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Inactivation of foodborne pathogens in powdered red pepper (*Capsicum annuum* L.) using combined UV-C irradiation and mild heat treatment

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ABSTRACT

This study was performed to investigate the effectiveness of combined ultraviolet (UV-C) irradiation and mild heating as an alternative to conventional inactivation of foodborne pathogens, including *Escherichia coli* O157:H7 and *Salmonella* Typhimurium on powdered red pepper. A cocktail of three strains of *E. coli* O157:H7 ATCC 35150, ATCC 43889, ATCC 43890) and *S.* Typhimurium (ATCC 19585, ATCC 43971, DT 104) was inoculated onto powdered red pepper and then treated with UV-C irradiation and mild heat. A constant UV intensity (3.40 mW/cm^2) of the emitting lamps was applied to samples for 5, and 10 min at 25, 35, 45, 55, and 65 °C, respectively. Also, quality change of powdered red pepper was measured in order to identify the efficiency of combined treatment. The reduction levels of *E. coli* O157:H7 and *S.* Typhimurium on powdered red pepper when treated with UV-C irradiation alone at 20.4 kJ/m^2 for 10 min was 0.22 and 0.29 log CFU/g, respectively. While, combined treatment with mild heating at 65 °C reduced the surviving numbers of each pathogens by 2.88 and 3.06 log CFU/g, respectively. Although the inactivation efficiency was influenced less by the UV-C radiation dose, the synergistic effect was observed with increasing temperature and UV-C radiation dose. CIE color value and extractable color value were not significantly ($P > 0.05$) different between non-treated and combination treated samples. The moisture and capsaicinoids contents showed significant ($P < 0.05$) differences when treated at 65 °C because of sample drying during heat treatment. Therefore, these results suggest that UV-C irradiation combined with mild heating can be utilized by the food industry in order to effectively inactivate *E. coli* O157:H7 and *S.* Typhimurium without incurring quality deterioration of powdered red pepper.

1. Introduction

Powdered red pepper (*Capsicum annuum* L.) is one of the most widely used spices. It is added to food without performing any prior processing other than drying and grinding (Christensen, Fanse, Nelson, Bates, & Microcha, 1967). Spices are often contaminated with microorganisms such as bacteria, molds, and yeasts which can cause food spoilage and foodborne outbreaks (Banerjee & Sarkar, 2003; Buckenhuskes & Rendlen, 2004; Oularbi & Mansouri, 1996), although only small amounts of spices are added to foods (Fowels, Mitchell, & McGrath, 2001). In the United States, several outbreaks of *Salmonella Montevideo* were reported by the Centers for Disease Control and Prevention (CDC, 2010) and also the recent count was confirmed as an illness of 272 persons in 44 states and DC. Therefore, it is necessary to decontaminate powdered red pepper during processing.

Various systems have been used for decontamination of spices, including super-heated steam and exposure to ionizing radiation, (Schweiggert, Carle, & Schieber, 2007; Tainter & Grenis, 2001). There are some major drawbacks to utilizing super-heated steam to reduce foodborne pathogens in spice, including loss of sensory properties and change of color although it can effectively inactivate

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pathogens. Furthermore, the higher moisture content following steam treatment is conducive to mold growth (Schweiggert et al., 2007; Tainter & Grenis, 2001). In recent years, treatment of spices with ionizing radiation such as gamma-rays, X-rays, and electron beam exposure has resulted in pathogen inactivation. Its effectiveness has been verified through many studies (Schweiggert et al,, 2007). One of them, Rico et al. (2010) demonstrated that irradiation treatment results in possibility of post decontamination of powdered red pepper without incurring the sensory deterioration associated with conventional steam treatment. On the other hand, it was also reported that oxidation and degradation of color or aromatic components of spices occurs at high irradiation doses (Hayashi, 1998; Variyar, Gholap, & Thomas, 1997).

For processing of spices, an alternative procedure is needed, not only to ensure microbiological safety, but also to preserve sensory properties. Capsaicinoids and color values are important quality indicators of red pepper. Capsaicin and dihydrocapsaicin comprise 80–90% of capsaicinoids (Pulseglove, Brown, Green, & Robbins, 1988). Also, color affects consumer preference to powdered red pepper (Locey & Guzinski, 2000).

During decontamination of spices, producers need to focus on surface pasteurization because microorganisms commonly attach to surfaces. In addition, this method causes less deterioration of spice quality (Hamanaka et al., 2000). It is generally known that UV-C light, with wavelengths of 250–260 nm, have the highest germicidal power (Sharma, 1999) by inducing DNA damage and formation of pyrimidine dimers in cellular microorganisms and viruses. These photoproducts block appropriate DNA replication and transcription. And it also transform the sugar phosphate backbone (Harm, 1980; Roberts & Hope, 2003). A wide range of microorganisms and viruses is ultimately inactivated through this non-thermal process. Also, UV-C irradiation does not leave any residues in products and both installation cost and processing expense are low (Chang et al., 1985; Gonźalez-Aguilar, Ayala-Zavala, Olivas, de la Rosa, & Álvarez-Parrilla, 2010). In addition, Baka and others demonstrated that the germicidal effect of UV-C irradiation can extend the shelf life of fresh produce (Baka, Mercier, Corcuff, Castaigne, & Arul, 1999). Considering these advantages, UV-C sterilization has been used for microbial inactivation by the pharmaceutical, medical, and food industries for a long time (Gil, Selma, López-G'alvez, & Allende, 2009).

Research has shifted toward developing a combined treatment in order to maintain sensory properties while simultaneously improving microbial safety of foods, along with reduced energy costs in food processing (Farkas, 1990). Above all, this study involving simultaneous UV irradiation and mild heating was initiated since it also facilitates the nutritional and sensory quality of food products (Leistner, 1992), since these properties may be adversely affected when subjected to thermal processing alone in order to inactivate foodborne pathogens and extend shelf life (AOAC, 1995).

Therefore, we initiated this study to investigate the efficacy of inactivation of foodborne pathogens on powdered red pepper using the simultaneous combination treatment of UV-C irradiation and mild heating.

2. Materials and methods

2.1. Bacterial strains

For this study, three bacterial strains each of *Escherichia coli* O157:H7 (ATCC 35150, ATCC 43889, ATCC 43890) and *S*. Typhimurium (ATCC 19585, ATCC 43971, DT 104) were obtained from the School of Food Science bacterial culture collection of Seoul National University (Seoul, Korea). All stock cultures were stored at −80 °C in 0.7 ml of Tryptic Soy Broth (TSB; Difco, Becton Dickinson, Sparks, MD, USA) and 0.3 ml of 50% glycerol. Working cultures were streaked onto Tryptic Soy Agar (TSA; Difco), incubated at 37 °C for 24 h, and stored at 4 °C.

2.2. Culture preparation

Each strain of *E. coli* O157:H7 and *S*. Typhimurium was cultured in 5 ml of TSB at 37 °C for 24 h, harvested by centrifugation at 4000 g for 20 min at 4 °C and washed three times with buffered peptone water (BPW; Difco, Sparks, MD). The final pellets were resuspended in 10 ml of BPW, corresponding to approximately 10^7–10^8 CFU/ml. Suspended pellets of the all strains of both pathogens were combined into a mixed culture cocktail at a final concentration of approximately 10^8 CFU/ml for use in this study.

2.3. Sample preparation and inoculation

Commercially dried red pepper powders were purchased at a local grocery store (Seoul, Korea) then strained through a sieve shaker (−16 + 25 mesh, Chung Gye Industrial Mfg., Co., Gyeonggi, Korea). For inoculation, 1 ml of culture cocktail was added to 25 g of samples contained in 500 ml glass beakers, and then mixed by sterilized stainless steel spoon for 5 min to be uniformly distributed. After mixing, samples were dried for 1 h inside a biosafety hood (22 ± 2 °C) with the fan running (Akbas and Ozdemir, 2008; Emer, Akbas, and Ozdemi, 2008). The concentration of final samples was 10^6–10^7 CFU/g.

2.4. UV irradiation system and treatment

The UV-C irradiation system consisted of two banks of 5 germicidal emitting lamps (G6T5, Sankyodenki, Japan) situated on the ceiling and bottom of an incubator (IL-11, Lab Companion, Daejeon, Korea), providing double-sided exposure of samples. UV intensity was measured using a UV-C light meter (RS-232, Lutron, Taipei, Taiwan) placed in the same location as that of samples. Prior to all experiments, the apparatus was turned on for at least 15 min in order to stabilize the UV-C lamps.

An inoculated sample was spread as a single layer on UV-C permeable Polypropylene film of 500 × 350 × 0.03 mm (length × width × thickness) placed on a UV-C transparent produce tray situated inside the incubator. The distance between the sample tray and UV-C lamps was 10 cm. To evaluate the inactivation effect of the combined treatment of UV-C irradiation and mild heating, a constant UV intensity (3.40 mW/cm^2) of the emitting lamps was applied to samples for 5 and 10 min at 25, 35, 45, 55, and 65 °C, respectively. By using a fiber optic temperature sensor (FOT-L, FISO Technologies Inc., Quebec, Canada) which is connected to a signal conditioner (FTI-10, FISO Technologies Inc., Quebec, Canada), treatment temperatures were verified. These records presented an error of less than 3 °C even when treated at 65 °C for 10 min (data not shown). The dosage of UV irradiation was calculated by multiplying UV intensities by the irradiation times. 20.4 kJ/m^2 and 40.8 kJ/m^2 of radiation energy was treated for 5 and 10 min of irradiation respectively.

2.5. Microbial enumeration

For enumeration of *E. coli* O157:H7 and *S*. Typhimurium, each treated red pepper sample was transferred into a sterile stomacher bag (Labplas Inc., Sainte-Julie, Quebec, Canada) containing 225 ml of 0.1% peptone water (Difco) and then homogenized in a stomacher (EASY MIX, AES Chemunex, Rennes, France) for 2 min. After homogenization, sample aliquots were serially tenfold diluted in

9 ml blanks of 0.1% peptone water, and 0.1 ml of diluted samples were duplicate spread-plated onto selective media. Sorbitol MacConkey agar (SMAC; Difco), Xylose Lysine Desoxycholate agar (XLD; Difco) were used as selective media for the enumeration of *E. coli* O157:H7, *S.* Typhimurium, respectively. All plates were incubated at 37 °C for 24–48 h before counting.

2.6. Quality measurement

In order to identify the quality changes of red pepper powder after combined treatment with UV-C irradiation and mild heating, visual inspection (CIE color value) and ingredients analysis (extractable color, moisture, and capsaicinoids contents of samples) were performed. All treated samples were stored in the biosafety hood for 1 h to equilibrate to room temperature. Subsamples of powdered red pepper were selected from three random locations.

2.6.1. Color

Color change of samples was measured using a Minolta colorimeter (model CR300, Minolta Co., Osaka, Japan) and presented in CIE 1976 color space. Colors were expressed as L^*, a^* and b^* values, which indicates color lightness, redness, and yellowness of the sample, respectively (Chen, Zhu, Zhang, Niu, & Du, 2010).

2.6.2. Extractable color

The extractable color of samples was measured with the American Spice Trade Association value (ASTA color value), according to the ASTA-20.1 method (ASTA, 1986). One hundred mg of sample was added to 100 ml of acetone, and stored at 0 °C for 4 h with intermittent mixing to ensure sufficient extraction. The absorbance of extracted samples was measured at 460 nm using a spectrophotometer (SpectraMax M2, Molecular Devices, U.S.A), and ASTA color value was calculated as following: ASTA color value = absorbance of acetone extracts × 16.4 × I_f/sample weight (g), where I_f is a correction factor for the apparatus.

2.6.3. Moisture contents

Moisture was determined by the AOAC method (AOAC, 1995). The moisture content of treated red pepper powder (2 g each) was determined using a halogen moisture analyzer (HB43-S, Mettler Toledo, Switzerland).

2.6.4. Capsaicinoids analysis

Capsaicinoid analysis was carried out according to the method of Attuquayefio and Buckle, 1987. Four g of powdered red pepper was added to 20 ml acetonitrile and vortexed for 2 min. One ml aliquot of the extract was diluted with 9.0 ml of distilled water and passed conditioned Sep-pak (Waters, Mass., U.S.A.). The capsaicinoids were then eluted with 4 ml of acetonitrile followed by 1.0 ml of acetonitrile containing 1% acetic acid. For HPLC determination, a Jasco liquid chromatograph (JASCO, Tokyo, Japan) equipped with a Model PU980 pump, a Model UV 975 detector and a Model 807-IT integrator was used. The wavelength was set at 280 nm, and a -BondapakC_{18} column (3.9 × 300 mm, 10 μm, Waters) connected to a guard-column (Waters Guard-PakTM) where temperature was controlled at 35 °C was used under these conditions of the mobile phase: Methanol/water(70:30, v/v) at a flow rate of 0.8 ml/min.

2.7. Statistical analysis

All experiments were repeated three times and data were analyzed using the ANOVA procedure and Duncan's multiple range tests (SAS Institute, Cary, NC, USA). Value of $P \leq 0.05$ was used to indicate significant difference.

3. Results

3.1. Combination of UV-C irradiation and mild heating on powdered red pepper

The effects of the combination of UV-C irradiation and mild heating treatment and each single treatment on reduce levels of viable populations of *E. coli* O157:H7 and *S.* Typhimurium are shown in Tables 1 and 2, respectively.

When UV-C irradiation was applied at 20.4 kJ/m^2 without raising the temperature (25 °C), reduction levels of *E. coli* O157:H7 and *S.* Typhimurium in powdered red pepper were 0.22 and 0.29 log CFU/g, respectively (Table 1). Moreover, there were no significant differences ($P > 0.05$) between mild heating and combined treatment at 35 and 45 °C. Reductions of *E. coli* O157:H7 were 0.88 and 1.23 log CFU/g when treated at 55 and 65 °C, respectively. Those of *S.* Typhimurium, were 0.85 and 1.29 log CFU/g, respectively.

Table 2 shows the reduction of these pathogens when treated at 40.8 kJ/m^2. The number of surviving cells exposed to UV-C irradiation treatment alone was slightly reduced independent of UV-C radiation dose. However, there were no significant differences ($P > 0.05$) between mild heating and combined treatment at 35, 45 °C for both pathogens. But in case of treatment at 55 and 65 °C, reductions of *E. coli* O157:H7 showed statistically significant ($P < 0.05$) differences between mild heating and combined treatment. Also the same tendency was observed for *S.* Typhimurium at 65 °C treatment.

3.2. Quality measurement

Color values of powdered red pepper after the non-treated control, UV-C irradiation and combined treatments are summarized in Table 2. L^*, a^*, and b^* values of the combination treated samples following UV-C irradiation (40.8 kJ/m^2) were not significantly ($P > 0.05$) different from those of non-treated samples. Also, there were no significant ($P > 0.05$) differences in extractable color value (ASTA). But the moisture content (%) was significantly ($P < 0.05$) decreased after mild heating at 65 °C. Table 4 shows the change of capsaicinoids contents of samples after each treatment. Similar to that for moisture content, capsaicinoids contents were significantly ($P < 0.05$) increased after mild heating at 65 °C. However, these alterations of capsaicinoids content might be

Table 1
Reduction levels of *Escherichia coli* O157:H7 and *Salmonella* Typhimurium on powdered red pepper following UV-C irradiation with double sided exposure at various temperatures, 3.40 mW/cm^2 for 5 min (UV dose: 20.4 kJ/m^2)[a].

	Log reduction (log CFU/g) by treatment type and organism[b]			
	UV-C irradiation (at 25 °C)	Heating temp. (°C)	Mild heating	Combined treatment with UV-C irradiation and mild heating
Escherichia coli O157:H7	0.22 ± 0.14 A	35	0.17 ± 0.02 Aa	0.18 ± 0.01 Aa
		45	0.33 ± 0.36 Aab	0.43 ± 0.45 Aa
		55	0.88 ± 0.42 Abc	1.03 ± 0.56 Aab
		65	1.23 ± 0.27 Bc	1.57 ± 0.60 Bb
Salmonella Typhimurium	0.29 ± 0.11 A	35	0.37 ± 0.18 Aa	0.41 ± 0.01 Aa
		45	0.53 ± 0.43 Aa	0.67 ± 0.48 Aa
		55	0.85 ± 0.27 ABab	1.02 ± 0.48 Bab
		65	1.29 ± 0.24 Bb	1.76 ± 0.50 Bb

[a] The initial numbers of *E. coli* O157:H7 and *S.* Typhimurium was 6.91 ± 0.26 and 7.38 ± 0.34 log CFU/g respectively.
[b] Means ± standard deviations from three replications. Means with the same uppercase letter in the same row are not significantly different ($P > 0.05$). Means with the same lowercase letter in the same column are not significantly different ($P > 0.05$).

Table 2
Reduction levels of *Escherichia coli* O157:H7 and *Salmonella* Typhimurium on powdered red pepper following UV-C irradiation with double sided exposure at various temperatures, 3.40 mW/cm^2 for 10 min (UV dose: 40.8 kJ/m^2)[a].

	Log reduction (log CFU/g) by treatment type and organism[b]			
	UV-C irradiation (at 25 °C)	Heating temp. (°C)	Mild heating	Combined treatment with UV-C irradiation and mild heating
Escherichia coli O157:H7	0.36 ± 0.34 A	35	0.47 ± 0.20 Aa	0.73 ± 0.67 Aa
		45	0.52 ± 0.17 Aa	1.31 ± 0.87 Aab
		55	1.23 ± 0.29 Ab	2.26 ± 0.60 Bbc
		65	1.75 ± 0.38 Bb	2.88 ± 0.47 Cc
Salmonella Typhimurium	0.47 ± 0.34 A	35	0.54 ± 0.46 Aa	0.94 ± 0.56 Aa
		45	0.67 ± 0.22 Aa	1.59 ± 0.88 Aab
		55	1.63 ± 0.53 Bb	2.41 ± 0.55 Bbc
		65	2.14 ± 0.45 Bb	3.06 ± 0.52 Cc

[a] The initial numbers of *E. coli* O157:H7 and *S.* Typhimurium was 6.91 ± 0.26 and 7.38 ± 0.34 log CFU/g respectively.
[b] Means ± standard deviations from three replications. Means with the same uppercase letter in the same row are not significantly different ($P > 0.05$). Means with the same lowercase letter in the same column are not significantly different ($P > 0.05$).

caused by drying of samples following combined treatment UV-C (40.8 kJ/m^2) and mild heating at 65 °C. In actually, there were no significant ($P > 0.05$) differences assuming the samples had identical moisture content (data not shown).

4. Discussions

Until now, few studies have researched the effect of UV-C irradiation on reducing foodborne pathogens in spices (Belgin and Ibrahim, 2011). The germicidal mechanisms of ultraviolet radiation have already been investigated, which consist of photochemical oxidation and pyrimidine dimer formation in DNA strands (Miller, Jeffrey, Mitchell, & Elasri, 1999). DNA cross linking formed as a result prevents normal operations such as transcription and cell replication, and ultimately leads to loss of cellular function and cell death (Allende, McEvoy, Luo, Artes, & Wang, 2006). The effect of UV-C disinfection is influenced by several factors such as UV intensity, distance from the lamp, treatment temperature, and exposure time (Allende et al., 2006; Cha, Park, Choi, Cheon, & Kil, 2010; Yaun, Sumner, Eifert, & Marcy, 2004). The surviving numbers of pathogens decreases with increasing UV-C intensity according to the previous studies (Gayán, Mañas, Álvarez, & Condón, 2013; Gayán, Serrano, Raso, Álvarez, & Condón, 2012; Kim et al., 2013). However, decontamination processing of spices with only UV-C irradiation had no notable effect. For instance, there was only 0.6 log CFU/g reduction on cumin seeds after UV-C irradiation (10.5 mW/cm^2) for 60 min even though treatment time extended up to 120 min (Belgin and Ibrahim, 2011). Fine and Gervais (2004) reported that microbial decontamination resulting from pulsed UV-C light on black pepper was ineffective. For these reasons, a combined system based on UV-C irradiation has been researched to complement the inactivation effect.

Table 4
Capsaicinoids contents of combination treated red pepper powder following double-sided UV-C exposure at various temperature, 3.40 mW/cm^2 for 10 min (UV dose: 40.8 kJ/m^2).

Heating temp. (°C)	Treatment	Capsaicinoids (mg/100g)[a]		
		Capsaicin	Dihydrocapsaicin	Total[b]
25	Non-treated	5.66 ± 0.27 a	4.14 ± 0.49 a	9.80 ± 0.67 a
	UV-C irradiation	5.69 ± 0.11 a	4.12 ± 0.05 a	9.82 ± 0.14 a
55	Mild heating	5.77 ± 0.07 a	4.13 ± 0.11 a	9.90 ± 0.15 a
	Combination treatment	5.77 ± 0.11 a	4.47 ± 0.01 a	10.24 ± 0.11 a
65	Mild heating	6.29 ± 0.16 b	4.49 ± 0.06 a	10.78 ± 0.16 b
	Combination treatment	6.70 ± 0.04 c	5.29 ± 0.05 b	11.99 ± 0.09 c

[a] Means ± standard deviations from three replications. Values with the same letter in the same column are not significantly different ($P > 0.05$).
[b] Total (capsaicin + dihydrocapsaicin).

Among these factors, Gayán et al. (2012, 2013) demonstrated the mechanism of synergistic inactivation of *E. coli* and *Salmonella enterica* when treated with UV-C light at mild temperature. Simultaneously treatment with UV-C irradiation and mild heat was shown to be more effective than either treatment alone or when applied sequentially. However, to date, no study has investigated the decontamination of food samples using combined treatment of UV-C light and mild heating. Therefore, in the present study, the degree of inactivation of foodborne pathogens on powdered red pepper after simultaneous UV-C irradiation and mild heat treatment was investigated with the ultimate goal of utilizing this combined intervention for commercial food processing.

The inactivation effect on powdered red pepper when treated at different UV-C irradiation doses (20.4 and 40.8 kJ/m^2) at room temperature (25 °C) was very minor with differences of less than 0.5 log CFU/g according to the results of this study. On the other hand, the synergistic effect was observed with increasing temperature. This phenomenon can be explained through the findings of previous research studies. Todo, Yonei, and Kato (1983) reported that bacterial cells sub-lethally injured by UV-irradiation could be recovered. Also, the fluidity of the cell membrane was increased by heating, making the affected cells more sensitive to UV exposure (Gayán et al., 2013).

However, thermal processing may affect color degradation of spices (Almela, Nieto-Sandoval, & Fernandez Lòpez, 2002). To evaluate the suitability of this combined decontamination system, quality properties of powdered red pepper was measured. According to Rico et al. (2010), commercial steam treatment resulted

Table 3
Quality changes of combination treated red pepper powder following double-sided UV-C exposure at various temperatures, 3.40 mW/cm^2 for 10 min (UV dose: 40.8 kJ/m^2).

Heating temp. (°C)	Treatment	Parameter[a]				
		CIE color value[b]			ASTA	Moisture (%), dry basis
		L^*	a^*	b^*		
25	Non-treated	25.27 ± 0.57 a	12.39 ± 0.33 a	11.85 ± 0.31 a	80.35 ± 0.80 a	11.40 ± 0.23 a
	UV-C irradiation	25.40 ± 0.10 a	12.42 ± 0.18 a	11.68 ± 0.58 a	82.06 ± 2.62 a	11.51 ± 0.33 a
55	Mild heating	25.50 ± 0.96 a	12.62 ± 1.07 a	10.49 ± 2.64 a	80.30 ± 2.00 a	11.45 ± 0.40 a
	Combination treatment	25.36 ± 0.42 a	12.29 ± 0.10 a	11.79 ± 0.35 a	80.81 ± 1.50 a	11.20 ± 0.83 a
65	Mild heating	25.87 ± 0.08 a	12.30 ± 0.64 a	11.69 ± 0.59 a	81.83 ± 1.46 a	10.29 ± 0.33 b
	Combination treatment	25.78 ± 0.56 a	12.64 ± 0.72 a	11.85 ± 0.64 a	83.27 ± 1.54 a	9.36 ± 0.35 c

[a] Means ± standard deviations from three replications. Values with the same letter in the same column are not significantly different ($P > 0.05$).
[b] Color parameters are L^* (Lightness), a^* (redness), and b^* (yellowness).

in quality changes in powdered red pepper, such as color and flavor degradation. Therefore, quality degradation of spices is an important factor when considering the application of a sterilization process using heat treatment. In this study, CIE color and extractable color values (ATSA) of powdered red pepper did not change significantly ($P > 0.05$). Moisture content decreased when treated at 65 °C due to sample drying as a result of heat treatment. However, when moisture contents were constants, capsaicin and dihydrocapsaicin levels did not change significantly (data not shown).

It is more effective to combine ultraviolet radiation with mild temperature heating for inactivation of *E. coli* O157:H7 and *S.* Typhimurium than to treat with UV-C irradiation alone. Moreover, this combined approach does not cause quality deterioration of powdered red pepper. Thus, this combined treatment can be utilized as an alternative to conventional decontaminating interventions such as application of super-heated steam. In particular, this combined intervention has very important implications for food safety since spices such as powdered red pepper are added to a variety of foods. Ultimately, the degree of food safety in the food industry might be enhanced through this combination procedure Table 3.

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