et al., 2009). Perkins-Veazie et al. (2008) showed that ferric-reducing antioxidant power values of blueberries were increased by ultraviolet-C treatment at 2 or 4 kJ/m^2. Our results suggest that the response of peach fruits to ultraviolet-C is influenced by fuzz removal, that is, ultraviolet-C exposure increased ORAC values in skins of peaches with fuzz, but had no effect in de-fuzzed fruits. Fuzz removal may serve as a mechanical injury inducing synthesis of antioxidants, such as phenolics. Additional stress (ultraviolet-C) as a surface treatment cannot further increase the accumulation of antioxidative compounds. Whether the ultraviolet-C–induced increase in antioxidants in fruit skin will affect the taste of fruit needs further study.

SEM of E. coli *O157:H7 on peach surface.* Trichomes with different lengths along with stomata and cuticle waxes were observed on peach surfaces under electron microscope (Fig. 4). The removal of fuzz from peach surface using the wet cloth eliminated only some of the trichomes, most notably the longer trichomes. Removing trichomes left many scars where the trichomes were de-rooted, providing sites for bacterial attachment. In general, *E. coli* O157:H7 were not found on the trichomes of peaches. Instead, the bacteria were attached on the stomata, on other cracks, and on the epidermic cuticle around trichome

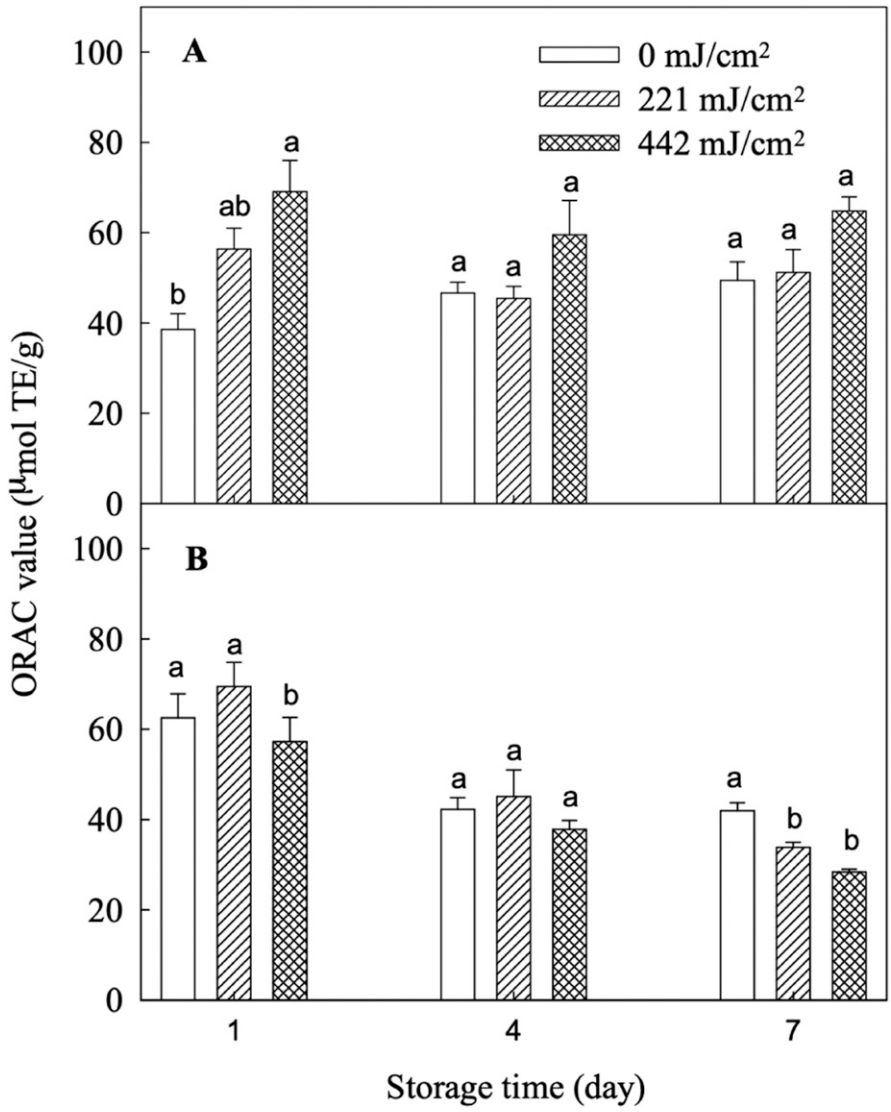

Fig. 3. Antioxidant capacity of peach skin as affected by ultraviolet-C treatment and fuzz removal. Peaches with (**A**) and without fuzz (**B**) were treated with ultraviolet-C at doses of 0, 221, and 442 mJ/cm^2. Oxygen radical absorbance capacity (ORAC) of the skins from the treated peaches was measured on day 1, 4, and 7 of storage at 20 °C. Vertical lines represent SDS (n = 4). Bars with the same letters within the same storage time are not significantly different (Bonferroni test, $P = 0.05$).

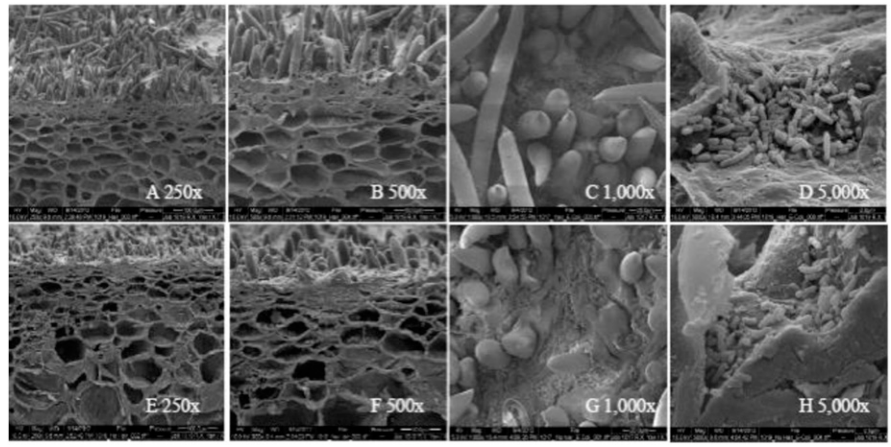

Fig. 4. Scanning electron microscopy images of peach skin cross sections (**A**, **B**, **E**, and **F**) and surfaces (**C**, **D**, **G**, and **H**) with natural fuzz (top row) and with fuzz removed (bottom row). Magnifications are indicated on each image. Fruit were inoculated with *E. coli* O157:H7.

bases. Ultraviolet-C had no obvious effect on the appearance of *E. coli* O157:H7 cells inoculated on peach surfaces immediately after ultraviolet-C treatments. After 7 d of storage, some bacterial cells had wrinkled and shrunken appearance (data not shown).

Our results demonstrated the removal of fuzz slightly increased the resistance of *E. coli* to ultraviolet-C. Based on the observation of the peach surface using SEM, it seems that the removal of fuzz created scars, protective sites for *E. coli*, that shaded ultraviolet-C from reaching some bacteria. Trichomes of peaches are covered by a thin cuticular layer containing 15% waxes and 19% cutin and are filled by polysaccharide material (63%) containing hydroxycinnamic acid derivatives and flavonoids (Fernández et al., 2011). The wax may reflect ultraviolet-C as well as shade cells from ultraviolet-C exposure.

In conclusion, our results suggest that ultraviolet-C at a dose of 442 mJ/cm^2 reduced the population of *E. coli* O157:H7 by up to 1.4 log CFU/fruit on the natural surface of peach fruit measured 1 d after treatment. On the surface with fuzz removed, the reduction was slightly less. The reduction caused by the ultraviolet-C treatment was not sustained during additional post–ultraviolet-C storage at 20 °C, and the population become similar regardless of fuzz removal after 7 d of storage. Removal of fuzz increased the loss of firmness and changes in color (hue values) during storage. In addition, fuzz removal influenced the ORAC values in response to ultraviolet-C. However, ultraviolet-C at doses we tested did not have a consistent effect on the quality of peaches during post–ultraviolet-C storage at 20 °C. Overall, our results demonstrate that ultraviolet-C did not significantly affect quality of peach fruits while reducing the populations of *E. coli* O157:H7.

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