REDUCTION OF PATHOGENS IN PORK JERKY BY ELECTRON BEAM IRRADIATION AND ADDITION OF ONION PEEL EXTRACT WITH BARBECUE FLAVOR INTO PORK JERKY

Hyun-Joo Kim, Samooel Jung, Hae In Yong, Young Sik Bae, Amail U. Alahakoon,

and Cheorun Jo

Department of Animal Science and Biotechnology, Chungnam National University, Daejeon, Korea

Abstract – The combined effects of electron-beam (EB) irradiation and addition of onion peel (OP) extract and barbecue flavor (BF) on inactivation of foodborne pathogens of pork jerky was investigated. Prepared pork jerky samples (control and samples with 0.5% OP extract and BF) were inoculated with pathgoens and subsequently irradiated at 0, 0.5, 1, 1.5, 2, and 3 kGy. In comparison with the control, samples showed significant reduction in the numbers of *Listeria monocytogenes, Escherichia coli* and *Salmonella* Typhimurium. No viable counts were detected for *S.* Typhimurium in both control and samples with 0.5% OP extract and BF and for *L. monocytogenes* and *E. coli* in the samples with 0.5% OP extract and BF exposed to 1.5 kGy. The D_{10} values of *L. monocytogenes*, *E. coli*, and *S.* Typhimurium observed in the treated samples were 0.19, 0.18, and 0.19 kGy, whereas those in control were 0.25, 0.23, and 0.20 kGy, respectively. Therefore, EB irradiation, combined with OP extract and BF, has positive effects on safety of pork jerky.

Key Words – Electron beam irradiation, Food borne, Onion peel, Pathogens pork jerky

I. INTRODUCTION

Jerky is a popular meat product item in the world due to its stability and nutritional value. However, several outbreaks of foodborne disease have been attributed to consumption of commercial jerky due to contamination with *Escherichia coli* O157:H7 [1]. In addition, beef jerky recalls have been issued due to contamination with *Salmonella* and *Listeria monocytogenes* [2].

Ionizing radiation is a well-known technology that improves microbiological safety and extends the shelf life of meat products [3]. Especially, electron beam (EB) irradiation has less influence on the quality of food because of its low penetrating power, and it does not generate radioisotope concern, making the method more environmentally friendly and highly acceptable to consumers [4].

A new trend in the processed food industry is to use a combined treatment that includes natural plant extracts. Various botanical extracts from spices and herbs that contain antibacterial compounds and antioxidant have been used in combination with irradiation [5]. Onion peel (OP) contains over 20 times more flavonoids, especially quercetin, than the onion flesh. Although onion peels have high levels of flavonoids, they are usually discarded before onions are processed for human consumption [6].

Our previous study [7] indicated that a combined treatment of EB irradiation and leek extract addition could eliminate all microorganisms present in pork jerky. However, improvement in sensory quality of the pork jerky was needed. Kim et al. [8] have reported that barbecue flavor (BF) has some antibacterial effects, as well as off-flavor masking effects, in jerky products irradiated for safety.

The objective of this study was to investigate the synergistic effect of a combined treatment of EB irradiation and onion peel (OP) extract with BF on the survival of *E. coli, L. monocytogenes,* and *S.* Typhimurium populations in pork jerky.

II. MATERIALS AND METHODS

Sample preparation

Pork loins and OP were purchased from a local market in Daejeon, Korea. BF was purchased from Saerom B&F (Cheonan, Korea).

OP was washed with tap water. OP extract was obtained by treating OP with 70% ethyl alcohol at room temperature for 72 h, followed by evaporation of the solvent. The extract was then lyophilized (TFD5505, Ilshin Lab Co. Ltd., Korea) to obtain a powder.

Pork loins were trimmed of all visible fat, and subsequently sliced to 0.7 cm thick pieces using a meat slicer (HFS 350G, Hankook Fugee Industries Co. Ltd., Seoul, Korea). The slices of pork were marinated at 4°C for 12 h in a jerky curing solution (w/w) with the following composition: water (10%), soy sauce (10%), starch syrup (7%), sugar (5%), d-sorbitol (6%), ginger powder (0.1%), garlic powder (0.2%), onion powder (0.2%), potassium sorbate (0.1%), pepper (0.3%), OP extract (0.5%), and BF (0.5%).

Cured meat was sequentially dried using a convection oven (JSOF–150; JS Research Inc., Korea) at 75°C, 65°C, and 55°C for 150, 90, and 60 min, respectively. After cooling, the jerky samples were packaged under vacuum conditions.

Inoculation test

Sterilization, test pathogens, and inoculation

For the inoculation test, samples were randomly selected and sterilized using EB irradiation (35 kGy at 2.5 MeV) with a linear electron beam RF accelerator (EB tech, Daejeon, Korea). *E. coli* and *L. monocytogenes* were cultivated in tryptic soy broth (Difco Laboratories, Detroit, MI, USA), and *S.* Typhimurium was cultivated in nutrient broth (Difco Laboratories) at 37°C for 48 h. The cultures were then centrifuged (3,000 × g for 10 min at 4°C) in a refrigerated centrifuge. The resulting pellet was washed twice with sterile saline (0.85%) and suspended in the same saline solution. The viable cell density was approximately 10^8 CFU/mL. The cut jerky samples (5 g, approximately 3.5 cm × 3.5 cm) were inoculated with 100 µL of this solution. Each sample was then resealed and shaken for homogenization.

EB irradiation

Each prepared sample was irradiated on both sides in a linear EB RF accelerator (Energy 2.5 MeV, beam power 40 kW, beam current 0-4.5 kW). Irradiation was performed with a conveyor velocity of 10 m/min and a dose rate of 1.1–4.4 kGy/s. Because the incident EB had a low penetration power, all the samples were sliced to a 0.7 cm thickness to enhance the effectiveness of irradiation. To confirm the target dose, alanine dosimeters, attached to the top and bottom surfaces of the sample packs, were read using a 104 Electron Paramagnetic Resonance unit (EMS-104; Bruker Instruments Inc., Bullerica, MA). The calculated maximum/minimum dose ratio was less than 1.004 for all samples. The doses employed in this study were 0, 0.5, 1, 1.5, 2, and 3 kGy.

Microbial analysis

After irradiation, each sample (5 g) was cut into small pieces (approximately 0.5 cm × 0.5 cm) and homogenized for 2 min in a sterile Stomacher bag containing 45 mL of sterile saline solution using the Stomacher BagMixer® 400 (Interscience Co., France). Then samples were serially diluted in sterile saline (0.85%), and each diluent (0.1 mL) was spread on each bacterial media. Tryptic soy agar (Difco Laboratories) was used for *E. coli* and *L. monocytogenes*, and nutrient agar (Difco Laboratories) was used for *S.* Typhimurium. Plates were incubated at 37°C for 48 h, and microbial counts were expressed as colony forming units per gram (CFU/g). Radiation sensitivity of the pathogens was calculated as D_{10}, a value that represents the dose required to inactivate 90% of the microbial population.

Statistical analyses

Data were analyzed using SAS software (Release 8.01, SAS Institute, Inc., Cary, NC, USA). Statistical analysis was performed by One-way Analysis of Variance (ANOVA). When significant differences were detected, the differences among the mean values were determined by the Duncan's multiple comparison test at a confidence level of $p < 0.05$.

III. RESULTS AND DISCUSSION

L. monocytogenes was initially loaded at 8.02 and 7.88 log CFU/g in control and sample with added OP extract and BF (Table 1). Irradiation of 1.5 kGy resulted in a ~6 decimal reduction in the number of *L. monocytogenes*. In addition, the jerky with OP extract and BF had a significantly lower *L. monocytogenes* population at each irradiation dose compared to control. Bacterial

population in the control and samples containing OP extract and BF were below the detection limit (10^1 CFU/g) following irradiation at 2 and 1.5 kGy, respectively.

The combination treatment of EB irradiation with OP extract and BF reduced the numbers of *E. coli* (Table 2). Irradiation of 2 and 1.5 kGy reduced the population of *E. coli* to an undetected level in control and treated samples, respectively. This result confirmed that OP extract and BF has a synergistic effect on the inhibition of growth of *E. coli* in jerky.

Table 1. Inactivation of *Listeria monocytogenes* (log CFU/g) of pork jerky by electron beam irradiation and by addition of onion peel extract and barbecue flavor

Dose (kGy)	Control	Sample*	SEM[2)]
0	8.02^{ax}	7.88^{ay}	0.021
0.5	5.49^{bx}	5.13^{by}	0.026
1	3.00^{cx}	1.85^{cy}	0.015
1.5	1.46^{dx}	ND^{dy}	0.010
2	$ND^{e3)}$	ND^{d}	-
3	ND^{e}	ND^{d}	-
SEM[1)]	0.018	0.012	

*Onion peel extract (0.5%) + barbecue flavor (0.5%)
Initial population : 10.48±0.05 log CFU/mL.
[1)]Standard errors of the mean (n = 24), [2)](n = 8).
[3)]Detection limit < 10^1 CFU/g.
[a-e]Values with different letters within the same column differ significantly ($p < 0.05$).
[x,y]Values with different letters within the same row differ significantly ($p < 0.05$).

Table 2. Inactivation of *Escherichia coli* (log CFU/g) of pork jerky by electron beam irradiation and by addition of onion peel extract and barbecue flavor

Dose (kGy)	Control	Sample*	SEM[2)]
0	8.49^{ax}	8.28^{ay}	0.007
0.5	5.99^{bx}	5.80^{by}	0.008
1	3.15^{cx}	2.67^{cy}	0.028
1.5	1.55^{dx}	ND^{dy}	0.021
2	$ND^{e3)}$	ND^{d}	-
3	ND^{e}	ND^{d}	-
SEM[1)]	0.014	0.016	

*Onion peel extract (0.5%) + barbecue flavor (0.5%)
Initial population : 9.25±0.01 log CFU/mL.
[1)]Standard errors of the mean (n = 24), [2)](n = 8).
[3)]Detection limit < 10^1 CFU/g.
[a-e]Values with different letters within the same column differ significantly ($p < 0.05$).
[x,y]Values with different letters within the same row differ significantly ($p < 0.05$).

Table 3 shows populations of *S.* Typhimurium for in the combined-treated pork jerky. The initial population of *S.* Typhimurium, for non-treated pork jerky samples was 7.77 log CFU/g, however, with increasing irradiation doses, these populations significantly decreased in both treated and non-treated pork jerky samples.
Table 4 shows D_{10} values of combined-treated pork jerky. For all tested microorganisms, the combined treatment was more effective than the control in microbial inactivation. The D_{10} value for *L. monocytogenes* in the control was 0.23 kGy and 0.18 kGy in samples. Similarly, for *E. coli*, we obtained D_{10} values of 0.25 kGy and 0.19 kGy for the control and samples, respectively; and 0.20 kGy and 0.19 kGy, for *S.* Typhimurium, respectively.

Table 3. Inactivation of *Salmonella* Typhimurium (log CFU/g) of pork jerky by electron beam irradiation and by addition of onion peel extract and barbecue flavor

Dose (kGy)	Control	Sample*	SEM[2)]
0	7.77^{ax}	7.63^{ay}	0.037
0.5	5.75^{bx}	5.25^{by}	0.044
1	3.75^{cx}	2.07^{cy}	0.030
1.5	$ND^{d3)}$	ND^{d}	-
2	ND^{d}	ND^{d}	-
3	ND^{d}	ND^{d}	-
SEM[1)]	0.020	0.016	

*Onion peel extract (0.5%) + barbecue flavor (0.5%)
Initial population : 8.53±0.05 log CFU/mL.
[1)]Standard errors of the mean (n = 24), [2)](n = 8).
[3)]Detection limit < 10^1 CFU/g.
[a-e]Values with different letters within the same column differ significantly ($p < 0.05$).
[x,y]Values with different letters within the same row differ significantly ($p < 0.05$).

Table 4. D_{10} value (kGy) for different pathogens inoculated in pork jerky containing onion peel extracts and barbecue flavour

Pathogens	Treatment	D_{10} values (kGy)
Escherichia coli	Control	0.25±0.001[2)]
	Sample	0.19±0.004
Listeria monocytogenes	Control	0.23±0.001
	Sample	0.18±0.001
Salmonella Typhimurium	Control	0.20±0.001
	Sample	0.19±0.002

*Onion peel extract (0.5%) + barbecue flavor (0.5%)
[1)] Mean±standard deviation (n = 4).

D_{10} values for pathogenic bacteria in food are affected by water activity, food composition, irradiation or storage temperature and presence of oxygen, among other factors. In addition, some of the constituents of complex food system, such as proteins, are thought to compete with cells for interactions with radiolytic free radicals, thereby reducing the net effect of radiation damage and making the organisms more radiation-resistant [9]. Several studies have reported D_{10} values in various meat products. D_{10} values for *L. inocua, S. enteritidis*, and *S.* Typhimurium in dry fermented sausages ranged from 0.41 to 0.54 kGy [10].

Plant extracts usually contain multiple compounds with antimicrobial activity attributed to a number of phenolic compounds. Shan et al. [11] suggested that phenolic compounds can degrade the cell wall, disrupt the cytoplasmic membrane, cause leakage of cellular components, change fatty acid and phospholipid constituents, influence synthesis of DNA and RNA, and destroy protein translocation. OP may possess antimicrobial and/or antifungal properties due to the presence of quercetin [12]. Kim et al. [13] have reported that OP extract, prepared using subcritical water extraction, exhibited a potent inhibitory effect on *Bacillus cereus*.

IV. CONCLUSION

The present study showed that a low dose of EB irradiation combined with the addition of OP extract with BF can effectively enhance the microbial safety of jerky and reduce the hazards of foodborne pathogens.

ACKNOWLEDGEMENTS

This work was carried out with the support of "Cooperative Research Program for Agricultural Science and Technology Development (Project No. PJ0092212013)" Rural Development Administration, Republic of Korea.

REFERENCES

1. Nummer, B. A., Harrison, J. A., Harrison, M. A., Kendall, P., & Sofos, J. N. (2004). Effects of preparation methods on the microbiological safety of home-dried meat jerky. Journal of Food Protection 67: 2337-2341.
2. Porto-Fett, A. C. S., Call, J. E., Hwang, C. A., Juneja, V., Ingham, S., Ingham, B., & Luchansky, J. B. (2009). Validation of commercial processes for inactivation of *Escherichia coli* O157:H7, *Salmonella* Typhimurium, and *Listeria monocytogenes* on the surface of whole-muscle turkey jerky. Poultry Science 88: 1275-1281.
3. Muhamed, H. M. H., Mansour, H. A., Farag, M. D. E. H. (2011). The use of natural herbal extracts for improving the lipid stability and sensory characteristics of irradiated ground beef. Meat Science 87: 33-39.
4. Black, J. L., Jaczynski, J. (2006). Temperature effect on inactivation kinetics of *Escherichia coli* O157:H7 by electron beam in ground beef, chicken breast meat, and trout fillets. Journal of Food Science 71: M221-M227.
5. Oussalah, M., Caillet S., Saucier, L., & Lacroix, M. (2007). Inhibitory effects of selected plant essential oils on the growth of four pathogenic bacteria: *E. coli* O157:H7, *Salmonella* Typhimurium, *Staphylococcus aureus* and *Listeria monocytogenes*. Food Control 18: 414-420.
6. Park, J., Kim, J., & Kim, M. K. (2007). Onion flesh and onion peel enhance antioxidant status in a aged rats. Journal of Nutritional Science and Vitaminology 53: 21-29.
7. Kim, H. J., Kang, M., Yong, H. I., Bae, Y. S., Jung, S., & Jo, C. (2013) Synergistic effects of electron-beam irradiation and leek extract on the quality of pork jerky during ambient storage. Asian-Australasian Journal of Animal Science 26: 596-602.
8. Kim, H. J., Kang, M., & Jo, C. (2012). Combined effects of electron beam irradiation and addition of onion peel extracts and flavoring on microbial and sensorial quality of pork jerky. CNU Journal of Agricultural Science 39: 341-347.
9. Jo, C., Lee, N. Y., Kang, H. J., Shin, D. H., & Byun, M. W. (2004). Inactivation of foodborne pathogens in marinated beef rib by ionizing radiation. Food Microbiology 21: 543-548.
10. Cabeza, M. C., de la Hoz, L., Velasco, R., Cambero, M. I., & Ordonez, J. A. (2009). Safety and quality of ready-to-eat dry fermented sausages subjected to E-beam radiation. Meat Science 83: 320-327.
11. Shan, B., Cai, Y. Z., Brooks, J. D., & Corke, H. (2007). The *in vitro* antibacterial activity of dietary spice and medicinal herb extracts. *International* Journal of Food Microbiology 117: 112-119.
12. Griffiths, G., Trueman, L., Crowther, T., Thomas, B., & Smith, B. (2002). Onions-A global benefit to health. Phytotheraphy Research 16: 603-615.
13. Kim, W., Lee, K. A., Kim, K. T., Chung, M. S., Cho, S., & Paik, H. D. (2011). Antimicrobial

effects of onion (*Allium cepa* L.) peel extracts produced via subcritical water extraction against Bacillus cereus strains as compared with ethanolic and hot water extraction. Food Science and Biotechnology 20: 1101-1106.