USE OF HIGH TEMPERATURE AGING FOR IRRADIATED BEEF

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Abstract – To determine the effect of irradiation and aging temperature on beef quality, a round of beef was irradiated at 2 kGy and stored at different aging temperature (2, 10, or 25°C). The microbial growth and meat quality parameters of the samples were analyzed during 8 days of storage. Irradiation decreased the population of inoculated *Listeria monocytogenes* and *E. coli* O157:H7, showing D_{10} values of 0.66 and 0.65 kGy respectively. Total aerobic bacteria counts were lowered by irradiation but increased with increasing aging temperature. Especially total aerobic bacteria sharply increased in nonirradiated samples exposed to 25°C. With increasing aging temperature and aging time, samples had lower shear force values. The color a* values of the irradiated beef were lower than those of the nonirradiated. As aging time and temperature increased, the amounts of inosine monophosphate decreased and the hypoxanthine increased. Considering meat quality and safety issues, irradiated beef could be aged at higher temperature (10°C) than conventional refrigerating temperature (4°C), to shorten the aging time.

Key Words – irradiation, meat quality, microbial safety

I. INTRODUCTION

Beef aging is extensively utilized in meat industry to improve tenderness and flavor, providing more acceptable product with consumers [1]. Beef is generally aged at refrigerated temperature (2~4°C) to secure the microbial safety. Aging temperature and time were the variables that can be controlled to affect meat aging [2]. The aging time, however, can be shortened if the microbial safety problems could be solved during the aging at high tempered zones.

Ionizing radiation is an excellent potential technology improving microbiological safety and extending shelf life of meat products, without compromising the nutritional properties and sensory quality of food [3]. Food irradiation causes little increase of product temperature, and can be used in a continuous process after packaging [4]. Thus irradiated meat can be aged at relatively high temperatures to accelerate aging process and shorten aging time and cost.

There is no previous research on inactivation of microbial spoilages of irradiated meat during the aging process and no comparative study on the aging time and temperature. Therefore this study was conducted to determine the effect of irradiation and aging temperature on the microbial safety and physicochemical quality of beef during the aging process.

II. MATERIALS AND METHODS

Eye of round (mainly m. *semitendinosus*) beef was trimmed of all visible fat, and subsequently sliced to 1 cm-thick pieces, individually vacuum-packaged, and stored at 4°C overnight before irradiation. Half of prepared beef samples were irradiated at 2 kGy using a linear EB RF accelerator (Energy 10 MeV, beam power 40 kW). The beam current was 0-7 mA. Irradiation was performed with a conveyor speed of 5.16 m/min and a dose rate of 2.95 kGy/s.

The irradiated and non-irradiated samples were immediately returned to a temperature of 3 different aging temperatures (2, 10, or 25°C). Total aerobic bacteria, shear force, lipid oxidation, color values, and nucleotide-related flavor compounds were analyzed during the 8 days of aging. The peaks of individual nucleotides were identified using retention times for the following standards: inosine-5-phosphate (IMP), inosine, and hypoxanthine.

The irradiation effect on inactivation of foodborne pathogens was also investigated. For the inoculation test, samples were sterilized using EB irradiation (35 kGy) with a linear electron beam accelerator (RF, EB tech, Daejeon, Korea). *Escherichia coli* O157:H7 (ATCC 43894) and *Listeria monocytogenes* (KCTC 3569) obtained from the Korean Collection for Type Culture (KCTC, Daejeon, Korea) were cultivated and the cultures were prepared with viable cell density of approximately 108 CFU/mL. Statistical analysis was performed by two-way (irradiation and aging temperature) analysis of variance (ANOVA).

III. RESULTS AND DISCUSSION

Consequently irradiation decimal reduction (D_{10}) values for *L. monocytogenes* and *E. coli* inoculated in beef eye of round were 0.66 kGy and 0.65 kGy, respectively (data not shown in table). It was found that D10 values for E. coli O157:H7 in ground beef at 5°C was 0.27 kGy [5]. The present results showed that electron beam irradiation can be effective in controlling *L. monocytogenes* and *E. coli* in beef eye of round.

Table 1 Total aerobic bacteria count

Storage (days)	Temperature (°C)	Total aerobic bacteria count (Log CFU/g)		
		Control	Irradiated (2 kGy)	SEM[2]
1	2	4.88^{c}	4.85^{b}	0.02
	10	5.83^{ax}	4.25^{cy}	0.11
	25	5.45^{b}	5.44^{a}	0.11
	SEM[1]	0.06	0.12	
4	2	5.41^{bx}	5.04^{by}	0.06
	10	6.18^{abx}	4.62^{cy}	0.38
	25	7.14^{ax}	5.23^{ay}	0.02
	SEM	0.32	0.04	
8	2	7.49^{x}	6.10^{y}	0.19
	10	7.46^{x}	6.13^{y}	0.26
	25	7.46^{x}	6.20^{y}	0.18
	SEM	0.28	0.10	

[1]Standard error of the means (n = 24), [2](n = 9).
[a-c]Figures with different letters within a same column differ significantly (p<0.05).
[x-y]Figures with different letters within a same row differ significantly (p<0.05).

Irradiation improved the safety of beef by reducing total aerobic bacteria counts by 4 days of storage (Table 1). However, there were no significant differences of total aerobic bacteria counts by aging temperature at 8 days. It can be summarized that irradiation of beef at 2 kGy was safer than nonirradiated sample regardless of aging temperature. Our investigation suggested that electron beam irradiation was effective reducing microbial levels in beef eye of round.

The color a* values decreased by irradiation throughout the storage and the irradiated beef had higher a* values than non-irradiated sample. This result agrees with other authors who reported that irradiated beef reduced a* values during storage [6].

No significant difference in shear force values was observed between the control and irradiated samples (p>0.05). With higher aging temperature, shear force values decreased regardless of irradiation (Table 2). The decrease in shear force may be due to the structural disruption of myofibrillar components which occurs during the aging period [7]. The result shows high aging temperature could affect shear force reduction and improve tenderness of beef. High temperature aging can be applied to irradiated meat to accelerate aging process.

Table 2 Shear force value

Storage (days)	Temperature (°C)	Shear force value (Kgf)		
		Control	Irradiated (2 kGy)	SEM[2]
1	2	3.39^{a}	3.20^{a}	0.23
	10	2.79^{b}	2.93^{a}	0.12
	25	2.41^{b}	2.36^{b}	0.14
	SEM[1]	0.16	0.18	
4	2	3.13^{a}	3.06^{a}	0.17
	10	2.59^{b}	2.83^{a}	0.12
	25	2.31^{b}	2.33^{b}	0.08
	SEM	0.11	0.15	
8	2	3.12^{a}	3.00^{a}	0.12
	10	2.52^{b}	2.68^{a}	0.24
	25	2.22^{b}	2.16^{b}	0.16
	SEM	0.19	0.17	

[1]Standard error of the means (n = 24), [2](n = 9).
[a, b]Figures with different letters within a same column differ significantly (p<0.05).

During beef aging, ATP converts into AMP by dephosphorylating and then becomes to IMP

which provides good flavor to meat. The amounts of IMP decreased and hypoxanthine increased with increasing aging time. With higher aging temperature, the IMP decreased and hypoxanthine increased indicating the IMP was transformed into inosine and hypoxanthine (Table 3). Thus the conversion of IMP to hypoxanthine was accelerated by high temperature of aging.

Table 3 Inosine monophosphate

Storage (days)	Temperature (°C)	IMP (Inosine monophosphate) (mg/100g)		
		Control	Irradiated (2 kGy)	SEM[2]
1	2	75.72^{ax}	37.11^{by}	9.63
	10	88.94^{a}	97.97^{a}	3.80
	25	37.63^{b}	30.84^{b}	9.98
	SEM[1]	4.65	10.78	
4	2	68.74^{a}	76.80^{a}	6.38
	10	56.46^{a}	75.12^{a}	6.14
	25	3.21^{b}	5.05^{b}	0.76
	SEM	6.96	2.04	
8	2	64.88^{ax}	33.10^{ay}	3.99
	10	11.71^{bx}	3.61^{by}	0.56
	25	3.44^{cy}	8.00^{bx}	0.49
	SEM	0.52	3.28	

[1]Standard error of the means (n = 24), [2](n = 9).
[a-c]Figures with different letters within a same column differ significantly (p<0.05).
[x-y]Figures with different letters within a same row differ significantly (p<0.05).

IV. CONCLUSION

Irradiation can be applied to beef to be aged at high temperature to shorten aging time and cost. Irradiated beef with high aging temperature (10°C, 25°C) has improved tenderness and lowered microbial counts than nonirradiated sample. Nevertheless, beef aged at 25°C had problem in both microbial counts and the profile of nucleotide-related flavor compounds. IMP was fast converted to hypoxanthine at 25°C. Under the conditions of the present study, an optimal aging condition of irradiated beef eye of round could be 4 days at 10°C, judging from the data of microbial growth, tenderness, and IMP content. Although irradiated beef at aged at high temperature had excellent tenderness, an appropriate aging temperature should be selected considering other meat quality parameters such as color and flavor compounds.

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