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IMPROVEMENT OF SAFETY AND SHELF-LIFE OF THE FERMENTED SAUSAGE BY USING ELECTRON-BEAM IRRADIATION AND ANTIOXIDANTS

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Introduction

Recently, the interest in irradiation has been increased in meat industry because irradiation is one of the most effective technologies for inactivating food-borne pathogens and improving the microbial safety of meat (Gants, 1996). In addition, irradiation aimed at improving food safety also effectively reduces the number of spoilage organisms, resulting in an extension of the shelf life, particularly, of muscle foods (Min et al., 1997). The FDA approved irradiation for red meats and poultry to control foodborne pathogens and extend the product shelf-life (Gants, 1998). Fermented sausages can primarily be produced by lactic acid bacteria, which reduce the pH of the sausage within a few days. One of the major concerns in irradiating meat is its effect on the generation of off-odor and lipid oxidation, either of which can impact negatively on acceptance of such treated meat products in the marketplace (Ahn et al., 2000). Although irradiation has been studied for about 50 years and bactericidal effects have been demonstrated in fresh and cooked meat products, very few studies have been done on fermented sausages by using electron-beam irradiation, especially following the emergence of E. coli O157:H7 as a major pathogen of concern in these products (Sommers et al, 2004, Dickson & Maxcy, 1985). It has become clear that packaging is a critical factor that affects the quality of irradiated meat (Nam and Ahn, 2003). There have been many studies showing that the addtion of antioxidants has been used to retard lipid oxidation in meat and meat products (Decker & Xu, 1998). However, there has been few attempt to combinate packaging and effect on the generation of off-odor in fermented sausages by using irradiation. In this respect, this research was conducted to examine the combined effect of electron-beam irradiation and antioxidants on the shelf -life of fermented sausages during cold storage

Objectives

The aim of this study was not only to improve of safety and shelf-life of an irradiated fermented sausage, but also to control the off-odor and lipid oxidation of the irradiated fermented sausage as related to packaging during cold storage

Methodology

Semi-dry type (Thuringer) fermented sausage was made which contained (wt%) the following: pork lean meat(74.73%), pork back fat(18.27%), starter culture(3.32%)(Rosellac ™, Canada), sodium chloride(2.33%), $NaNO_2$(0.008%), ginger(0.06%), pepper(0.29%) and glucose(1%). The raw meat and ingredients were blended to form a batter. This mix is stuffed into cellulose casings (15 mm diameter). The samples were vacuum-packaged and then irradiated at 2, 4, 6 kGy using RF Accelerator (Korea Atomic Energy Research Institute, Daejeon, Korea). The energy and electric current were 2 MeV, 10 mA, respectively. Non-irradiated samples (i.e., control) were kept at cold temperature during the irradiation process. After irradiation, these samples were taken to lab and then fermented and aged in a chamber (Bastra, Germany) until aging(below pH 5.3). The following conditions of relative humidity (RH) and temperature were applied : day 0 until day 3, 80-94% RH and 25 . According to irradiation dose, these samples were used for microbiological analysis and determinations of pH. After the fermented sausage aged, samples were divided into aerobic and vacuum packaging and then these samples were stored at 4±1 for 2weeks. The irradiated samples were stored together with the non- irradiated samples (i.e., control). The microbial quality (total aerobic microbes, lactic acid bacteria, E-coli), pH, the color (Colorimeter, CR-210, Minolta, Japan), VBN, TBA values (Witte et al, 1970), sensory characteristics of the fermented sausage were measured after 0, 7 and 14 days of storage. To control off-odor and lipid oxidation in the fermented sausage by using irradiation, four antioxidants treatment were formulated as follows: (1) control; (2) Ascorbic acid at 1000 ppm; (3) dl- a-tocopheryl Acetate at 1000 ppm (4) Ascorbic acid + dl-α-tocopheryl Acetate at 1000 ppm (5) Rosemary powder at 1000 ppm. Also, TBA values(Witte et al, 1970), meat color, sensory characteristics(descriptive analysis with scaling) of the fermented sausage were measured after 0, 7 and 14 days storage

Results & Discussion

The pH value of fermented sausage was decreased (below pH 5.3) regardless of irradiation until aging (Table 1). American Meat Institute requires the final pH of semi-dry type sausage to fall to 5.3 within times determined by the fermentation temperature (e.g. 80 hrs at 24). These criteria are presumed to prevent the growth of S. aureus. As shown in Table 1, the final pH value of irradiated and non-irradiated sausage corresponded to these criteria.

Table 2 and 3 show the effects of irradiation dose on microbial quality of sausages. Total aerobic counts and lactic acid bacteria count reflected the addition of the starter culture (Dickson and Maxcy 1985). As the fermentation progressed, total aerobic counts closely paralleled the lactic acid bacteria counts. The population of the total aerobic and lactic acid bacteria increased slowly regardless of irradiated and non-irradiated samples until aging. Dickson Dickson and Maxcy (1985) reported that the population of coliforms and Staphylococci could be reduced by irradiation but the growth of lactic acid bacteria increased slowly after irradiation. As shown in Table 2 and 3, irradiation with 2kGy was effective in the survival of lactic acid bacteria.

The results suggested that irradiation of 2kGy in producing fermented sausages was more effective in reducing the population of the total aerobic than non-irradiated sausage during cold storage (Table 4 and 5). The population of the total aerobic and lactic acid bacteria showed lower value with the vacuum packaging than these for aerobic packaging. Results indicated that irradiation coupled with vacuum packaging may enhance the microbial safety of fermented sausage during cold storage.

TBARS values of 2kGy-irradiated samples were significantly higher than those of non-irradiated samples during cold storage. And also, TBARS value of 2kGy-irradiated samples increased in aerobic packaging during storage, but those in vacuum packaging decreased a little (Table 6). Previous studies showed that irradiation increased lipid oxidation in aerobically packaged meat and developed off-flavors (Ahn, Nam, Du, & Jo, 2001; Patterson & Stevenson, 1995). Recently, Ahn et al. (2001) suggested that aerobic packaging would be more beneficial in reducing the characteristic irradiation off-odor during cold storage than vacuum packaging, unless lipid oxidation is a problem.

Redness (a value) of non-irradiated samples became higher than that of 2kGy-irradiated samples and also Redness (a value) of vacuum packaging samples became higher than that of aerobic packaging one as the storage period increased. Yellowness (b value) of non-irradiated samples became higher than that of 2kGy-irradiated samples and also yellowness (b value) of aerobic packaging samples became higher than that of vacuum packaging one as the storage period increased (Table 7 and 8).

Studies reporting irradiation effects on meat color have been inconsistent. An increase in redness of pork color due to irradiation has been reported (Grants and Patterson, 1991). Recently, Nam and Ahn (2002) suggested that aerobic packaging would be more desirable for the irradiated meat color than vacuum packaging, if lipid oxidation was not considered.

In the descriptive analysis, Aroma, off-flavor and color values were higher in irradiated samples than in non-irradiated samples, but overall acceptability values were lower in irradiated samples than in non-irradiated samples (Table 9)

The effects of antioxidants addition to retard lipid oxidation and off-odor in irradiated fermented sausage are shown in Table 10 and 11.

Jo and Ahn (2000) reported that the radiolytic degradation of amino acids, especially sulfur amino acids, was the main mechanism of off-odor production in irradiated meat.

In the descriptive analysis with scaling for fermented sausage (D-14), flavor, off-flavor and tenderness were better in rosemary treatment than others, and also, rosemary treatment gone highest values in the overall acceptance (Table 10). TBARS value of all treatments were lower than control treatment, especially, TBARS values of rosemary treatment samples was the showed lowest as the storage period increased (Table 11).

Conclusions

Combinations of irradiation of 2kGy and vacuum packaging in producing fermented sausage were more effective in surviving lactic acid bacteria during aging than other treatments. Also, The addition of rosemary powder could help to control off-odor and lipid oxidation of the fermented sausage during cold storage. From this result, it can be concluded that irradiation coupled with the addition of rosemary may enhance the safety and quality of the fermented sausage during cold storage

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Tables and Figures

Table 1. The pH change of the fermented sausage irradiated with electron beam

Irradiation dose (kGy)	Days			
	0 day	1 day	2 day	3 day
control	6.37±0.02^{ab}	6.22±0.13^{b}	6.43±0.08^{a}	5.24±0.07
2kGy	6.37±0.02^{b}	6.52±0.04^{a}	5.93±0.17^{b}	5.23±0.11
4kGy	6.42±0.05^{a}	6.52±0.05^{a}	5.76±0.07^{b}	5.23±0.07
6kGy	6.43±0.02^{a}	6.41±0.05^{a}	5.95±0.23^{b}	5.16±0.11

a~b Means ±S.D were significantly different in the same column(p<0.01)

Table 2. Changes of total plate counts(log CFU/g) of the fermented sausage irradiated with electron beam

Irradiation dose (kGy)	Days			
	0 day	1day	2 day	3 day
control	7.37±0.12^{a}	7.98±0.22^{a}	7.91±0.41	7.92±0.26^{a}
2kGy	6.24±0.27^{b}	6.83±0.31^{c}	7.99±0.27	7.97±0.10^{a}
4kGy	6.20±0.20^{b}	7.30±0.72^{b}	7.81±0.28	7.56±0.31^{b}
6kGy	6.12±0.12^{b}	5.77±0.15^{d}	7.62±0.15	7.83±0.14^{a}

a~d Means ±S.D were significantly different in the same column(p<0.01)

Table 3. Changes of lactic acid bacteria(log CFU/g) of the fermented sausage irradiated with electron beam

Irradiation dose (kGy)	Days			
	0 day	1 day	2 day	3 day
control	6.89±0.09^{a}	7.60±0.17^{a}	7.96±0.14^{a}	7.97±0.14^{a}
2kGy	6.02±0.09^{b}	6.41±0.35^{b}	7.73±0.23^{b}	7.94±0.30^{a}
4kGy	5.76±0.15^{c}	7.39±0.64^{a}	7.63±0.16^{b}	7.65±0.23^{a}
6kGy	5.51±0.09^{d}	5.66±0.60^{b}	7.63±0.15^{b}	7.68±0.21^{b}

a~d Means ±S.D were significantly different in the same column(p<0.01)

Table 4. Changes of total plate counts(log CFU/g) of differently packaged sausages irradiated during storage 4

Packaging	Irradiation dose	Storage(day)		
		0	7	14
Aerobic	0kGy	8.72±0.31 ^{A}	8.60±0.33^{Aa}	7.97±0.13^{Ba}
	2kGy	8.64±0.12^{A}	7.94±0.14^{Bb}	7.91±0.13^{Ba}
Vacuum	0kGy	8.70±0.21^{A}	7.88±0.15^{Bb}	7.90±0.35^{Ba}
	2kGy	8.58±0.23^{A}	7.83±0.43^{Bb}	7.49±0.24^{Ba}

a~b Means ±S.D were significantly different in the same column(p<0.01)

A-B Means ± S.D were significantly different in the same row (p<0.01)

Table 5. Changes of lactic acid bacteria(log CFU/g) of differently packaged sausages irradiated during storage 4

Packaging	Irradiation dose	Storage(day)		
		0	7	14
Aerobic	0kGy	8.53±0.23	8.50±0.14^{a}	7.97±0.23
	2kGy	8.57±0.12	8.10±0.14^{b}	7.94±0.13
Vacuum	0kGy	8.62±0.22^{A}	7.99±0.15^{Bb}	7.76±0.13^{B}
	2kGy	8.57±0.41^{A}	8.00±0.16^{Bb}	7.50±0.44^{C}

a~b Means ±S.D were significantly different in the same column(p<0.01)
A-C Means ± S.D were significantly different in the same row (p<0.01)

Table 6.TBARS values of differently packaged sausages irradiated during storage at 4

Packaging	Irradiation dose	Storage(day)		
		0	7	14
Aerobic	0kGy	0.44±0.04^{b}	0.42±0.03^{c}	0.47±0.04^{c}
	2kgy	0.80±0.04^{a}	1.79±0.05^{a}	1.43±0.03^{b}
Vacuum	0kGy	0.43±0.04^{b}	0.43±0.12^{c}	0.52±0.57^{c}
	2kgy	0.79±0.04^{a}	1.61±0.18^{b}	1.30±0.15^{d}

a~d Means ±S.D were significantly different in the same column(p<0.01)

Table 7. a-values of differently packaged sausages irradiated during storage at 4

Packaging	Irradiation dose	Storage(day)		
		0	7	14
Aerobic	0kGy	7.15±0.02^{a}	5.60±0.20^{B}	4.87±0.08^{C}
	2kgy	6.16±0.19^{a}	5.00±0.22^{C}	3.74±0.12^{D}
Vacuum	0kGy	7.15±0.02^{b}	6.87±0.16^{A}	5.89±0.18^{A}
	2kgy	6.16±0.19^{b}	5.46±0.09^{C}	5.44±0.11^{B}

a~b Means ±S.D were significantly different in the same column(p<0.01)

Table 8. b-values of differently packaged sausages irradiated during storage at 4

Packaging	Irradiation dose	Storage(day)		
		0	7	14
Aerobic	0kGy	4.79±0.13^{a}	3.94±0.06^{A}	3.66±0.06^{a}
	2kgy	4.46±0.16^{b}	3.73±0.17^{a}	3.33±0.32^{ab}
Vacuum	0kGy	4.79±0.13^{a}	3.79±0.13^{a}	3.04±0.33^{b}
	2kgy	4.46±0.16^{b}	3.39±0.09^{b}	3.03±0.17^{B}

a~b Means ±S.D were significantly different in the same column(p<0.01)
A~D Means ±S.D were significantly different in the same column(p<0.01)

Table 9. Descriptive analysis with scaling of vacuum packaged sausages irradiated during storage at 4

	Aroma	Off-flavor	Color	Acceptability
0 kGy	4.35±1.8^{B}	4.55±2.4	5.00±1.3	4.60±1.6
2 kgy	5.95±1.8^{A}	5.90±2.2	5.95±1.9	4.00±1.9

A~B Means ±S.D were significantly different in the same column(p<0.01)

Table 10. Descriptive analysis with scaling of vacuum packaged sausages irradiated by antioxidants (D-14)

	Aroma	flavor	Off-flavor	Color	juiciness	tenderness	Acceptability
control	6.9±1.55	7.4±1.19	5.0±2.33	6.1±1.13	5.8±1.83	5.8±1.39	4.1±2.03
vit.C	6.8±1.91^{AB}	6.6±1.19^{A}	5.5±2.14^{BC}	6.4±1.41^{AB}	5.8±2.55^{ABC}	6.3±1.98^{ABC}	4.5±2.45^{C}
vit.E	6.4±2.33	6.5±1.85	4.4 ±2.45	5.3±2.19	5.3±1.91	6.4±1.41	4.6±1.77
vit.C+vit.E	6.6±0.92	6.0±0.93	5.0 ±1.93	5.4±0.74	5.0 ±1.77	6.1±1.25	4.9±2.23
rosemary	6.4±1.19^{A}	5.8±1.49^{AB}	3.9 ±2.03^{B}	5.5±1.31^{AB}	4.1±1.55^{B}	5.6±2.00^{AB}	5.6±2.07^{AB}

A-B Means ± S.D were significantly different in the same row (p<0.01)

Table 11. TBARS values of vacuum packaged sausages irradiated by antioxidants

	D-0	D-7	D-14
control	1.61±0.50	1.93^{a}±0.31	1.78±0.33
vit.C	1.56 ±0.32	1.44^{b}±0.19	1.46±0.13
Vit. E	1.43 ±0.13	1.47^{b}±0.18	1.41±0.22
vit c+vit.E	1.50 ±0.28	1.33^{b}±0.13	1.34±0.12
Rosemary	1.55 ±0.33	1.49^{b}±0.23	1.38±0.26

a~b Means ±S.D were significantly different in the same column(p<0.01)