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ARTICLE

Combined Effect of Kimchi Powder and Onion Peel Extract on Quality Characteristics of Emulsion Sausages Prepared with Irradiated Pork

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Abstract

This study was conducted to investigate the effects of kimchi powder and onion peel extract on the quality characteristics of emulsion sausage manufactured with irradiated pork. The emulsion sausages were formulated with 2% kimchi powder and/or 0.05% onion peel extract. The changes in pH value of all treatments were similar, depending on storage periods. The addition of kimchi powder increased the redness and yellowness of the emulsion sausage. The addition of onion peel extract decreased the thiobarbituric acid reactive substances value of the emulsion sausages prepared with irradiated pork. The volatile basic nitrogen value of the emulsion sausage prepared with kimchi powder was the highest, whereas that of the emulsion sausage prepared with onion peel extract was the lowest. The treatment without kimchi powder or onion peel extract and the treatments prepared with onion peel extract showed lower microbial populations than the other treatment. Sensory evaluations indicated that a higher acceptability was attained when kimchi powder was added to the emulsion sausages manufactured with irradiated pork. In conclusion, our results suggest that combined use of kimchi powder and onion peel extract could improve quality characteristics and shelf stability of the emulsion sausage formulated with irradiated pork during chilled storage.

Keywords: emulsion sausage, irradiation, kimchi, onion peel

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Introduction

Food irradiation is one of technologies for improving the shelf-stability of meat and meat products during storage. Irradiation, involving various chemical changes on microorganism, has indirect and direct effects. Indirect effects cause the destruction of deoxyribonucleic acid (DNA) molecule, and direct effects result in the formation of free radicals from water in the DNA surroundings (Molins, 2001). Although both effects lead to the inhibition of pathogenic microorganism growth, and extend shelf-life, irradiation can accelerate lipid oxidation and produce off-flavor in meat products (Ahn *et al*., 2000). To solve these problems in irradiated meat and meat products, many researchers have attempted to use natural antioxidants (Du *et al*., 2000; Ismail *et al*., 2008; Mohamed *et al*., 2011) and modify packaging method (Ahn *et al.,* 1998; Ahn *et al*., 2001).

Kimchi is a traditional fermented food in Korea and contains vitamin C, carotene, and phenol compounds etc., and provides anticancer effects, hypertension prevention, and antioxidative effect (Lee *et al*., 2008). Kimchi has a specific flavor due to the presence of free amino acids, organic acids, and saccharide etc., which are produced during fermentation. For this reason, kimchi has been used to improve the flavor of meat products, and Lee *et al*. (2008) reported that the quality of meat products, including off-odor, was improved through the addition of kimchi, and the color of meat product was also affected by adding hot air dried kimchi powder. However, a number of previous studies have reported that kimchi acts as a pro-oxidant in some situations. Lee and Kunz (2005) reported that the effect of kimchi on lipid oxidation

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depends on its fermentation temperature. Choi (2012) reported that although kimchi powder masked the flavor and off-odor induced by irradiation, it also led to the acceleration of lipid oxidation in irradiated pork sausage. Also, Kim *et al*. (2014) reported that the combined use of kimchi powder and smoking technique could improve the quality characteristics and shelf life of cooked sausages formulated with irradiated pork.

The antioxidant activity of onion is widely known, and previous studies have reported that onion exerts an antioxidative effect due to its flavonol and phenolic content (Huber *et al*., 2009). Especially, the outer dry layer of onion showed the great antioxidative properties, because the concentration of quercetin, one of the flavonols in onion peel, is higher here than in others part (Prakash *et al*., 2007). Shim *et al.* (2012) reported that onion peel ethanol extracts inhibited the lipid oxidation of ground pork meat.

Therefore, the objectives of this study were to evaluate the effects of hot air dried kimchi powder and onion peel extract on the quality characteristics of emulsion type sausages formulated with irradiated pork, for improving shelf stability during chilled storage.

Materials and Methods

Gamma irradiated meat preparation

Fresh pork ham (*Musculus biceps femoris, M. emitendinosus, M. semimembranosus*) and back fat were purchased in a local market. All subcutaneous, intermuscular fat and visible connective tissue were removed from the fresh pork muscles. Trimmed muscles were ground through an 8 mm plate, after which the ground tissue was placed in polyethylene bags, vacuum-packaged using a vacuum packaging system (FJ-500XL, Fugee Tech, Korea) and stored -20°C until irradiation.

The meat was irradiated at 10 kGy in a cobalt-60 irradiator (point source, AECL, IR-79, Nordion international, Canada) with source strength of 100 kCi in Advanced Radiation Technology Institute of Korea Atomic Energy Research Institute (Korea). The dose rate was 10 kGy/h at 18±0.5°C. Dosimetry was performed using 5 mm diameter alanine dosimeters (Bruker Instruments, Germany), and the free-radical signal was measured using a Bruker EMS 104 EPR Analyzer. The actual dose was within ±2% of the target dose. The irradiated ground pork meat was transferred to a refrigerator and stored until required for product manufacture within 3 d.

Preparation of onion peel extract and kimchi powder

Onion peel extract was prepared as described by Shim *et al*. (2012). Onions were obtained from a local market. The onions were washed, the onion peels were dried for 8 h at 50°C in a hot air drier (Enex-CO-600, Enex, Korea), powdered (35 mesh), and stored in polythene bags at 4°C. Dried onion powder was extracted with 50% ethanol overnight on a shaker at room temperature. The extract was filtered through filter paper (Ø110 mm, No. 1, Whatman Inc., UK) and evaporated with a rotary evaporator (EYELA N-1000, Rikakikai Co. Ltd., Japan) below 55°C. After evaporation the ethanol, the onion peel ethanol extracts were dissolved in distilled water to adjust identical solid concentration in extract (5 mg/mL). Commercial Chinese cabbage kimchi was purchased from a local market (Chongga Kimchi, Daesang FNF, Korea). Kimchi powder was prepared with the method of Lee *et al*. (2008) and stored in a 4°C refrigerator until manufacturing sausage.

Manufacturing of emulsion type pork sausage

Emulsion type pork sausages were manufactured with following formulation: 60% lean pork meat, 20% pork back fat, 20% ice water, nitrite pickled salt (NPS, 1.5%), sodium tripolyphosphate (0.3%), monosodium L-glutamate (0.06%), onion powder (0.3%), garlic powder (0.3%). Control treatment was manufactured with non-irradiated pork meat and the other treatments were manufactured with irradiated pork meat. Control and IR treatments were prepared without onion peel extract or kimchi powder. IRO treatment contained 0.05% onion peel extract and IRK treatment contained 2% kimchi powder. IROK treatment contained both 0.05% onion peel extract and 2% kimchi powder. Meat, fat, water and other ingredients were emulsified using a silent cutter (Nr-963009, Scharfen, Germany). After emulsification, the meat batter was stuffed into collagen casings (#240, NIPPI Inc., Japan; approximate 25 mm diameter) using a stuffer (IS-8, Sirman, Italy), and then were heated at 80°C until 75°C at core temperature for 30 min in smoke house. The cooked sausages were cooled and vacuum-packaged. All samples were stored in a 4°C refrigerator until use.

pH measurement

The pH values of cooked samples were determined with a pH meter (Model 340, Mettler-Toledo GmbH, Switzerland). The pH values were measured by blending a 5 g sample with 20 mL distilled water for 1 min in a homogenizer (Ultra-Turrax T25, Janke & Kunkel, Ger-

many).

Instrumental color evaluation

The instrumental color of each cooked samples was determined using a colorimeter (Minolta Chroma meter CR-210, Japan; illuminate C, calibrated with a white plate, CIE L*=+97.83, a*=-0.43, b*=+1.98), and are reported in the CIE system values of lightness (CIE L*), redness (CIE a*), and yellowness (CIE b*).

Thiobarbituric acid reactive substance (TBARS)

TBARS was measured by the modified 2-thiobarbituric acid extraction method of Witte *et al*. (1970). TBARS were calculated as mg of malondialdehyde (MDA) per kg sample.

Volatile basic nitrogen (VBN)

Volatile basic nitrogen was determined by the Conway micro-diffusion method according to Pearson (1968), and was express as mg% of sample. The VBN value was then calculated using the following equation.

$$\text{VBN (mg\%)} = [\{(a - b) \times f \times 28.014\} / S] \times 100$$

Where S is the sample weight in grams, a is the volume (mL) of added H_2SO_4 in sample and b is the volume (mL) of added H_2SO_4 in blank, and f is the standard factor of H_2SO_4.

Total plate count

To determine the bacterial count for each sample, 10 g of the sample was aseptically transferred into a sterile stomacher bag and 100 mL of sterile 0.1% peptone water (Difco, USA) was added. The sample was then homogenized in a stomacher (Masticater-Paddle-Blender, IUL Instrument, Spain) for 2 min at normal speed and aliquots were plated out directly at 1:10 dilution in 0.1% peptone water. After serially diluting each sample in sterile peptone water, 0.1 mL portions were separately plated onto plates. The total bacterial count was determined on plate count agar (PCA, Difco, USA) at 35°C for 48 h. Microbial colonies were counted and expressed as Log CFU (colony forming units)/g sample of sausage.

Sensory evaluations

The sensory evaluations were performed in duplicate on each sausage by sensory panelist. A trained ten-member panel was used to evaluate the emulsion type cooked sausage made with irradiated pork meat. The samples were cut into 10 mm slices and served to the panels when samples were at room temperature. The sausages were evaluated for color, flavor, tenderness, off-flavor and overall acceptability using a 10 point horizontal scale.

Statistical analysis

An analysis of variance were performed on all the variables measured using the General Linear Model (GLM) procedure of the SAS statistical package (SAS, 2008). Duncan's multiple range test ($p<0.05$) was used to determine differences between treatment means.

Results and Discussion

pH value of emulsion sausages during chilled storage

The effects of kimchi powder and onion peel extract on the changes in the pH value of emulsion sausages prepared with irradiated pork are presented in Table 1. Immediately after manufacture, the emulsion sausage prepared with kimchi powder (IRK and IROK treatments) showed slightly lower pH values than the other treatments. Similarly, Lee *et al*. (2008) reported that breakfast sausages containing freeze dried kimchi powder or hot air dried kimchi powder reduced the pH value of the breakfast sausages due to the pH reduction by the kimchi powder. In addition, Choi (2012) reported that the reduction in pH value due to the addition of kimchi powder was observed for the emulsion sausages prepared with irradiated pork. During storage period, the pH values of all treatments increased for 1 wk and decreased thereafter. Generally, the change in pH value of meat products during storage gradually decreased due to the growth of lactic acid bacteria during storage (Fernandez-Lopez *et al*., 2008). Han *et al*. (2006) reported a similar result that the pH of oriental medicinal seasoned pork slightly increased at the early storage and then gradually decreased. In this study, at the final storage time (4 wk), IRK and IROK treatments still showed the decreased pH values when compared to the other treatments. Thus, this result suggests that the addition of kimchi powder greatly influence on the change in pH value during storage period of emulsion sausages prepared with irradiated pork.

Color of emulsion sausages during chilled storage

The effects of kimchi powder and onion peel extract on color of emulsion sausage prepared with irradiated pork are shown in Table 2. CIE L* value (lightness) of IRK and IRKO treatments were lower than the other treat-

Table 1. Effects of kimchi powder and onion peel extract on the pH values of emulsion sausages prepared with irradiated pork during chilled storage

Storage period (wks)	Con	Treatments[1)]			
		IR	IRO	IRK	IROK
0	6.28±0.02^{Ac}	6.29±0.01^{Ab}	6.29±0.01^{Ab}	6.27±0.01^{Abc}	6.25±0.01^{Babc}
1	6.32±0.01^{Ba}	6.37±0.04^{Aa}	6.34±0.01^{ABa}	6.33±0.01^{Ba}	6.29±0.03^{Ca}
2	6.28±0.02^{Bbc}	6.34±0.03^{Aa}	6.28±0.01^{Bc}	6.28±0.01^{Bb}	6.26±0.04^{Bab}
3	6.30±0.02^{Aab}	6.26±0.01^{Bbc}	6.23±0.01^{Cd}	6.27±0.02^{ABbc}	6.22±0.04^{Cbc}
4	6.25±0.01^{Ad}	6.24±0.01^{ABc}	6.22±0.01^{BCd}	6.25±0.02^{Ac}	6.20±0.03^{Cc}

All values are mean±SD.
$^{A-C}$Mean sharing different letters in the same row are significantly different (p<0.05).
$^{a-d}$Mean sharing different letters in the same column are significantly different (p<0.05).
[1)]Treatments: Con, non-irradiated pork; IR, 10 kGy irradiated pork; IRO, 10 kGy irradiated pork and 0.05% onion peel extract; IRK, 10 kGy irradiated pork and 0.5% kimchi powder; IROK, 10 kGy irradiated pork, 0.05% onion peel extract, and 0.5% kimchi powder.

Table 2. Effects of kimchi powder and onion peel extract on the instrumental color of emulsion sausages prepared with irradiated pork during chilled storage

Traits	Storage period (wks)	Con	Treatments[1)]			
			IR	IRO	IRK	IROK
CIE L* (lightness)	0	77.59±0.65^{A}	77.57±1.11^{Ac}	77.71±0.51^{Ab}	74.63±0.36^{Bc}	74.73±1.04^{Bc}
	1	77.81±1.07^{B}	78.88±0.52^{Aab}	78.06±0.63^{ABab}	75.65±0.60^{Cb}	74.75±0.81^{Dc}
	2	78.37±0.69^{AB}	79.09±0.53^{Aa}	78.27±0.83^{Bab}	78.64±0.48^{ABa}	75.15±0.56^{Cbc}
	3	77.72±0.56^{B}	78.01±0.60^{Bbc}	78.65±0.29^{Aa}	75.81±0.42^{Cb}	75.97±0.29^{Cab}
	4	78.18±0.79^{B}	78.92±0.57^{Aa}	78.81±0.56^{ABa}	75.40±0.83^{Db}	76.71±0.46^{Ca}
CIE a* (redness)	0	3.29±0.11^{Bab}	2.76±0.15^{Ca}	2.81±0.08^{Ca}	4.36±0.18^{Aa}	4.38±0.18^{A}
	1	3.41±0.19^{Ba}	2.58±0.12^{Cb}	2.81±0.09^{Cab}	4.46±0.13^{Aa}	4.47±0.34^{A}
	2	3.16±0.10^{Bc}	2.46±0.10^{Dbc}	2.77±0.06^{Cabc}	2.79±0.10^{Cb}	4.23±0.24^{A}
	3	3.26±0.11^{Babc}	2.54±0.16^{Dbc}	2.66±0.16^{Cbc}	4.48±0.22^{Aa}	4.54±0.20^{A}
	4	3.21±0.06^{Bbc}	2.42±0.05^{Dc}	2.66±0.10^{Cc}	4.43±0.28^{Aa}	4.29±0.25^{A}
CIE b* (yellowness)	0	10.30±0.22^{Cb}	10.51±0.23^{CBc}	10.66±0.18^{Bc}	17.87±0.22^{Ab}	17.85±0.40^{Ac}
	1	10.74±0.20^{Ba}	11.00±0.17^{Ba}	10.99±0.19^{Bab}	18.36±0.25^{Aa}	18.51±0.54^{Aab}
	2	10.79±0.28^{Ca}	10.77±0.20^{Cbc}	10.92±0.19^{BCb}	11.05±0.16^{Bc}	18.01±0.51^{Abc}
	3	10.70±0.16^{Ca}	10.87±0.37^{BCab}	11.10±0.17^{Ba}	18.35±0.31^{Aa}	18.55±0.32^{Aa}
	4	10.75±0.12^{Ba}	10.87±0.09^{Bab}	10.92±0.21^{Bab}	18.34±0.27^{Aa}	18.50±0.25^{Aab}

All values are mean±SD.
$^{A-D}$Mean sharing different letters in the same row are significantly different (p<0.05).
$^{a-c}$Mean sharing different letters in the same column are significantly different (p<0.05).
[1)]Treatments: Con, non-irradiated pork; IR, 10 kGy irradiated pork; IRO, 10 kGy irradiated pork and 0.05% onion peel extract; IRK, 10 kGy irradiated pork and 0.5% kimchi powder; IROK, 10 kGy irradiated pork, 0.05% onion peel extract, and 0.5% kimchi powder.

ments. Also, adding kimchi powder led to an increase in CIE a* (redness) and b* (yellowness) values. These results indicate that the red color of kimchi powder affects the color of emulsion sausage made with irradiated pork. As a similar result, Lee *et al*. (2008) reported that the redness and yellowness of breakfast sausage increased with increasing concentration of kimchi powder. On the other hand, the redness of emulsion sausage prepared with irradiated pork and onion peel extract was lower than that of the control (non-irradiated treatment).

Generally, nitrites are extensively used to develop cured pink color. Nitrite is combined with myoglobin to form nitrosomyoglobin which is converted to the nitrosomyochromogen (cured pink color pigment) by cooking. Interestingly, previous studies reported that irradiation caused the changes in meat color. Nam and Ahn (2002) suggested that the change of oxidative status of heme-iron and the production of new gaseous ligand compounds can affect the color of meat, because fresh meat color is influenced by the status of heme-iron and the sixth ligand of myoglobin. Irradiation produced carbon monoxide (CO) gas and the authors further speculated that CO-myoglobin is a major factor affecting the increased red or pink color in irradiated turkey breast. On the other hand, Choi (2012) presented that the redness of sausage decreased due to irradiation of pork, and suggested that the reason for decreased redness of sausage prepared with irradiated pork is the denaturation of myoglobin, resulting in the

Table 3. Effects of kimchi powder and onion peel extract on thiobarbituric reactive substances (TBARS, mg MDA / kg meat) value of emulsion sausages prepared with irradiated pork during chilled storage

Storage period (wks)	Con	Treatments[1)]			
		IR	IRO	IRK	IROK
0	0.34±0.01^{Ce}	0.47±0.03^{Ac}	0.33±0.01^{CDd}	0.40±0.02^{Bd}	0.30±0.01^{Dc}
1	0.38±0.03^{Cd}	0.52±0.02^{ABc}	0.40±0.02^{Cc}	0.54±0.02^{Ac}	0.47±0.05^{Bb}
2	0.42±0.01^{Cc}	0.58±0.02^{Ab}	0.43±0.02^{Cc}	0.57±0.02^{Ab}	0.48±0.03^{Bb}
3	0.53±0.02^{Bb}	0.62±0.04^{Ab}	0.50±0.03^{Bb}	0.60±0.01^{Ab}	0.52±0.01^{Bb}
4	0.62±0.02^{Ba}	0.73±0.01^{Aa}	0.61±0.01^{Ba}	0.70±0.02^{Aa}	0.64±0.04^{Ba}

All values are mean±SD.
$^{A-D}$Mean sharing different letters in the same row are significantly different (p<0.05).
$^{a-e}$Mean sharing different letters in the same column are significantly different (p<0.05).
[1)]Treatments: Con, non-irradiated pork; IR, 10 kGy irradiated pork; IRO, 10 kGy irradiated pork and 0.05% onion peel extract; IRK, 10 kGy irradiated pork and 0.5% kimchi powder; IROK, 10 kGy irradiated pork, 0.05% onion peel extract, and 0.5% kimchi powder.

delay of formation of nitrosomyoglobin.

TBARS value of emulsion sausages during chilled storage

Thiobarbituric acid reactive substances (TBARS) values of all treatments increased during chilled storage periods (Table 3). The TBARS value of the IR treatment was the highest (p<0.05) at the initial storage time (0 wk). This result indicated that irradiation accelerated lipid oxidation. In many previous studies, irradiation contributed for accelerating the lipid oxidation of meat products due to the formation of free radicals. Diehl (1995) suggested that hydroxyl radicals produced due to irradiation in aqueous systems accelerated lipid oxidation, and Ismail *et al*. (2008) reported that irradiation significantly affects lipid oxidation of meat because meat contains over 75% water. Zanardi *et al*. (2009) demonstrated that Italian dry-cured pork products (salame, coppa and pancetta) irradiated at 8 kGy showed significantly different TBARS values from those of non-irradiated pork products. In previous studies, kimchi could act as a pro-oxidant as well as antioxidant in some situations, depending on its fermentation temperature, and the presence of transition metal ions. Lee *et al*. (2011b) reported that the addition of kimchi ethanolic extracts decreased the TBARS values of cooked pork, btu, Choi (2012) reported that emulsion type cooked sausage manufactured with kimchi powder showed very high TBARS values, and suggested that kimchi powder accelerates lipid oxidation. In this study, the emulsion sausage containing only kimchi powder (IRK treatment) showed a higher TBARS value than IROK treatment (p<0.05), whereas similar TBARS value to that of IR treatment (p> 0.05). This result might be associated with the pro-oxidant effect of kimchi powder at the final storage time (4 wk). As expected, the TBARS values of IR treatments prepared with onion peel extract were lower than that of IR treatments without onion peel. It is considered that lipid oxidation is inhibited by antioxidative compounds within onion peel extract. Shim *et al*. (2012) reported that the addition of onion peel extract significantly reduced the TBARS values of ground pork throughout storage. Kim and Kim (2006) reported that both the quercetin levels and free radical scavenging activity of onion skin, were higher than those of any other part of the onion. For this reason, our results suggest that onion peel extract may retard lipid oxidation of emulsion sausage prepared

Table 4. Effects of kimchi powder and onion peel extract on the volatile basic nitrogen (VBN, mg%) value of emulsion sausages prepared with irradiated pork during chilled storage

Storage period (wks)	Con	Treatments[1)]			
		IR	IRO	IRK	IROK
0	10.77±0.91^{Bc}	11.55±0.45^{ABc}	8.07±0.46^{Cc}	12.30±0.82^{Ae}	11.13±0.38^{ABd}
1	11.54±0.90^{Bc}	12.87±0.70^{Bc}	8.80±0.60^{Cbc}	15.00±1.11^{Ad}	11.58±0.60^{Bd}
2	12.70±1.21^{Cbc}	15.17±1.04^{Bb}	8.80±0.53^{Dbc}	17.33±0.99^{Ac}	15.03±0.90^{Bc}
3	14.60±1.25^{Bb}	14.67±0.42^{Bb}	10.00±0.90^{Cb}	19.23±0.85^{Ab}	13.47±0.61^{Bb}
4	18.50±1.55^{Ba}	16.73±0.95^{Ca}	13.07±1.30^{Da}	23.47±0.58^{Aa}	16.35±0.65^{Ca}

All values are mean±SD.
$^{A-D}$Mean sharing different letters in the same row are significantly different (p<0.05).
$^{a-e}$Mean sharing different letters in the same column are significantly different (p<0.05).
[1)]Treatments: Con, non-irradiated pork; IR, 10 kGy irradiated pork; IRO, 10 kGy irradiated pork and 0.05% onion peel extract; IRK, 10 kGy irradiated pork and 0.5% kimchi powder; IROK, 10 kGy irradiated pork, 0.05% onion peel extract, and 0.5% kimchi powder.

with irradiated pork.

VBN value of emulsion sausages during chilled storage

Volatile basic nitrogen (VBN) is an important index to determine freshness of meats and meat products. Decomposition of meat protein during storage causes the formation of volatile compounds, resulting in an increase in the VBN value (Jay, 1992). VBN values of all treatments increased, depending on storage times. While VBN value of IRK treatment is highest ($p<0.05$), VBN value of IRO treatment is lowest. This result indicated that the addition of kimchi to meat products leads to an increase in the VBN value. Similarly, a previous study has demonstrated that kimchi ethanolic extract results in an increased VBN value for refrigerated cooked pork (Lee, 2011). The VBN value of kimchi consistently increased during the fermentation period and it is considered that soused shrimp, a kimchi ingredient, may affect the high VBN value of kimchi (Chung *et al*., 1994). On the other hand, Liu *et al*. (2009) reported that chicken sausages with the addition of rosemary or Chinese mahogany might have significantly decreased VBN values, because rosemary or Chinese mahogany contained some antimicrobial compounds. Thus, this study suggested that VBN value is greatly associated with the growth of microorganisms. In our study, the VBN value of the IRO treatment was lowest at the end of the storage period and an inhibition of the putrefaction of meat appeared to be caused by the onion peel. The VBN value of the IROK treatment is lower than that of the IRK treatment, and is higher than VBN value of IRO treatment. Previously, antimicrobial effect of onion peel against *Bacillus cereus*, *Staphylococcus aureus*, *Microcroccus luteus*, and *Listeria monocytogenes* has been reported (Kim *et al*., 2011b; Lee *et al*., 2011a; Santas *et al*., 2010). Thus, our result which showed a slight decreasing the VBN value might be due to the antimicrobial effect of onion peel extract. Consequently, our study demonstrated that the addition of onion peel extract decreased the VBN value of emulsion sausages prepared with irradiated raw meat and kimchi powder.

Total plate count of emulsion sausages during chilled storage

Table 5 presented the level of total bacterial loading on refrigerated emulsion sausages for 4 wk. The bacterial populations of all treatments tended to increase during the storage period. Sausages made with IR treated meat showed lower bacterial counts than sausages made with non-IR treated meat. Food irradiation technology generally has an anti-microbial effect (Kanatt *et al*., 2005). The maximal dose of irradiation used in food for commercial applications is 10 kGy (Crawford and Ruff, 1996). In this study, however, IRK and IROK treatments exhibited high levels of bacteria until 3 wk. It is considered that kimchi powder results in a significant increase in the overall initial microbial count due to the presence of lactic acid bacteria and *Bacillus* spp. (Chang *et al*., 2011). Hong *et al*. (2007) reported that powder of fermented kimchi showed a total microbial load of 6 Log CFU/g. However, the total bacterial population of IRK and IROK treatments showed lower levels than those of the control at the end of storage. IRO treatment had a lower level of total microbial loading due to the addition of onion peel extract. Kim *et al*. (2011a) reported that 0.06% minimum inhibitory concentration values of the ethyl acetate fraction of onion peel extract on *Staphylococcus aureus* showed a significant antibacterial effect. A previous study has suggested that the antibacterial effect of onion is due to the presence of sulfur compounds (Sheo, 1999). Although all treatments were manufactured with irradiated pork meat except control, each treatment presented a different level of total bacterial population. This result revealed the tendency for total bacterial population to be more greatly affected by additives than by irradiation on raw material.

Table 5. Effects of kimchi powder and onion peel extract on the total aerobic bacterial counts (Log CFU/g) of emulsion sausages prepared with irradiated pork during chilled storage

Storage period (wks)	Con	Treatments[1)]			
		IR	IRO	IRK	IROK
0	1.88	1.56	1.64	2.00	2.11
1	2.15	1.88	1.95	2.58	2.58
2	2.66	2.11	2.23	2.81	2.89
3	3.13	2.73	2.81	3.28	3.52
4	4.45	2.89	3.13	3.90	4.02

[1)]Treatments: Con, non-irradiated pork; IR, 10 kGy irradiated pork; IRO, 10 kGy irradiated pork and 0.05% onion peel extract; IRK, 10 kGy irradiated pork and 0.5% kimchi powder; IROK, 10 kGy irradiated pork, 0.05% onion peel extract, and 0.5% kimchi powder.

Table 6. Effects of kimchi powder and onion peel extract on the sensory properties of emulsion sausages prepared with irradiated pork during chilled storage

Traits	Storage period (wks)	Con	Treatments[1)]			
			IR	IRO	IRK	IROK
Color	0	7.83±0.98	7.67±1.03	7.50±1.05	8.33±0.82	8.33±0.82
	1	7.33±0.52^{B}	7.33±0.52^{B}	7.17±0.41^{B}	8.60±0.55^{A}	8.60±0.55^{A}
	2	8.00±0.76^{AB}	7.75±0.71^{B}	7.75±0.71^{B}	8.75±0.71^{A}	8.75±0.71^{A}
	3	8.00±0.58^{AB}	7.00±0.82^{C}	7.14±0.69^{BC}	8.43±0.53^{A}	8.29±0.95^{A}
Flavor	0	8.25±0.96^{ab}	7.00±0.89	7.50±1.29	8.00±1.15^{ab}	8.00±1.00^{a}
	1	7.83±0.41^{ABab}	6.50±1.05^{C}	6.83±0.75^{BC}	7.83±0.41^{Aab}	7.83±0.41^{Aab}
	2	8.50±0.76^{ABa}	7.71±0.49^{B}	8.00±0.58^{AB}	8.71±0.76^{Aa}	8.71±0.76^{Aa}
	3	7.14±0.38^{b}	7.57±0.98	7.57±0.98	7.00±1.10^{a}	6.86±1.07^{b}
Tenderness	0	8.33±0.82	8.17±0.98	8.67±0.82	8.67±0.82	8.67±0.82
	1	7.83±0.41	7.83±0.41	7.83±0.41	7.83±0.41	7.83±0.41
	2	8.63±0.74	8.50±0.76	8.25±0.89	8.50±0.76	8.50±0.76
	3	8.00±0.58	8.14±0.38	8.29±0.49	7.86±0.69	7.86±0.69
Off-flavor	0	1.67±0.82^{Bb}	4.83±0.75^{Ab}	4.33±0.82^{A}	2.17±0.98^{Bb}	2.33±0.82^{Bb}
	1	2.83±0.75^{Bab}	4.67±0.82^{Ab}	5.17±0.75^{A}	4.33±0.82^{Aa}	4.00±0.89^{Aa}
	2	2.50±0.93^{Cab}	5.63±0.74^{Aab}	5.00±0.93^{AB}	4.63±0.52^{Ba}	4.25±0.71^{Ba}
	3	3.14±0.90^{Ca}	6.00±0.82^{Aa}	5.00±0.82^{B}	4.86±0.90^{Ba}	4.29±0.49^{Ba}
Overall acceptability	0	8.67±0.82^{a}	7.67±0.82^{ab}	8.25±0.96^{a}	9.00±0.89	8.83±0.98
	1	7.50±0.55^{Aa}	6.50±1.05^{Bb}	6.33±0.82^{Bb}	7.67±0.52^{A}	7.83±0.41^{A}
	2	8.50±0.76^{a}	7.80±0.45^{ab}	8.00±0.82^{a}	8.17±1.17	8.33±0.82
	3	7.43±0.53^{b}	7.71±0.95^{a}	7.71±0.76^{a}	7.71±0.76	8.00±0.82

All values are mean±SD.

$^{A-C}$Mean sharing different letters in the same row are significantly different (p<0.05).

^{a,b}Mean sharing different letters in the same column are significantly different (p<0.05).

[1)]Treatments: Con, non-irradiated pork; IR, 10 kGy irradiated pork; IRO, 10 kGy irradiated pork and 0.05% onion peel extract; IRK, 10 kGy irradiated pork and 0.5% kimchi powder; IROK, 10 kGy irradiated pork, 0.05% onion peel extract, and 0.5% kimchi powder.

Sensory properties of emulsion sausages during chilled storage

IRK and IROK treatments had the highest preference score in terms of color. Also, the flavor score of IRK and IROK treatments presented significantly higher values. However, there was no difference between the tenderness of all treatments. The off-flavor score of the IR treatment was the highest while the off-flavor score of control treatment is the lowest. This result further confirms that irradiation has a negative effect on flavor. Ahn *et al*. (1998) found that irradiated pork produced stronger odor than that of non-irradiated pork. In terms of overall acceptability, control, IRK and IROK treatments returned higher scores than other treatments. Lee (2011) reported that low-fat sausages containing kimchi powder scored higher in a sensory evaluation due to their improved color and flavor resulting from the presence of kimchi powder, and this study showed similar results. The addition of kimchi powder not only reduces irradiation off-odor, but also improves the color and flavor of irradiated meat products.

In conclusion, the addition of kimchi powder had positive effects on color and sensory properties of emulsion sausages prepared with irradiated pork, whereas negative effects on the lipid oxidation, protein deterioration, and the growth of micro-bacteria. The addition of onion peel extract improved these problems due to its antioxidant and antimicrobial effects. Thus, combined use of kimchi powder and onion peel extract could be an effective way to improve quality characteristics and shelf stability of the emulsion sausages formulated with irradiated pork during chilled storage.

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