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Effects of electron beam irradiation on the microbial growth and quality of beef jerky during storage

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ABSTRACT

Electron beam irradiation was applied to improve the microbial safety of beef jerky during storage. Beef jerky samples were irradiated at doses of 1, 3, 5, and 10 kGy and stored at 20 °C for 60 d. Microbiological data indicated that the populations of total aerobic bacteria significantly decreased with increasing irradiation dosage. In particular, the populations of total aerobic bacteria were significantly decreased by 1.76 log CFU/g at 10 kJ/m^2, compared to the control. Color measurements showed reduced Hunter *L* and *a* values of beef jerky for all the treatments during storage, and the Hunter *L*, *a*, and *b* values of beef jerky were not significantly different among the treatments. Sensory evaluation results also showed that electron beam irradiation did not affect sensory scores in overall during storage. Therefore, the results suggest that electron beam irradiation could be useful in improving the microbial safety without impairing the quality of beef jerky during storage.

1. Introduction

As a meat product, beef jerky is nutritious and shelf-stable due to its low water content, resulting in its high demand as a snack food (Calicioglu et al., 2003). However, although the moisture content of beef jerky is low, there are still microbial safety problems during marketing and distribution in Korea, as well as worldwide (Park et al., 2009). Therefore, the efficacy of pretreatment on the inactivation of foodborne pathogens in the beef jerky-making process has been investigated. In particular, studies have focused on the inactivation of *E. coli* O157:H7 or *L. monocytogenes* inoculated in beef jerky to ensure microbial decontamination (Calicioglu et al., 2003; Yoon et al., 2005). However, there are fewer studies available on post-processing treatments, such as electron beam irradiation of beef jerky.

Electron beam irradiation is a well-established method for providing hygienic quality by reducing microbial spoilage of foods (Hong et al., 2008; Chun et al., 2008). Electron beam irradiation has a short processing time, does not produce radioactive waste (Black and Jaczynski, 2006), and destroys major pathogenic foodborne bacteria (Rodriguez et al., 2006). Thus, it can be applied as a preservation method for beef jerky to achieve microbial decontamination. Electron beam irradiation treatment has been applied to beef patties (Wong et al., 2005) and ready-to-eat poultry frankfurters (Johnson and Resurreccion, 2009). However, there is no report on the inactivation of microorganisms in beef jerky by electron beam irradiation.

Therefore, the objectives of this study were to examine the effects of electron beam irradiation on the microbial safety and quality of beef jerky during storage and to suggest appropriate processing conditions.

2. Materials and methods

2.1. Materials

Ready-to-eat beef jerky (50 × 120 × 4 mm) was purchased from a local market in Daejeon, Korea, where it was manufactured from the ingredients of sliced beef (89%), refined sugar, seasoning, sorbitol syrup, processed salt, potassium sorbate, and sodium nitrite, and dried by hot-air drying using a custom-made dehydrator.

2.2. Electron beam irradiation treatment

Electron beam irradiation was performed using an electron-beam accelerator (Model ELV-4, 1 MeV, Eb-Tech, Yuseong, Daejeon, Korea). Samples were individually packaged in 100 × 170 mm low-density polyethylene bags (thickness less than 4 mm), and they were exposed to four dose levels of 1, 3, 5, and 10 kGy at 1 MeV (beam current 2–8 mA, beam dimension 600 × 600 mm, and conveyer velocity 20–25 m/min). The absorption dose was determined using

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a cellulose triacetate dosimeter. After irradiation, the samples were stored at 20 °C for 60 days.

2.3. UV-C irradiation treatment

To compare with electron beam irradiation, UV-C irradiation treatment was performed using unfiltered germicidal emitting lamps (G15T8, Sylvania, Phillips, Haarlem, Netherlands) located in a metal cabinet ($80 \times 55 \times 47$ cm). The UV-C intensity was determined using a UV radiometer (UV-340, Lutron Electronic Co., 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 beef jerky samples were exposed to three different dose levels: 27, 54, and 108 J/m^2. The irradiation times for the UV-C doses of 27, 54, and 108 kJ/m^2 were 30, 60, and 120 min, respectively.

2.4. Microbiological analysis

The samples (20 g) were placed in 180 ml peptone water (0.1% sterile peptone, w/v) in a sterile stomacher bag. Samples were then homogenized using a stomacher (MIX 2, AES Laboratoire, Combourg, France) for 6 min and diluted with peptone water for a microbial count. Serial dilutions were performed in triplicates. Total aerobic bacteria counts were determined by plating the diluted samples onto plate count agar (PCA, Difco, Detroit, MI, USA) and incubating the plates at 37 °C for 48 h. Yeasts and molds were plated on potato dextrose agar (PDA, Difco) and incubated the plates at 25 °C for 72 h. Each microbial count was the mean of three determinations. Microbial counts were expressed as log CFU/g.

2.5. Color measurement

The color of the samples was analyzed using a colorimeter (CR-400 Minolta Chroma Meter, Konica Minolta Sensing Inc., Tokyo, Japan). Samples were placed on a white standard plate, and Hunter values (L, a, and b) were measured. Hunter values for the standard plate were $L=97.35$, $a=-0.14$, and $b=2.05$. Five measurements were taken at different locations for each sample.

2.6. Sensory evaluation

During storage, samples were analyzed for their appearance, firmness, odor, and the overall acceptability by eight trained panelists. Sensory qualities of samples were evaluated using a nine-point scoring method. Sensory scores of 8–9 were given for very good; 6–7 for good; 4–5 for fair; 2–3 for poor; and 1 for very poor.

2.7. Statistical analysis

Analyses of variance and Duncan's multiple range tests were performed to analyze the data using the SAS program (SAS Institute, Inc., Cary, NC, USA). Differences at $p<0.05$ were considered significant. All results were expressed as the mean ± standard deviation.

3. Results and discussion

3.1. Microbiological analysis

To examine the efficacy of electron beam irradiation on the inactivation of microorganisms in beef jerky, electron beam and UV-C irradiation were first compared regarding the change in the microbial populations of the beef jerky samples (Tables 1 and 2). The initial populations of total aerobic bacteria for the beef jerky samples before treatment were 4.77 log CFU/g (Table 1), suggesting that the level of microbial contamination in beef jerky should be decreased, since the population of bacteria can increase during storage. Thus, the results indicate that microbial decontamination is needed to ensure the microbial safety of beef jerky.

Increasing the dosage of electron beam irradiation decreased the populations of total aerobic bacteria (Table 1). After electron beam irradiation treatment, the populations of total aerobic bacteria for the samples treated with 1, 3, 5, and 10 kGy decreased to 4.36, 3.99, 3.33, and 3.01 log CFU/g, respectively, resulting in significant reductions in microbial populations. In particular, the reduction observed at 10 kGy was 1.76 log CFU/g, resulting in a D_{10} of 5.8 kGy. This D_{10} value is somewhat high value compared to fresh beef patties, due to low water activity and high sugar levels of jerky. Therefore, complete sterility of beef jerky may require high dose like 25–40 kGy. To secure the microbial safety of beef jerky, Albright et al. (2003) reported on the effect of pretreatment on inactivation of *Escherichia coli* O157:H7 inoculated on beef jerky, where the pretreatment of seasoning (4 °C, 24 h), immersion in a pickling brine (78 °C, 90 s), and 10 h drying reduced *E. coli* O157:H7 populations by 5.7–5.8 log cycles, as compared to the control.

There have been many studies regarding the effect of electron beam irradiation on the inactivation of microorganisms in foods (Sarrías et al., 2003; Ko et al., 2005). Sarrías et al. (2003) reported on the microbial decontamination of unhusked and husked rice grains by electron beam irradiation and demonstrated that a 7.5 kGy dose was sufficient for decontamination. Ko et al. (2005) also reported that electron beam irradiation at 8 kGy decreased the populations of total aerobic bacteria, yeast, and mold, as well as coliforms in sliced dried squid by 1–2 log cycles. Along with these reports, our current investigation suggests that electron beam irradiation is an effective microbial decontamination method in processed foods.

Table 1
Effect of electron beam irradiation on the microbial populations in the beef jerky during storage.

Microorganism	Storage period (day)	Irradiation dose (kGy)				
		0	1	3	5	10
Total aerobic bacteria	0	$4.77 \pm 0.06^{Ac*}$	4.36 ± 0.02^{Bc}	3.99 ± 0.09^{Ca}	3.33 ± 0.09^{Da}	3.01 ± 0.11^{Ea}
	15	4.81 ± 0.04^{Ac}	4.48 ± 0.14^{Bc}	3.88 ± 0.06^{Ca}	3.21 ± 0.04^{Dab}	3.02 ± 0.17^{Ea}
	30	5.10 ± 0.08^{Ab}	4.71 ± 0.12^{Bb}	3.71 ± 0.09^{Cb}	3.27 ± 0.06^{Dab}	2.91 ± 0.13^{Ea}
	60	5.77 ± 0.06^{Aa}	5.11 ± 0.07^{Ba}	3.69 ± 0.09^{Cb}	3.12 ± 0.11^{Db}	2.86 ± 0.24^{Ea}
Yeast and mold	0	ND**	–	–	–	–

* Any means in the same row (A–E) or column (a–c) followed by different letters are significantly ($p<0.05$) different by Duncan's multiple range test.
** Not detected.