J Food Sci Nutr
Vol 14, p 226~232 (2009)
DOI: 10.3746/jfn.2009.14.3.226

J Food Science and Nutrition

Effects of UV-C Irradiation on the Quality of *Sunsik* and *Misutkaru* during Storage

Ho Hyun Chun, Ju Yeon Kim, Hyun Jin Kim, and Kyung Bin Song†

Department of Food Science & Technology, Chungnam National University, Daejeon 305-764, Korea

Abstract

The effects of UV-C irradiation on the quality characteristics of powdered foods, *sunsik* and *misutkaru*, were examined during storage, where samples were irradiated at doses of 27, 54, and 108 kJ/m^2, respectively. In addition, *sunsik* and *misutkaru* samples were inoculated with *Enterobacter sakazakii* as a pathogen and then irradiated at doses of 0.5, 1, and 5 kJ/m^2, respectively. After treatment, the *sunsik* and *misutkaru* samples were stored at 20°C. The microbiological data represented that populations of total aerobic bacteria, *Bacillus cereus*, and *E. sakazakii* were significantly ($p<0.05$) reduced with increasing UV-C doses. In addition, UV-C irradiation did not cause inferiority in the color quality of the samples during storage. Sensory evaluation results also indicated that there were no significant differences ($p<0.05$) among the irradiated samples. These results suggest that UV-C irradiation may be useful in maintaining the quality of *sunsik* and *misutkaru* during storage.

Key words: *sunsik*, *misutkaru*, UV-C treatment, quality change

INTRODUCTION

Sunsik is a powdered food typically made of unheated and dried vegetable, nut, and seaweed products, whereas *misutkaru* is made of heated and powdered grains, such as corn and barley, as well as beans and peanuts. Recently, these ready-to-eat powdered foods have become very popular among consumers, yet there are concerns regarding the microbial safety of these ready-to-eat foods since they are not reheated (1).

The main bacterial contaminants in *sunsik* and *misutkaru* include *Bacillus cereus* and *Enterobacter sakazakii*. *B. cereus* is a Gram-positive, spore-forming, and facultative bacterium that can grow over a wide range of growth conditions and has been found in powdered food products (2). In addition, *E. sakazakii* is a Gram-negative, rod-shaped, and motile bacterium that is considered an emerging foodborne pathogen, resulting in meningitis, sepsis, and necrotizing enterocolitis (3).

To improve the microbial safety of powdered foods including *sunsik* and *misutkaru*, various processing methods such as gamma irradiation (4), hot water and microwave heating (5), infrared heating (6), ethylene oxide fumigation (7), and ozone treatment (8) have been used to reduce bacterial counts. However, these processes can change the texture and nutritional components of foods, and there are also health concerns due to the presence of harmful chemicals. Consequently, there is a need for an alternative sanitation method that is effective, non-toxic, and easily applicable.

UV-C irradiation has numerous advantages over several existing sanitation methods. For example, it does not require chemicals or heat, and it is not expensive (9,10). Compared to thermal processing, UV irradiation causes fewer changes in the nutritional and sensory quality of foods (11). Thus, UV irradiation technology is widely used as an alternative to the chemical sterilization of food products. In particular, a UV-C wavelength of 253.7 nm causes cross-linking between neighboring pyrimidine bases in DNA strands, resulting in the blockage of DNA transcription and replication and eventual cell death (12-14). UV-C irradiation also has been approved by the FDA as a means for controlling surface microorganisms on food products (15). However, few studies have been conducted to examine the application of UV-C irradiation in powdered foods. Therefore, in this study, UV-C irradiation treatments were applied as a processing method to examine their effects on microbial inactivation and sensory quality in *sunsik* and *misutkaru* samples during storage.

MATERIALS AND METHODS

Materials

The *sunsik* and *misutkaru* (manufactured in January, 2009) were purchased from a local market in Daejeon, Korea.

†Corresponding author. E-mail: kbsong@cnu.ac.kr
Phone: +82-42-821-6723, Fax: +82-42-825-2664

Bacterial strains and culture preparation

A strain of *E. sakazakii* (ATCC 51329) was stored at -70°C in 20% glycerol stock. The *E. sakazakii* culture was streaked and grown on *E. sakazakii* agar (Oxoid, Basingstoke, Hampshire, UK) at 37°C for 24 hr. A single colony of *E. sakazakii* was then inoculated into 50 mL tubes containing 25 mL of *Enterobacteriaceae* enrichment broth (Oxoid) and incubated overnight with shaking at 37°C. Next, 2 mL of the overnight *E. sakazakii* culture was transferred to 200 mL of fresh medium and incubated with shaking at 37°C for 24 hr. The bacterial cell cultures were centrifuged (2,000 × *g* at 4°C for 15 min) and washed twice with sterile 0.1% peptone water (Difco Co., Detroit, MI, USA). An inoculation solution of *E. sakazakii* was prepared by dilution in peptone water to obtain a concentration of approximately 6～7 log CFU/mL, as determined by plate counting on the *E. sakazakii* agar (Oxoid).

Inoculation

The *sunsik* and *misutkaru* samples (10 g) were put in sterile weighing dishes (14 cm × 14 cm). The surfaces of the samples were evenly spread using a sterile glass rod and then 1 mL of the inoculum solution was spotted onto the surface of each sample.

UV-C irradiation

The UV-C irradiation treatments were performed using unfiltered germicidal emitting lamps (Sylvania, G15T8, Phillips, Netherlands) located in a metal cabinet (Fig. 1). The *sunsik* and *misutkaru* samples were placed on a tray and irradiated with the germicidal emitting lamps on both their upper and lower surfaces at a distance of 18 cm. Eight germicidal emitting lamps were placed on both sides. In order to accomplish reproducible results, the UV lamps were warmed-up for 30 min before UV-C irradiation. The UV-C intensity was determined using a UV radio meter (UV-340, Lutron Electronic Ent. Co., Ltd., Taipei, Taiwan) calibrated at 254 nm, and the UV-C irradiation dose was changed by altering the exposure time (dose rate; 15 W/m^2). The *sunsik* and *misutkaru* samples were then exposed to 3 different dose levels: 27, 54, and 108 kJ/m^2. The irradiation times for the UV-C doses of 27, 54, and 108 kJ/m^2 were 30, 60, and 120 min. After the *sunsik* and *misutkaru* samples were spread using a sterile glass rod, the UV-C irradiation treatments were performed in a dark room to minimize photoreactivation of the pathogenic bacteria. Following treatment, the samples were individually packed using low density polyethylene (LDPE) bags and stored at 20±1°C for 4 weeks. The *sunsik* and *misutkaru* samples inoculated with *E. sakazakii* were exposed to 4 different dose levels: 0.25, 0.5, 1, and 5 kJ/m^2 (dose rate; 15 W/m^2). After irradiation, the samples were individually packed using LDPE bags and stored at 20±1°C for 8 days.

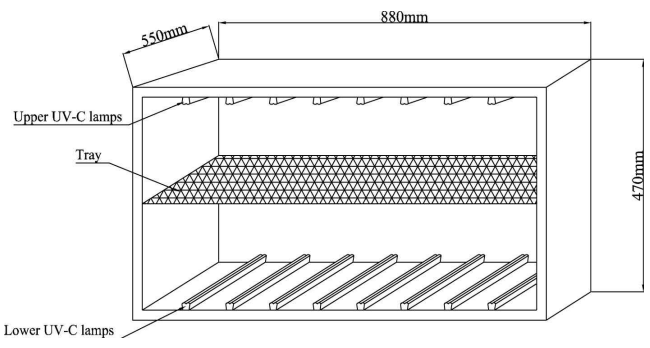

Fig. 1. Metal cabinet for UV-C irradiation.

Microbiological analysis

The samples (10 g) were placed in sterile stomacher bags containing 90 mL of peptone water (0.1% sterile peptone, w/v). They were then homogenized using a Stomacher (MIX 2, AES Laboratoire, France) for 3 min, filtered through a sterile cheese cloth, and diluted with peptone water for microbial counts. Serial dilutions were performed in triplicate. Total aerobic bacterial counts were determined by plating the diluted samples onto plate count agar (PCA, Difco Co.) and incubating the plates at 37°C for 72 hr. *B. cereus* counts were determined by plating the diluted samples onto mannitol egg yolk polymyxin (MYP, Oxoid) and incubating the plates at 30°C for 24 hr. The *E. sakazakii* counts were determined by plating the diluted samples on *E. sakazakii* agar (Oxoid) and incubating the plates at 37°C for 24 hr. Each microbial count was the mean of three determinations, and was expressed as log CFU/g.

Color measurements

The color characteristics of the UV-C irradiated samples (not inoculated with *E. sakazakii*) were analyzed using a colorimeter (CR-300 Minolta Chroma Meter, Minolta Camera Co., Osaka, Japan). The samples were placed on a white standard plate and Hunter values (L, a, b) were measured. The Hunter L, a, and b values for the standard plate were L=98.34, a=-0.03, b=1.62, respectively. Three measurements were taken at different locations for each sample.

Sensory evaluation

The UV-C irradiated samples (not inoculated with *E. sakazakii*) were analyzed for their freshness, decay, odor, and overall acceptability by 10 trained panelists (3 men; 7 women; age range, 23 to 29). Color changes and microbial decay during storage were assessed visually in

the UV-C irradiated samples and were compared to non-irradiated samples. The sensory qualities of the samples were evaluated using the following 9-point scoring method: 9～8, very good; 7～6, good; 5～4, fair; 3～2, poor; 1, very poor.

Statistical analysis

To analyze the results, analysis of variance and Duncan's multiple range tests were performed using the SAS program (16). Significance was set at the level of $p<0.05$.

RESULTS AND DISCUSSION

Microbiological changes during storage

From the results, the population of total aerobic bacteria in the *sunsik* samples was 2.94 log CFU/g, while the population of *B. cereus* was below the detection limit (2 CFU/g) (Table 1). In contrast, for the *misutkaru*, these levels were 5.75 and 4.96 log CFU/g, respectively, indicating that the *misutkaru* was contaminated with more bacteria than the *sunsik*. Lee et al. (1) reported that *sunsik* was contaminated with 2～5 log CFU/g of total aerobic bacteria and 3 log CFU/g of *B. cereus*. Cho et al. (2) also reported that *B. cereus* was isolated from 57 out of 161 *sunsik* samples. However, in the present study, *B. cereus* was not detected in the *sunsik* samples. This difference could be attributed to the characteristics of the different samples. Along with these reports, our results suggest that *sunsik* and *misutkaru* need microbial decontamination treatments.

For the *sunsik,* UV-C irradiation decreased the population of total aerobic bacteria (Table 1). In the sample irradiated at 27 kJ/m^2, the population of total aerobic bacteria was reduced to 2.36 log CFU/g, compared to 2.94 log CFU/g for the non-irradiated sample (Table 1). In particular, at irradiation doses of 54 and 108 kJ/m^2, total aerobic bacteria were not detected in the samples. In addition, during storage of the *sunsik*, the population of total aerobic bacteria did not change significantly ($p<0.05$), maintaining the microbial reduction effect of the UV-C. Finally, *B. cereus* was not detected in any of the *sunsik* samples (Table 1).

For the *misutkaru*, populations of total aerobic bacteria and *B. cereus* were reduced to 4.82 and 4.06 log CFU/g with irradiation at 108 kJ/m^2, respectively, indicating that the 108 kJ/m^2 UV-C treatment level decreased the populations of total aerobic bacteria and *B. cereus* by about 1 log cycle (Table 2). During storage of the *misutkaru*, the population of total aerobic bacteria did not change significantly ($p<0.05$), while the populations of *B. cereus* in the non-irradiated and irradiated samples increased. After 8 weeks of storage, populations of *B. cereus* in the non-irradiated samples increased to 5.33 log CFU/g, while those in the samples irradiated at 108 kJ/m^2 reached 4.30 log CFU/g, indicating a slight difference in microbial reduction during storage. Kim et al. (4) reported that the population of *Bacillus* spp. in *saengsik* was reduced by about 5 log CFU/g after gamma irradiation at 10 kGy. Ko et al. (17) also reported on the effects of electron beam irradiation on sliced dried squid at the dose of 8 kGy, which resulted in 2～3 log cycle reductions in yeasts and molds. Thus, compared to gamma or electron beam irradiation, the UV-C irradiation used in this study was less effective for microbial inactivation, yet gamma or electron beam irradiation may have problems such as changes in texture and nutritional components as well as poor consumer acceptance. Therefore, when selecting a non-thermal treatment method for microbial decontamination, one should carefully examine the method according to the purpose of processing and the characteristics of the sample, such as the level of microbial contamination. In addition, it should be noted that UV-C irradiation has greater difficulty in terms of penetration power compared to gamma or elec-

Table 1. Effects of UV-C irradiation on microbial populations in *sunsik* during storage (log CFU/g)

Microorganism	Irradiation dose (kJ/m^2)	Storage period (week)				
		0	1	2	3	4
Total aerobic bacteria	0	2.94^{Aa}	2.95^{Aa}	2.98^{Aa}	2.82^{Aa}	2.85^{Aa}
	27	2.36^{Ba}	2.37^{Ba}	2.39^{Ba}	2.28^{Bb}	2.25^{Bb}
	54	ND	ND	ND	ND	ND
	108	ND	ND	ND	ND	ND
B. cereus	0	ND	ND	ND	ND	ND
	27	ND	ND	ND	ND	ND
	54	ND	ND	ND	ND	ND
	108	ND	ND	ND	ND	ND

^{A,B}Any means in the same column followed by different letters are significantly ($p<0.05$) different by Duncan's multiple range test.
^{a,b}Any means in the same row followed by different letters are significantly ($p<0.05$) different by Duncan's multiple range test.
ND: Not detected within detection limit.

Table 2. Effects of UV-C irradiation on microbial populations in *misutkaru* during storage (log CFU/g)

Microorganism	Irradiation dose (kJ/m^2)	Storage period (week)				
		0	1	2	3	4
Total aerobic bacteria	0	5.75^{Aa}	5.72^{Aa}	5.70^{Aab}	5.63^{Ac}	5.65^{Abc}
	27	5.31^{Ba}	5.24^{Ba}	5.24^{Ba}	5.27^{ABa}	5.29^{Ba}
	54	4.99^{Ca}	5.07^{BCa}	5.04^{BCa}	5.12^{BCa}	5.05^{Ba}
	108	4.82^{Da}	4.86^{Ca}	4.83^{Ca}	4.75^{Ca}	4.72^{Ca}
B. cereus	0	4.96^{Ac}	5.07^{Ab}	5.12^{Ab}	5.37^{Aa}	5.33^{Aa}
	27	4.52^{Bb}	4.56^{Bb}	4.69^{ABb}	5.08^{Aa}	4.95^{ABa}
	54	4.24^{Cc}	4.36^{BCbc}	4.53^{Bab}	4.63^{Ba}	4.69^{BCa}
	108	4.06^{Ca}	4.15^{Ca}	4.25^{Ba}	4.20^{Ca}	4.30^{Ca}

$^{A-D}$Any means in the same column followed by different letters are significantly ($p<0.05$) different by Duncan's multiple range test.
$^{a-d}$Any means in the same row followed by different letters are significantly ($p<0.05$) different by Duncan's multiple range test.

tron beam irradiation.

Choi et al. (3) reported that *E. sakazakii* was isolated from 8 out of 23 samples of *sunsik.* Therefore, we chose to perform a UV-C irradiation study using *sunsik* and *misutkaru* inoculated with *E. sakazakii*. Here, UV-C decreased the population of *E. sakazakii* with increasing radiation doses (Fig. 2). The population of *E. sakazakii* in the *sunsik* treated at 5 kJ/m^2 was reduced to 5.45 log CFU/g, indicating that UV-C at the level of 5 kJ/m^2 decreased *E. sakazakii* by 0.88 log CFU/g, compared to 6.33 log CFU/g for the non-irradiated sample. During storage, the population of *E. sakazakii* for the non-irradiated sample decreased to 5.88 log CFU/g after 8 days, while in the sample irradiated at 5 kJ/m^2 the population reached 4.88 log CFU/g. These differences can be explained by the growth characteristics of *E. sakazakii* with regard to the availability of nutrients and water activity during storage.

A similar result was obtained for the *misutkaru* inoculated with *E. sakazakii* (Fig. 3). The population of *E. sakazakii* in the *misutkaru* treated at 5 kJ/m^2 was reduced to 5.70 log CFU/g, indicating a decrease in the population of *E. sakazakii* by a 1.23 log cycle compared to the non-irradiated sample. In addition, during storage, the population of *E. sakazakii* for the non-irradiated sample decreased to 6.50 log CFU/g after 8 days, while it reached 5.31 log CFU/ in the sample irradiated at 5 kJ/m^2, indicating that the initial microbial inactivation resulting from UV-C treatment was maintained. Lyon et al. (18) reported an approximate 2 log reduction in viable *L. monocytogenes* for broiler breast fillets treated with UV. Also, Kim et al. (19) reported that populations of total aerobic bacteria, yeast, and mold in imported dried fish decreased by 0.8～1.2 log CFU/g after UV-C treatment at 20 kJ/m^2. Yaun et al. (20) also demonstrated that UV-C treatment at 24 mW/cm^2 reduced *E. coli* O157:H7 on the surfaces of apples, lettuce, and tomatoes by 3.3 log CFU/g. These reports are comparable to our results.

The differences in microbial inactivation between the

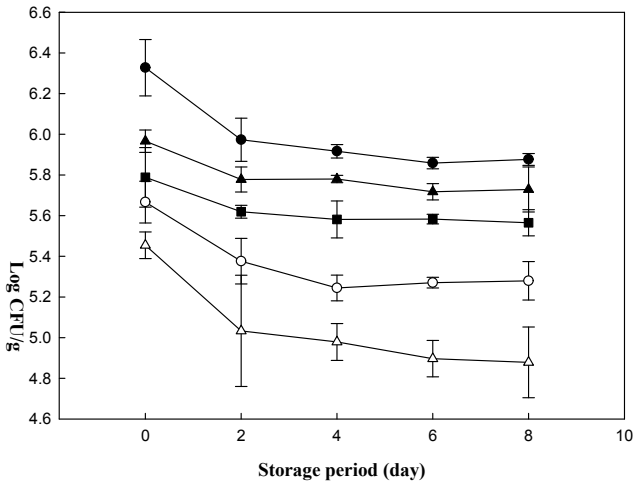

Fig. 2. Effects of UV-C irradiation on the survival of *E. sakazakii* inoculated on *sunsik*. ●: 0 kJ/m^2, ▲: 0.25 kJ/m^2, ■: 0.5 kJ/m^2, ○: 1 kJ/m^2, △: 5 kJ/m^2

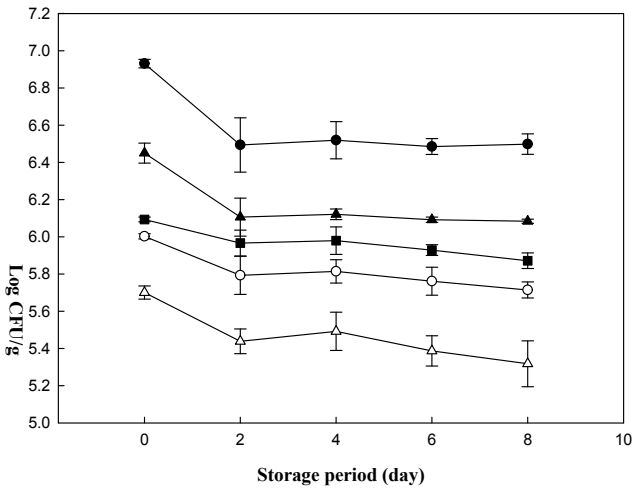

Fig. 3. Effects of UV-C irradiation on the survival of *E. sakazakii* inoculated on *misutkaru*. ●: 0 kJ/m^2, ▲: 0.25 kJ/m^2, ■: 0.5 kJ/m^2, ○: 1 kJ/m^2, △: 5 kJ/m^2

sunsik and *misutkaru* samples can be attributed to variation in their physical properties, solid content, initial populations of microorganisms, and surface topography. In particular, UV-C irradiation is a surface sterilization method, and the different compositions and surface topographies of foods may play an important role in the efficiency of UV-C irradiation in reducing microbial contamination (14,21,22).

Overall, our results suggest that UV-C irradiation can inactivate populations of total aerobic bacteria and *E. sakazakii* in *sunsik* and *misutkaru*, enhancing their microbial safety.

Color changes during storage

Color change during storage is one of the most important factors in determining the quality of *sunsik* and *misutkaru*. The Hunter L, a, and b values of the UV-C irradiated *sunsik* samples are shown in Table 3. After UV-C irradiation, Hunter L and b values were similar among the treatments, while there were slight differences in Hunter a values among the treatments. For the *misutkaru*, Hunter b values were similar among the treatments, while there were slight differences in Hunter L and a values (Table 4). In particular, the Hunter a values of the irradiated *sunsik* and *misutkaru* samples were higher than those of the non-irradiated samples. Kim et al. (19) reported that UV-C irradiation did not affect the color of imported dried fish, which is comparable to our results. On the other hand, Fonseca and Rushing (23) reported that red color fading occurred in UV-C irradiated watermelon cubes, resulting in a higher L value

Table 3. Changes in Hunter color values of UV-C irradiated *sunsik* during storage

Color[1)] parameter	Irradiation dose (kJ/m^2)	Storage period (week)				
		0	1	2	3	4
L	0	74.88 ± 0.45^{Ab}	75.12 ± 0.94^{Ab}	75.06 ± 0.99^{Ab}	76.66 ± 0.99^{Aa}	76.73 ± 0.25^{Ca}
	27	74.72 ± 0.51^{Abc}	74.30 ± 0.38^{Ac}	75.03 ± 0.38^{Ab}	74.98 ± 0.16^{Bb}	76.65 ± 0.12^{Ca}
	54	74.44 ± 0.19^{Ac}	72.34 ± 0.06^{Bd}	74.16 ± 0.80^{ABc}	75.16 ± 0.18^{Bb}	77.79 ± 0.09^{Aa}
	108	74.37 ± 1.00^{Ab}	72.85 ± 0.95^{Bc}	72.79 ± 0.83^{Bc}	74.19 ± 0.26^{Bbc}	77.10 ± 0.24^{Ba}
a	0	-2.54 ± 0.06^{Cd}	-2.10 ± 0.04^{Cc}	-1.40 ± 0.18^{ABa}	-1.77 ± 0.04^{Cb}	-1.68 ± 0.09^{Cb}
	27	-2.41 ± 0.12^{BCc}	-2.08 ± 0.06^{Cb}	-1.43 ± 0.04^{Ba}	-1.42 ± 0.02^{Ba}	-1.50 ± 0.03^{Ba}
	54	-2.31 ± 0.06^{Bd}	-1.74 ± 0.03^{Bc}	-1.21 ± 0.03^{ABa}	-1.42 ± 0.06^{Bb}	-1.48 ± 0.01^{Bb}
	108	-2.08 ± 0.03^{Ac}	-1.47 ± 0.04^{Ab}	-1.01 ± 0.37^{Aa}	-1.01 ± 0.06^{Aa}	-0.98 ± 0.03^{Aa}
b	0	24.49 ± 0.16^{Aa}	23.32 ± 0.54^{Ab}	23.54 ± 0.63^{Ab}	23.34 ± 0.44^{Ab}	22.79 ± 0.25^{Ab}
	27	24.29 ± 0.79^{Aa}	23.24 ± 0.62^{Ab}	22.54 ± 0.39^{ABb}	23.15 ± 0.07^{Ab}	22.66 ± 0.25^{Ab}
	54	23.39 ± 0.25^{ABa}	23.56 ± 0.17^{Aa}	21.80 ± 0.66^{Bb}	23.34 ± 0.21^{Aa}	21.74 ± 0.20^{Bb}
	108	23.02 ± 0.86^{Bab}	22.83 ± 0.32^{Aab}	21.33 ± 0.79^{Bc}	23.48 ± 0.06^{Aa}	22.23 ± 0.45^{ABbc}

[1)]L, degree of whiteness (0 black～100 white); a, degree of redness (-80 greenness～100 redness); b, degree of yellowness (-80 blue～70 yellowness).
[A-C]Any means in the same column followed by different letters are significantly ($p<0.05$) different by Duncan's multiple range test.
[a-d]Any means in the same row followed by different letters are significantly ($p<0.05$) different by Duncan's multiple range test.

Table 4. Changes in Hunter color values of UV-C irradiated *misutkaru* during storage

Color[1)] parameter	Irradiation dose (kJ/m^2)	Storage period (week)				
		0	1	2	3	4
L	0	77.34 ± 0.26^{Ab}	77.58 ± 0.03^{Ab}	77.63 ± 0.38^{Ab}	77.89 ± 0.49^{Ab}	79.15 ± 0.49^{Aa}
	27	76.25 ± 0.20^{BCc}	77.42 ± 0.32^{Ab}	76.93 ± 0.51^{Bbc}	77.80 ± 0.83^{Ab}	79.68 ± 0.19^{Aa}
	54	76.58 ± 0.23^{Bbc}	76.12 ± 0.11^{Cc}	76.29 ± 0.17^{Bbc}	77.10 ± 0.71^{ABab}	77.94 ± 0.69^{Ba}
	108	75.87 ± 0.22^{Ca}	76.61 ± 0.29^{Ba}	76.30 ± 0.28^{Ba}	76.19 ± 0.25^{Ba}	76.59 ± 0.71^{Ca}
a	0	2.39 ± 0.08^{Cb}	2.31 ± 0.10^{Bb}	2.46 ± 0.08^{Ab}	2.48 ± 0.17^{Bb}	2.76 ± 0.04^{Aa}
	27	2.55 ± 0.08^{Bb}	2.44 ± 0.02^{Bbc}	2.29 ± 0.09^{Bc}	2.48 ± 0.11^{Bb}	2.74 ± 0.12^{Aa}
	54	2.61 ± 0.08^{Bab}	2.63 ± 0.09^{Aab}	2.43 ± 0.05^{Ab}	2.61 ± 0.09^{ABab}	2.68 ± 0.23^{Aa}
	108	2.90 ± 0.05^{Aa}	2.62 ± 0.04^{Abc}	2.51 ± 0.07^{Ac}	2.80 ± 0.15^{Aab}	2.96 ± 0.13^{Aa}
b	0	20.58 ± 0.37^{Aa}	20.09 ± 0.09^{Cb}	20.80 ± 0.05^{Aa}	19.93 ± 0.10^{Ab}	19.98 ± 0.09^{Ab}
	27	20.59 ± 0.13^{Aa}	20.28 ± 0.20^{BCa}	20.34 ± 0.30^{Ba}	19.68 ± 0.56^{Ab}	19.31 ± 0.20^{Bb}
	54	20.85 ± 0.25^{Aa}	20.52 ± 0.22^{ABa}	20.49 ± 0.27^{ABa}	20.06 ± 0.11^{Ab}	19.48 ± 0.26^{Bc}
	108	20.74 ± 0.07^{Aa}	20.61 ± 0.08^{Aa}	20.68 ± 0.20^{ABa}	20.05 ± 0.50^{Ab}	19.50 ± 0.37^{Bc}

[1)]L, degree of whiteness (0 black～100 white); a, degree of redness (-80 greenness～100 redness); b, degree of yellowness (-80 blue～70 yellowness).
[A-C]Any means in the same column followed by different letters are significantly ($p<0.05$) different by Duncan's multiple range test.
[a-d]Any means in the same row followed by different letters are significantly ($p<0.05$) different by Duncan's multiple range test.

and lower a and b values compared to the control. These differences could be attributed to differences in food composition such as moisture, fiber, crude protein, and lipid.

Sensory evaluation during storage

The sensory evaluation results during storage of the *sunsik* and *misutkaru* samples are shown in Tables 5 and 6, respectively. Sensory qualities such as freshness, decay, and odor were examined among the treatments. During 4 weeks of storage there were no significant ($p<0.05$) differences among the treatments. In particular, after 4 weeks, the sensory scores were higher than 8.4, indicating there were no significant ($p<0.05$) differences among the treatments. Allende et al. (14) also reported no significant differences in sensory quality among UV-C irradiated and non-irradiated lettuce samples. Our results are comparable to their results.

In summary, this study clearly indicates that UV-C irradiation can decrease populations of microorganisms in *sunsik* and *misutkaru* samples during storage, and therefore can improve the microbial safety of these products. In addition, UV-C treatment appears to be ef-

Table 5. Sensory evaluations of UV-C irradiated *sunsik* during storage

Organoleptic parameter	Irradiation dose (kJ/m^2)	Storage period (week)				
		0	1	2	3	4
Freshness	0	9.00 ± 0.00^{Aa}	9.00 ± 0.00^{Aa}	8.90 ± 0.32^{Aa}	8.70 ± 0.48^{Aab}	8.40 ± 0.52^{Ab}
	27	9.00 ± 0.00^{Aa}	9.00 ± 0.00^{Aa}	8.90 ± 0.32^{Aa}	8.70 ± 0.48^{Aab}	8.50 ± 0.53^{Ab}
	54	9.00 ± 0.00^{Aa}	9.00 ± 0.00^{Aa}	8.90 ± 0.32^{Aa}	8.80 ± 0.42^{Aab}	8.50 ± 0.53^{Ab}
	108	9.00 ± 0.00^{Aa}	9.00 ± 0.00^{Aa}	8.90 ± 0.32^{Aa}	8.80 ± 0.42^{Aab}	8.50 ± 0.53^{Ab}
Decay	0	9.00 ± 0.00^{Aa}	9.00 ± 0.00^{Aa}	8.90 ± 0.32^{Aa}	8.80 ± 0.42^{Aa}	8.70 ± 0.48^{Aa}
	27	9.00 ± 0.00^{Aa}	9.00 ± 0.00^{Aa}	9.00 ± 0.00^{Aa}	8.90 ± 0.32^{Aa}	8.80 ± 0.42^{Aa}
	54	9.00 ± 0.00^{Aa}	9.00 ± 0.00^{Aa}	9.00 ± 0.00^{Aa}	8.90 ± 0.32^{Aa}	8.80 ± 0.42^{Aa}
	108	9.00 ± 0.00^{Aa}	9.00 ± 0.00^{Aa}	9.00 ± 0.00^{Aa}	8.90 ± 0.32^{Aa}	8.80 ± 0.42^{Aa}
Odor	0	9.00 ± 0.00^{Aa}	9.00 ± 0.00^{Aa}	8.80 ± 0.42^{Aab}	8.70 ± 0.48^{Aab}	8.50 ± 0.53^{Ab}
	27	9.00 ± 0.00^{Aa}	9.00 ± 0.00^{Aa}	8.90 ± 0.32^{Aa}	8.80 ± 0.42^{Aab}	8.50 ± 0.53^{Ab}
	54	9.00 ± 0.00^{Aa}	9.00 ± 0.00^{Aa}	8.90 ± 0.32^{Aa}	8.80 ± 0.42^{Aab}	8.50 ± 0.53^{Ab}
	108	9.00 ± 0.00^{Aa}	9.00 ± 0.00^{Aa}	8.90 ± 0.32^{Aa}	8.80 ± 0.42^{Aab}	8.50 ± 0.53^{Ab}
Overall	0	9.00 ± 0.00^{Aa}	9.00 ± 0.00^{Aa}	8.90 ± 0.32^{Aa}	8.80 ± 0.42^{Aa}	8.40 ± 0.52^{Ab}
	27	9.00 ± 0.00^{Aa}	9.00 ± 0.00^{Aa}	8.90 ± 0.32^{Aa}	8.80 ± 0.42^{Aab}	8.50 ± 0.53^{Ab}
	54	9.00 ± 0.00^{Aa}	9.00 ± 0.00^{Aa}	8.90 ± 0.32^{Aa}	8.80 ± 0.42^{Aab}	8.50 ± 0.53^{Ab}
	108	9.00 ± 0.00^{Aa}	9.00 ± 0.00^{Aa}	8.90 ± 0.32^{Aa}	8.80 ± 0.42^{Aab}	8.50 ± 0.53^{Ab}

[A]Any means in the same column followed by different letters are significantly ($p<0.05$) different by Duncan's multiple range test.
[a,b]Any means in the same row followed by different letters are significantly ($p<0.05$) different by Duncan's multiple range test.

Table 6. Sensory evaluations of UV-C irradiated *misutkaru* during storage

Organoleptic parameter	Irradiation dose (kJ/m^2)	Storage period (week)				
		0	1	2	3	4
Freshness	0	9.00 ± 0.00^{Aa}	9.00 ± 0.00^{Aa}	8.90 ± 0.32^{Aa}	8.80 ± 0.42^{Aa}	8.40 ± 0.52^{Ab}
	27	9.00 ± 0.00^{Aa}	9.00 ± 0.00^{Aa}	8.90 ± 0.32^{Aa}	8.80 ± 0.42^{Aab}	8.50 ± 0.53^{Ab}
	54	9.00 ± 0.00^{Aa}	9.00 ± 0.00^{Aa}	8.90 ± 0.32^{Aa}	8.80 ± 0.42^{Aab}	8.50 ± 0.53^{Ab}
	108	9.00 ± 0.00^{Aa}	9.00 ± 0.00^{Aa}	8.90 ± 0.32^{Aa}	8.80 ± 0.42^{Aab}	8.50 ± 0.53^{Ab}
Decay	0	9.00 ± 0.00^{Aa}	9.00 ± 0.00^{Aa}	8.90 ± 0.32^{Aa}	8.80 ± 0.42^{Aa}	8.80 ± 0.42^{Aa}
	27	9.00 ± 0.00^{Aa}	9.00 ± 0.00^{Aa}	8.90 ± 0.32^{Aa}	8.90 ± 0.32^{Aa}	8.80 ± 0.42^{Aa}
	54	9.00 ± 0.00^{Aa}	9.00 ± 0.00^{Aa}	8.90 ± 0.32^{Aa}	8.90 ± 0.32^{Aa}	8.80 ± 0.42^{Aa}
	108	9.00 ± 0.00^{Aa}	9.00 ± 0.00^{Aa}	8.90 ± 0.32^{Aa}	8.90 ± 0.32^{Aa}	8.80 ± 0.42^{Aa}
Odor	0	9.00 ± 0.00^{Aa}	9.00 ± 0.00^{Aa}	8.80 ± 0.42^{Aab}	8.70 ± 0.48^{Aab}	8.50 ± 0.53^{Ab}
	27	9.00 ± 0.00^{Aa}	9.00 ± 0.00^{Aa}	8.90 ± 0.32^{Aa}	8.80 ± 0.42^{Aab}	8.50 ± 0.53^{Ab}
	54	9.00 ± 0.00^{Aa}	9.00 ± 0.00^{Aa}	8.90 ± 0.32^{Aa}	8.80 ± 0.42^{Aab}	8.50 ± 0.53^{Ab}
	108	9.00 ± 0.00^{Aa}	9.00 ± 0.00^{Aa}	8.80 ± 0.42^{Aab}	8.70 ± 0.48^{Aab}	8.50 ± 0.53^{Ab}
Overall	0	9.00 ± 0.00^{Aa}	9.00 ± 0.00^{Aa}	8.90 ± 0.32^{Aa}	8.80 ± 0.42^{Aab}	8.50 ± 0.53^{Ab}
	27	9.00 ± 0.00^{Aa}	9.00 ± 0.00^{Aa}	8.90 ± 0.32^{Aa}	8.80 ± 0.42^{Aab}	8.50 ± 0.53^{Ab}
	54	9.00 ± 0.00^{Aa}	9.00 ± 0.00^{Aa}	8.90 ± 0.32^{Aa}	8.80 ± 0.42^{Aab}	8.50 ± 0.53^{Ab}
	108	9.00 ± 0.00^{Aa}	9.00 ± 0.00^{Aa}	8.90 ± 0.32^{Aa}	8.80 ± 0.42^{Aab}	8.50 ± 0.53^{Ab}

[A]Any means in the same column followed by different letters are significantly ($p<0.05$) different by Duncan's multiple range test.
[a,b]Any means in the same row followed by different letters are significantly ($p<0.05$) different by Duncan's multiple range test.

fective in maintaining the quality of *sunsik* and *misutkaru* during storage.

ACKNOWLEDGEMENTS

This work was supported by the Youlchon Foundation, Korea.

REFERENCES

1. Lee EJ, Kim SG, Yoo SR, Oh SS, Hwang IG, Kwon GS, Park JH. 2007. Microbial contamination by *Bacillus cereus*, *Clostridium perfringens*, and *Enterobacter sakazakii* in *sunsik*. *Food Sci Biotechnol* 16: 948-953.
2. Cho YS, Jung EY, Lee MK, Yang CY, Shin DB. 2008. Survival, isolation and characterization of *Bacillus cereus* from *sunshik*. *J Food Hyg Safety* 23: 343-347.
3. Choi JW, Kim YJ, Lee JK, Kim YH, Kwon KS, Hwang IG, Oh SW. 2008. Multiple confirmation and RAPD-genotyping of *Enterobacter sakazakii* isolated from *sunsik*. *Korean J Food Sci Technol* 40: 101-105.
4. Kim DH, Song HP, Yook HS, Chung YJ, Kim YJ, Byun MW. 2002. Distribution of microflora in powdered raw grains and vegetables and improvement of hygienic quality by gamma irradiation. *J Korean Soc Food Sci Nutr* 31: 589-593.
5. Kim JB, Park YB, Lee MJ, Kim KC, Huh JW, Kim DH, Lee JB, Kim JC, Choi JH, Oh DH. 2008. Effect of hot water and microwave heating on the inactivation of *Enterobacter sakazakii* in reconstituted powdered infant formula and *sunsik*. *J Food Hyg Safety* 23: 157-162.
6. Staack N, Ahrne L, Borch E, Knorr D. 2008. Effect of infrared heating on quality and microbial decontamination in paprika powder. *J Food Eng* 86: 17-24.
7. Cho HO, Kwon JH, Byun MW, Kim YJ, Yang JS. 1986. Effect of ethylene oxide fumigation and gamma irradiation on the quality of ground red and black peppers. *Korean J Food Sci Technol* 18: 294-300.
8. Lee SH, Lee HJ, Byun MW. 1997. Effect of ozone treatment and gamma irradiation on the microbial decontamination and physicochemical properties of red pepper powder. *J Korean Soc Food Sci Nutr* 26: 462-467.
9. Mok CK, Lee NH. 2008. Distribution of ultraviolet intensity and UV leaking of commercial UV sterilizers used in restaurants. *Korean J Food Sci Technol* 40: 228-233.
10. Devine DA, Keech AP, Wood DJ, Killington RA, Boyes H, Doubleday B, Marsh PD. 2001. Ultraviolet disinfection with a novel microwave-powered device. *J Appl Microbiol* 91: 786-794.
11. Lamikanra O, Kueneman D, Ukuku D, Bett-Garber KL. 2005. Effect of processing under ultraviolet light on the shelf life of fresh-cut cantaloupe melon. *J Food Sci* 70: 534-539.
12. Keyser M, Muller IA, Cilliers FP, Nel W, Gouws PA. 2008. Ultraviolet radiation as a non-thermal treatment for the inactivation of microorganisms in fruit juice. *Innov Food Sci Emerg Technol* 9: 348-354.
13. Allende A, Artes F. 2003. UV-C radiation as a novel technique for keeping quality of fresh processed 'Lollo Rosso' lettuce. *Food Res Int* 36: 739-746.
14. Allende A, McEvoy JL, Luo Y, Artes F, Wang CY. 2006. Effectiveness of two-sided UV-C treatments in inhibiting natural microflora and extending the shelf-life of minimally processed 'Red Oak Leaf' lettuce. *Food Microbiol* 23: 241-249.
15. US Food and Drug Administration. 2007. Irradiation in the production, processing and handling of food. 21CFR. part 179.39. Code of Federal Regulations 3. p 439-440.
16. SAS Institute. 2001. *SAS system for windows*. Version 8.2, SAS Institute, Inc., Cary, NC, USA.
17. Ko JK, Ma YH, Song KB. 2005. Effect of electron beam irradiation on the microbial safety and qualities of sliced dried squid. *J Korean Soc Food Sci Nutr* 34: 433-437.
18. Lyon SA, Fletcher DL, Berrang ME. 2007. Germicidal ultraviolet light to lower numbers of *Listeria monocytogenes* on broiler breast fillets. *Poult Sci* 86: 964-967.
19. Kim JY, Chun HH, Song KB. 2008. Effect of UV-C irradiation on the quality of imported dried fish during storage. *Korean J Food Preserv* 15: 922-926.
20. Yaun BR, Sumner SS, Eifert JD, Marcy JE. 2004. Inhibition of pathogens on fresh produce by ultraviolet energy. *Int J Food Microbiol* 90: 1-8.
21. Woodling SE, Moraru CI. 2005. Influence of surface topography on the effectiveness of pulsed light treatment for the inactivation of *Listeria innocua* on stainless-steel surfaces. *J Food Sci* 70: 345-351.
22. Sastry SK, Datta AK, Worobo RW. 2000. Ultraviolet light. *J Food Sci Suppl* 65: 90-92.
23. Fonseca JM, Rushing JW. 2006. Effect of ultraviolet-C light on quality and microbial population of fresh-cut watermelon. *Postharvest Biol Technol* 40: 256-261.

(Received March 17, 2009; Accepted July 30, 2009)