Korean J. Food Preserv.
Vol. 12, No. 1. pp. 28-35, February 2005

사단법인 한국식품저장유통학회
THE KOREAN SOCIETY OF FOOD PRESERVATION

Quality Improvement of Chicken Breast Meat in a Group-Meal Service by Gamma Irradiation

Jang-Ho Kim[1], Jin-Yong Jeon[2], Sang-Ryeol Ryu[2], Ju-Woon Lee[1], Jae-Hun Kim[1], Sang-Hee Oh[1], Ji-Hyun Seo[1] and Myung-Woo Byun[1†]

[1]*Radiation Food Science and Biotechnology Team, Korea Atomic Energy Research Institute, Deajeon 305-353, Korea*

[2]*Department of Food Science and Technology, Seoul National University, Seoul 151-742, Korea*

감마선조사에 의한 단체급식용 닭 가슴살의 품질 개선

김장호 · 전진용 · 유상렬 · 이주운 · 김재훈 · 오상희 · 서지현 · 변명우
한국원자력연구소 방사선이용연구부, 서울대학교 식품공학과

Abstract

The storage temperature significantly affected the microbiological quality of the chicken breast. In the non-inadiated samples at 30℃, aerobic plate counts (APC) and *Escherichia coli* counts of the samples considerably increased during 3 days of storage and were eliminated by an irradiation at dose of 10 kGy or more. The APC and *E. coli* counts of the samples stored at 5℃ were reduced to below the limit of detection (< 2 log CFU/g) through the whole storage period by an irradiation at 5 kGy or more. There was no significant difference in the TBA values between the non-inadiated and irradiated samples, which were not significantly higher in the irradiated samples than the non-inadiated samples during 2 weeks of storage at 5℃. According to the same-different test and acceptance test, the sensory quality of the irradiated chicken breast was not significantly different from that of the non-inradiated sample even at 10 kGy. It is found that gamma irradiation is an effective tool to improve the quality of chicken breast in a group-meal service. It was also found that there was no evidence that an irradiation induced mutagenicity in the chicken breast meat.

Key words : chicken breast, irradiation, microbial quality, TBA values, sensory quality

Introduction

In Korea, chicken meat is a favorite food containing high protein and low cholesterol and its consumption has gradually increased (1). Chicken meat is cooked in various types of dishes, such as chicken broth with ginseng, boiled chicken with rice, chicken stew, chopped roast chicken, fried chicken, and a chicken salad. Also, chicken is widely used in the group-meal service due to its nutritional value, flavor, etc. (2, 3).

Recently, food borne diseases have frequently broken out in a group-meal service mainly due to contaminated food materials(4). An outbreak in a group-meal service may lead to severe results in which numerous cases of food poisoning and even casualties could occur. In 2003, 77% of all the cases of food borne outbreaks resulted from group meal services(4). Consequently, it is essential to prevent a contamination of the food material to reduce the risk of food borne outbreaks.

Chicken is easily contaminated from a bowels removal and their rupture during the process(5) and is very perishable even under chilling storage conditions(6, 7). For these reasons, several studies have concentrated on developing the methods

† Corresponding author. E-mail : mwbyun@kaeri.re.kr, Phone : 82-42-868-8060, Fax : 82-42-866-8043

to extend its shelf-life and improve the quality of the chicken carcass such as a sodium tripolyphosphate treatment (8), various packaging methods (9, 10), storage temperature control (11), and a chemical preservative treatment (12).

Gamma irradiation has proven to be an effective treatment to eliminate a microbial contamination without any defects. Food irradiation uses a low energy, causes little increase of the product temperature and residual components, and can be used in a continuous process after packaging (13-15). The wholesomeness of a food irradiation has already been approved by the international organizations or health authorities, such as such the World Health Organization (WHO), the Food and Agriculture Organization (FAO), the International Atomic Energy Agency (IAEA), and the U. S. Food and Dug Administration (FDA).

Therefore, the present study investigated into irradiation effect on the microbial quality and the physiochemical properties of chicken breast under different storage conditions.

Materials and Methods

Sample preparation and gamma irradiation

Frozen chicken breast meat was obtained from a local chicken processing plant and packaged in air and a vacuum. The samples in the bags were irradiated with a dose rate of 7 kGy per hour of gamma ray to obtain 2.5, 5.0, 7.5, and 10 kGy for the samples stored at 5℃, and 10, 20, and 30 kGy for the samples stored at 30℃ by using a Co-60 gamma ray irradiating facility (IR-79, Nordion International Ltd., Ontario, Canada, 100 kCi). The irradiation dose was validated by using 5-mm diameter alanine dosimeters (Bruker Instrument, Rheinsttten, Germany) and the free radical was measured by using an EMS 104 EPR Analyzer (Bruker Instrument). The actual doses were within ± 2% of the target doses.

Microbiological analysis

After an irradiation, for 0, 3, 6, and 9 days of storage at 30℃ and 0, 1, 2, and 4 weeks of storage at 5℃ the samples were blended with 0.1% (W/V) peptone solution (Difco Laboratories, Detroit, MI) using a stomacher (BagMixer® 400, Interscience Inc., St. Nom, France) for 2 min. After serial dilutions, 0.1 ml aliquots from appropriate dilutions were plated onto plate count agar (Difco Laboratories) for the aerobic plate counts and eosin methylene blue agar (Merck, Darmstad, Germany) for *E. coli* using a standard spread plate method. The plates in duplicate were incubated at 30℃ for 48 hrs for the aerobic plate counts, at 37℃ for 24 hrs for the *E. coli.* counts.

2-Thiobarbituric acid (TBA) value measurement

Based on the method of Jo and Ahn (16), TBA values of the frozen chicken breast meat were measured during storage. A five gram sample was homogenized in a 50-ml centrifuge tube with a 50 ul of BHA (7.2% in ethanol) and 15 ml of distilled water using a homogenizer (DIAX 900, Heidolph Co., Ltd., Germany). One milliliter of the homogenate was mixed with 2 ml of thiobarbituric acid (TBA)/trichloroacetic acid (TCA) solution (20 mM TBA in 15 % TCA) and heated in boiling water for 15 min. After cooling, the mixture was centrifuged for 25 min at 2,000 rpm using a centrifuge (UNION 5KR, Hanil Science Industrial, Co., Ltd., Incheon Korea). The absorbance of the supernatant was measured at 532 nm using a spectrophotometer (UV 1600 PC, Shimaszu, Tokyo, Japan). The concentration (mg/kg sample on the basis of wet weight) of malondialdehyde was calculated by using a determination curve.

Texture analysis

Chicken breast meat in a polyethylene bag was heated in a waterbath (Thermominder EX, Teitec Co., Nagasaki, Japan) and the core temperature inside the sample was maintained at 75℃ for 30 min. After cooling at room temperature, the core portion was obtained, cut into a 1 cm^3 piece, and the shear force was measured at right angles to the meat grain orientation. The maximum shear force and the total shear force were measured using a texture analyzer (TA-XT2I, Stable Micro Systems Co., Ltd., Surrey, UK) equipped with a probe that consisted of a blade set with knife. Using the strength (N/mm) versus time curve, the maximum shear force and the total shear force were computerized from the maximum peak and the area inside curve, respectively. After the chicken breast was heated and cooled at room temperature as described above, the weight loss of the chicken breast was measured as follows:

$$\text{The weight loss of the chicken breast (\%)} = \frac{\text{Weight before heated (g)} - \text{Weight after heated (g)}}{\text{Weight before heated (g)}} \times 100$$

Sensory evaluation

The sensory characteristics of the non-irradiated and irradiated chicken breast were evaluated by 22 trained

panelists using same difference and acceptance tests. Chicken breast in a polyethylene bag was served after the core temperature inside the sample had reached 75℃ in a waterbath (Teitec Co.). In the same difference test, an irradiated and 2 non0irradiated samples were given and a different sample (the irradiated sample) was selected by the panelists. In the acceptance test, four sensory attributes were used to grade the overall quality in terms of the appearance, flavor, texture, taste, and overall acceptance. A 5-point scoring system was used to evaluate the sensory attributes; where 1-dislike very much, 2-dislike, 3-fair, 4-like, 5-like very much.

Mutagenicity assay

The *Salmonella mutagenicity* assay (Ames test) was performed according to the method of Maron and Ames (17). *S. typhimurium* strains TA 98 and TA 100 were obtained from the Korea Research Institute of Chemical Technology (KRICT, Daejeon, Korea). The test strains were inoculated on Oxoid nutrient broth No. 2 (Oxoid Co., Ltd., Hampshire, England) and cultured for 10 hrs at 37℃ with a continuous agitation at 200 rpm (Vision Scientific Co., Incheon, Korea). The cell density was 2 x 10^9 CFU/mL. The doses tested were 0.312, 0.625, 1.25, 2.5 and 5 mg sample/plate. The S9 mix was purchased from Oriental Yeast Co., Ltd. (Lot No. 0042101, Tokyo, Japan). The 5% S-9 mix was prepared by using the S-9 mix fraction mentioned above and a cofactor (Wako Co., Lot Np. 999902, Tokyo, Japan). The treatment was 0.5 mL/plate. The activity of the S9 was confirmed from induced an mutagenesis using 2-arninoanthracene (2-AA, Sigma Aldrich Co., Gmbh., Inc., Steinheim, Germany). The positive controls were sodium azide (SA, Sigma-Aldrich Co.), 4 nitroquinoline 1 oxide (4 NQO, Sigma-Aldrich Co.), and 20AA. They were dissolved in deionized distilled water (DDW) or dimethylsulfoxide (DMSO, Aldrich Chem. Gmbh, Inc., Milwaukee, USA). The direct plate incorporation method was used with two plates per each concentration to be tested. The culture (0.1 ml, 2 x 10^9 CFU/mL), 0.1 ml of the sterilized DDW suspension, and 0.5 mL of the S-9 mixture were mixed. Then 2 ml of the top agar containing histidine-biotin was mixed with a minimal glucose agar and solidified. The plates were incubated at 37℃ for 48 hrs and the number of revertant colonies was counted. The negative control was 100 μL of DDW. The positive control was 100 μL of SA, 4 NQO, and 2-AA when the metabolic activation was not incorporated or 100 uL of 2-AA when the metabolic activation was incorporated.

Statistical analysis

Experimental data was analyzed using an analysis of the variance (ANOVA) and the General Linear Models Procedure of a Statistical Package for Social Science 10.05 (18). Duncan's multiple range test was used to separate the treatment means at a significance of $p<0.05$.

Results and Discussion

Microbial analysis

Table 1 shows the aerobic plate and *E. coli* counts of the irradiated chicken beast stored at 5℃. On 0 week of storage, the aerobic plate counts of the non-irradiated chicken breast were 4.88 and 4.85 log CFU/g in air- and vacuum-packaging, respectively, and the aerobic plate counts of the samples irradiated at 2.5 kGy were reduced by 1.38 and 1.31 log CFU/g, respectively. The aerobic plate counts were increased as the storage time was extended. In the samples irradiated at 5 kGy or more, the aerobic plate counts were reduced to below the limit of detection (< 2 log CFU/g) (Table 1). *E. coli* counts of the non-irradiated samples were 2.15 and 2.24 in air- and vacuum packaging, respectively, on 0 week of storage and increased in proportion to the storage time. *E. coli* counts of the samples irradiated at 2.5 kGy were effectively reduced to below the limit of detection (< 2 log CFU/g) for up to 2 weeks of storage. However, in the samples stored at 30℃, the aerobic plate and *E. coli* counts reached >8 log CFU/g and >6 log CFU/g, respectively, and the samples were completely putrefied (Table 2). The aerobic plate counts and *E. coli* counts of the samples were not eliminated with an irradiation at 7.5 kGy or less but with an irradiation at higher doses (10 kGy or more) (Table 2). Licciardello et al. (19) reported that a 4.75 kGy-irradiation reduced the microbial counts of poultry meat by 10^7 CFU/g. Firstenberg-Eden et al. (20) also reported that a 3 kGy-irradiation at 5℃ reduced the natural microflora on chicken skin from $10^4 \sim 10^5$ to $10 \sim 500$ cells/7 cm^2. Cho et al. (21) found that 7.8 x 10^5 CFU/g of mesophilic bacteria in chicken were reduced to 1.3 x 10^3 CFU/g and 4.0 x 10 CFU/g by a 5 and 8 kGy-irradiation, respectively, and completely eliminated by a 10 kGy-irradiation. Kwak et al. (22) stated that 9.5 x 10^4 CFU/g of the total aerobic bacterial counts of chicken were eliminated with a 3 kGy-irradiation and 2.2 x 10^3 CFU/g of the *Salmonella* counts were reduced to below the limit of detection by a 1 kGy-irradiation. Kwak et al. (23) reported that *E. coli* of chicken stored at a cold temperature was completely reduced with 3 kGy.

Table 1. The aerobic plate and E. coli counts of the irradiated chicken breast meat stored at 5℃

Storage period	Air Packaging					Vacuum Packaging				
	Irradiation Dose (kGy)					Irradiation Dose (kGy)				
	0	2.5	5	7.5	10	0	2.5	5	7.5	10
	Total aerobic bacterial count									
0 w[3)]	4.88$^{f1)}$	3.50^{g}	ND[2)]	ND	ND	4.85^{f}	3.54^{h}	ND	ND	ND
1 w	6.07^{cd}	4.86^{f}	ND	ND	ND	6.00^{dc}	4.14^{g}	ND	ND	ND
2 w	8.31^{a}	6.37^{c}	ND	ND	ND	7.80^{b}	6.27^{d}	ND	ND	ND
4 w	8.24^{a}	7.55^{b}	ND	ND	ND	8.37^{a}	7.33^{bc}	ND	ND	ND
	E. coli count									
0 w	2.15^{e}	ND	ND	ND	ND	2.24^{fg}	ND	ND	ND	ND
1 w	3.37^{c}	ND	ND	ND	ND	3.65^{c}	ND	ND	ND	ND
2 w	5.33^{b}	2.75^{cde}	ND	ND	ND	5.60^{b}	2.45^{f}	ND	ND	ND
4 w	6.52^{a}	5.32^{b}	ND	ND	ND	6.47^{a}	5.44^{cd}	ND	ND	ND

[1)]Means of 12 replications followed by different letters are significantly different ($p<0.05$).
[2)]ND means 'not detected'.
[3)]w : week

Table 2. The aerobic plate and *E. coli* counts of the irradiated chicken breast meat stored at 30℃

Storage period	Air Packaging					Vacuum Packaging				
	Irradiation Dose (kGy)					Irradiation Dose (kGy)				
	0	2.5	5	7.5	10	0	2.5	5	7.5	10
	Total aerobic bacterial count									
0 d[2)]	5.22	ND[1)]	ND	ND	ND	5.22	ND	ND	ND	ND
3 d	8.31	ND	ND	ND	ND	8.58	ND	ND	ND	ND
	E. coli count									
0 d	2.50	ND	ND	ND	ND	2.50	ND	ND	ND	ND
3 d	>6.00	ND	ND	ND	ND	>6.00	ND	ND	ND	ND

[1)]ND means 'not detected'.
[2)]d : day

2-Thiobarbituric acid (TBA) value

Table 3 shows the changes of the 2-thiobarbituric acid (TBA) values of the irradiated chicken breast meat stored at different storage conditions. In the present study, the TBA values of the samples were slightly increased as the storage period was extended. In general, the TBA values of the irradiated samples were considerably higher than those of the non-irradiated samples and they were increased in proportion to the irradiation dose (Table 3). This result is in accordance with other studies. Chuang et al. (24) reported that the storage time and irradiation dose affected the TBA values of chicken patties and the TBA values were increased as the irradiation dose was increased. Lee and Kim (25) also reported that the TBA values were increased in proportion to the irradiation dose. Gomez et al. (26) stated that the TBA -values of irradiated mechanically deboned chicken meat (MDCM) were higher than those of non-irradiated MDCM and that they were increased as the irradiation dose was increased. Zhu et al. (27) stated that the TBA values were increased by the oxidation caused by the free radicals during the irradiation process. They reported that the TBA values of the irradiated samples were proportionally increased depending on the irradiation dose and storage period. In addition, the TBA values of the air-packaged samples were higher than those of the vacuum-packaged samples (Table 3). This result is also in agreement with other studies that found that the increase in the TBA value was due to an oxidation of the fat induced by an irradiation (24, 27). It is likely that the vacuum-packaging inhibits the rancidification of the irradiated samples by blocking the oxygen inflow.

Texture analysis

Table 4 shows the maximum shearing force (N/mm) and the total work of the shearing (N/mm • S) of the irradiated chicken breast meat stored at different conditions. In this study, there was no significant change in the maximum shearing force as the irradiation dose was increased, but the maximum shearing forces of the chicken breast samples were increased as the storage period was extended. The maximum shearing forces of the air-packaged samples were higher than those of the vacuum-packaged samples and those of the irradiated samples were higher than those of the non-irradiated samples (Table 4). The total work of the shearing of the chicken breast meat was slightly changed in a similar manner

Table 3. Changes of the TBA values of the irradiated chicken breast meat during storage at 5℃

Storage periods	Air Packaging					Vacuum Packaging				
	Irradiation Dose (kGy)					Irradiation Dose (kGy)				
	0	2.5	5	7.5	10	0	2.5	5	7.5	10
0 w	0.21$^{bxyz1)}$	0.24^{bxy}	0.19^{cz}	0.27^{bwx}	0.26^{bwx}	0.21^{ayz}	0.26^{bwx}	0.23^{bxyz}	0.39^{bw}	0.30^{abw}
1 w	0.42^{aw}	0.46^{aw}	0.41^{bw}	0.37^{bwx}	0.39^{bxy}	0.28^{ay}	0.27^{by}	0.34^{bwxy}	0.28^{by}	0.34^{abwx}
2 w	-$^{2)}$	0.68^{aw}	0.40^{bw}	0.37^{bwx}	0.36^{bwx}	0.29^{bz}	0.32^{bxy}	0.27^{by}	0.26^{by}	0.28^{axy}
4 w	-		1.62^{aw}	1.65^{aw}	1.69^{aw}		0.70^{ax}	0.76^{ax}	0.70^{ax}	0.53^{axy}

[1)]Means of 12 replications followed by different letters (a-c) within a same column are significantly different ($p<0.05$). Means of 12 replications followed by different letters (x-z) within a same row are significantly different ($p<0.05$).
[2)]The samples were not tested due to severe deterioration.
[3)]w : week

to the maximum shearing force. Lee and Kim (25)reported that the salt-soluble proteins were degraded by an irradiation and the chicken might be tenderized. However, Yoon (28) showed that the chicken breast meat irradiated at a low dose became tougher due to the destruction of the myofibril and the contraction of the sacromeres and reported that the texture was also affected by a cooking loss. The result of this study also showed that the shearing force of the chicken breast meat was increased as the cooking loss was increased (Table 4 and 5). At 4 weeks of storage, the shearing forces of the non-irradiated samples and 2.5 kGy-irradiated samples which were air-packaged were not measured due to a severe deterioration of the samples. According to these finding, it is likely that an irradiation causes very little textural degradation of the samples.

Sensory evaluation

Table 6 shows the results of the same-different test (triangle test) and the acceptance test of the irradiated chicken breast meat to evaluate the effect of an irradiation on the sensorial quality of the chicken breast meat. In the present study, the sensorial quality of the irradiated chicken breast meat was different depending on the packaging method. In the air-packaged samples irradiated at 10 kGy, the acceptance characteristics such as the appearance and flavor were significantly decreased, and 63% of the panel in the same different test discriminated the irradiated samples from the non-irradiated samples. In the vacuum-packaged samples irradiated at 10 kGy, all the acceptance characteristics but the flavor were not significantly different from the non-irradiated samples. In the same-different test, the irradiated samples were not discriminated from the non irradiated samples (Table 6). Several researches (29, 30) have reported that sulfur compounds appear to be the main volatile components responsible for the irradiation odor of meat. Ahn et al. (31) reported that the differences in off-odors between irradiated and non-irradiated raw chicken was not correlated to an oxidation. Gomes et al. (26) found that burnt skin and off-flavor such as scorched odor were detected from the irradiated MDCM and that volatile compounds such as

Table 4. Shearing force of the irradiated chicken breast meat at 5℃ during 4 week

Storage period	Air Packaging					Vacuum Packaging				
	Irradiation Dose					Irradiation Dose				
	0	2.5	5	7.5	10	0	2.5	5	7.5	10
	Maximum shearing force (N/mm)									
0 w$^{3)}$	1.38^{bz}	2.39^{ax}	2.12^{bxy}	1.59^{ayz}	2.21^{bx}	1.38^{bz}	1.34^{bz}	1.65^{cyz}	2.08^{bxy}	1.99^{abxy}
1 w	1.43^{bz}	2.53^{vwx}	1.38^{byz}	2.20^{bwxy}	2.74^{avw}	2.11^{axy}	1.95^{bxyz}	1.83^{bcyz}	2.91^{ax}	2.34^{avwxy}
2 w	3.13^{ax}	2.34^{xy}	3.27^{ax}	2.42^{ax}	2.53^{ax}	1.99^{ayz}	1.65^{az}	2.08^{byz}	2.29^{bxy}	1.79^{bz}
4 w			3.12^{aby}	2.49^{az}	2.53^{bz}		2.19^{az}	3.02^{ay}	2.24^{bz}	2.48^{az}
	Total work (N/mm · s)									
0 w	3.53^{byz}	5.48^{v}	4.94^{bcvwx}	3.88^{bxyz}	5.15^{bvw}	3.53^{byz}	3.35^{bz}	3.95^{bwxyz}	4.85^{bvwx}	4.65^{abvwxy}
1 w	3.66^{bz}	5.81^{wx}	4.13^{cz}	4.76^{bxyz}	6.83^{ax}	4.47^{ayz}	4.59^{ayz}	4.15^{bz}	6.95^{ax}	5.64^{axy}
2 w	7.48^{au}	5.67^{vwx}	7.83^{au}	5.85^{aw}	5.74^{bvw}	4.85^{axyz}	4.14^{abz}	4.93^{bwxyz}	5.22^{bvwxy}	4.52^{byz}
4 w	-$^{2)}$		7.25^{by}	5.89^{az}	5.91^{bz}		5.22^{az}	7.42^{ay}	5.39^{bz}	6.01^{az}

[1)]Different letters (a-c) within a same column indicate significant difference ($p<0.05$).
Different letters (x-z) within a same row indicate significant difference ($p<0.05$).
[2)]The samples were not tested due to severe deterioration.
[3)]w : week

Table 5. Determination of the cooking loss (%) of the irradiated chicken breast after cooking at 80℃

Storage period	Air Packaging					Vacuum Packaging				
	Irradiation Dose (kGy)					Irradiation Dose (kGy)				
	0	2.5	5	7.5	10	0	2.5	5	7.5	10
0 w[2)]	25.12	22.60	25.62	26.34	22.27	25.17	26.42	26.86	23.70	24.34
4 w	-[1)]		22.23	24.20	24.29		23.91	25.85	23.91	20.67

[1)]The samples were not tested due to severe deterioration.
[2)]w : week

Table 6. Changes of the sensory characteristics of the irradiated chicken breast meat

	Air packaging					Vacuum packaging				
	Irradiation dose (kGy)					Irradiation dose (kGy)				
	0	2.5	5.0	7.5	10	0	2.5	5.0	7.5	10
	(A) Same different test (triangle test)[1)]									
Correct (number of panels)		9	11	6	14		8	7	10	8
Incorrect (number of panels)		13	11	16	8		14	15	12	14
	(B) Acceptance test[2)]									
Appearance	$3.6^{a3)}$	3.5^{ab}	3.0^{ab}	3.0^{ab}	2.9^{b}	3.5^{ab}	3.5^{ab}	3.2^{ab}	3.2^{ab}	3.0^{ab}
Flavor	3.8^{a}	3.3^{abcd}	2.7^{e}	2.6^{de}	2.9^{cde}	3.6^{a}	3.5^{ab}	3.4^{abc}	3.0^{bcde}	3.0^{bcde}
Texture	3.8	3.6	3.5	3.5	3.3	3.7	3.6	3.3	3.3	3.4
Taste	3.7	3.5	3.4	3.4	3.5	3.5	3.6	3.6	3.6	3.4
Overall acceptance	3.8^{a}	3.5^{a}	3.4^{ab}	3.2^{ab}	2.9^{b}	3.6^{a}	3.5^{a}	3.2^{ab}	3.0^{ab}	3.2^{ab}

[1)]Twenty-two panelists were employed and the test was performed to choose one different sample in each tow non-irradiated and one sample with duplication.
[2)]Twenty-two panelists were employed. Very poor corresponded to 1.0 and very good to 5.0.
[3)]Different letters a-e within the same row indicate significant difference (P<0.05).

dimethyl trisulfide, cis 3 and trans 6 nonenals, oct 1 en 3 one and bis(methylthio) methane could be responsible for the irradiation odor. The results in this study showed that there was no significant difference in the sensorial qualities between the irradiated samples vacuum packaged and the non-irradiated samples.

Mutagenicity assay

To evaluate the genetoxicological safety of irradiated chicken breast meat, a mutagenicity test was conducted by the method of Maron and Ames (17), the results are shown in Tables 7 and 8. There was no significant difference in revertant colonies of *S. typhimurium* TA98 and TA100 between the non irradiated samples and the 30 kGy irradiated samples. The solvent type, water soluble and organic solvents-soluble fraction, and the S-9 mixture did not affect the number of the revertant colonies (Table 7 and 8). The results of this study were in accordance with the studies by Thayer and Murry (32) and Kwak et al. (22). They also conducted the mutagenicity test using the same test microorganisms and reported that an irradiation on chicken did not induce mutagenicity. In addition, WHO (33) has reported that a large number of toxicological studies have not demonstrated any toxicity related to the irradiation process.

Table 7. Revertant colonies in the S. *typhimurium* reversion assay with the water soluble and the organic solvents mixture[a)]-soluble fraction of the non irradiated chicken

Test material	Dose (μg/plate)	S-9	Number of revertant colonies per plate	
			TA98	TA100
Water fraction	5000		27±4	251±10
	2500		35±1	193±22
	1250		40±10	240±56
	625		23±1	228±24
	312		31±11	204±2
	5000	+	38±3	225±53
	2500	+	47±6	225±32
	1250	+	60±10	264±1
	625	+	55±1	241±7
	312	+	32±3	226±65
Solvent fraction	5000		28±5	209±13
	2500		29±12	192±18
	1250		30±3	223±12
	625		25±6	205±8
	312		29±1	223±24
	5000	+	41±1	190±14
	2500	+	38±3	248±23
	1250	+	27±3	210±3
	625	+	43±10	232±14
	312	+	44±16	210±2
H_2O			33±4	153±9
H_2O		+	32±7	161±19
4NQO[1)]	0.5		330	
SA[2)]	0.5			796
2-AA[3)]	2	+	306	4000

Each value represents the mean ± standard deviation of the results obtained from experiments repeated with five times (P<0.05).
[a)]Organic solvents mixture was prepared with the mixing rate of 2 to 1 of methanol to chloroform, respectively.
[1)]4-Nitroquinoline-1-oxide(4NQO),[2)] Sodium azide(SA),[3)] 2-Aminoanthracene(2-AA) were used as positive controls for the corresponding strains.

Table 8. Revertant colonies in the S. *typhimurium* reversion assay with the water soluble and the organic solvents mixture[a]-soluble fraction of the 30 kGy gamma irradiated chicken

Test material	Dose (μg/plate)	S-9	Number of revertant colonies per plate	
			TA98	TA100
Water fraction	5000		34±18	273±20
	2500		36±1	217±11
	1250		44±2	212±27
	625		33±10	238±1
	312		37±8	179±10
	5000	+	50±12	277±14
	2500	+	51±10	315±44
	1250	+	48±8	294±17
	625	+	43±1	237±32
	312	+	427±4	184±70
Solvent fraction	5000		29±13	235±8
	2500		37±3	216±23
	1250		37±2	231±13
	625		31±6	224±21
	312		37±3	195±7
	5000	+	53±1	285±7
	2500	+	47±3	286±27
	1250	+	47±7	275±34
	625	+	45±5	300±22
	312	+	42±3	283±23
H_2O			33±4	153±9
H_2O		+	32±7	161±19
4NQO[1]	0.5		330	
SA[2]	0.5			796
2-AA[3]	2	+	306	4000

Each value represents the mean ± standard deviation of the results obtained from experiments repeated with five times ($P<0.05$).

[a]Organic solvents mixture was prepared with the mixing rate of 2 to 1 of methanol to chloroform, respectively.

[1]4-Nitroquinoline-1-oxide(4NQO), [2]Sodium azide(SA), [3]2-Aminoanthracene (2-AA) were used as positive controls for the corresponding strains.

Maron and Ames (17) reported that mutagenicity can be considered positive when the number of revertant colonies is more than double when compared to the negative control and it is dose-dependent. For these reasons, there was no evidence that an irradiation induced mutagenicity in chicken breast meat.

Acknowledgement

This project has been carried out under the Nuclear R & D Program by the Korea Ministry of Science and Technology.

요 약

저장온도는 닭고기 가슴살의 미생물학적 품질에 유의적 영향을 주었다. 30℃에서 저장된 비조사시료에서 총균수와 대장균수는 저장후 3일 동안 현저히 증가하였고, 10 kGy 이상의 감마선조사에 의하여 사멸되었다. 5℃에서 저장된 시료의 총균수와 대장균수는 5 kGy 이상의 감마선조사에 의하여 검출제한(< 2 log CFU/g) 미만으로 감소되었다. 일반적으로 비조사시료와 조사시료 간의 TBA값에는 유의적 차이가 없었으며, 2주 동안의 5℃ 저장에서 조사시료의 TBA값은 비조사시료의 TBA 값에 비해 뚜렷한 증가를 보이지 않았다. 차이식별검사와 수용도검사의 결과에 따르면, 10 kGy의 감마선조사로도 닭고기 가슴살의 관능적인 품질은 비조사된 시료의 품질과 뚜렷한 차이가 없었다. 감마선조사는 단체급식용 닭고기 가슴살의 품질을 개선하는 효과적인 수단이라는 사실을 알 수 있었다. 또한 감마선조사는 닭고기 가슴살에서의 돌연변이를 유발하지 않는 것으로 판단된다.

References

1. Oh, S.Y. and Yoo, I.J. (2001) Comparative analysis of Korean consumption behavior in chicken. Korean J. Food Sci. Anim. Res., 21, 110-115
2. Cho, K.D. and Lee, B.H. (2004) HACCP system application on chicken entrees served by lunch program of elementary schools. Korean J. Food Cookery Sci., 20, 63-75
3. Park, J.H. (2001) Isolation and identification of *Campylobacter* spp. from raw chicken carcasses on food service. J. Food Hyg. Safety, 16, 258-263
4. Korean Food and Drug Administration. (2004) Statistics of foodborne disease outbreaks status. Available from: http://www.kfda.go.kr. Accessed Apr., 14, 2004
5. Kim, D.H., Chae, H.S. and Chang, K.M. (2004) Implication of fed withdrawal in broiler meat safety and quality. Korean J. Food Sci. Ani. Resour., 24, 202-208
6. Jimenez, S.M., Salsi, M.S., Tiburzi, M.C. Rafaghelli, R.C., Tessi, M.A. and Coutaz, V.R. (1997) Spoilage microflora in fresh chicken breast stored at 4℃. J. Appl. Microbiol., 83, 613-618
7. Bailey, J.S, Lyon, B.G., Lyon, C.E. and Windham, W.R. (2000) The microbiological profile of chilled and frozen chicken. J. Food Prot., 63, 1228-1230
8. Choi, Y.I. (1992) Effect of phosphate on binding ability and storage characteristics of pre-cooked restructured chicken meat product. Korean J. Anim. Sci., 34, 307-315
9. Gill, C.O. and Harrison, J.C.L. (1989) The storage life of chilled pork packaged under carbon dioxide. Meat Sci., 26, 313-319
10. Hart, C.D., Mead, G.C. and Norris, A.P. (1991) Effect of gaseous environment and temperature on the storage behavior of *Listeria monocytogenes* on chicken breast meat. J. Appl. Bacteriol., 70, 40-49

11. Winger, R.J. and Fennema, O. (1976) Tenderness and water holding properties of beef muscle as influenced by freezing and subsequent storage at 3 or 15℃. J. Food Sci., 41, 1433-1439
12. Yamamoto, K. and Samejima, K. (1977) A comparative study of the change in hem pectoral muscle during storage at 4 and 2℃. J. Food Sci., 42, 1642-1647
13. Cramwinckel, A.B. and Mazijk Bokslag, D.M. (1989) Dutch consumer attitudes toward food irradiation. Food Technol., 43, 104-110
14. McKinley, R.C. (1994) Food irradiation: past, present, and future. J. Food Hyg. Safety, 9, S1-S11
15. Schutz. H.G., Bruhn, C.M. and Diaz Knauf, K.V. (1989) Consumer attitude toward irradiated foods: effects of labeling and benefits information. Food Technol., 43, 80-86
16. Jo, C. and Ahn, D.U. (2000) Production of volatile compounds from irradiated oil emulsions containing amino acids or proteins. J. Food Sci., 65, 612-616
17. Maron, D.M. and Ames, B.N. (1983) Revised methods for the *Salmonella* mutagenicity test. Mutat. Res., 113, 173-215
18. SPSS, Inc. (1999) SPSS for Windows. Rel. 10.05. SPSS Inc. Chicago, IL
19. Licciardello, J.J., Nixjweaib, J.T.R. and Goldblith, S.A. (1968) Elimination of *Salmonella* in poultry with ionizing reaction. In Elimination of Harmful Organisms from Food and Feed by Irradiation. Vienna, IAEA.
20. Firstenberg Eden, R., Rowley, D.B. and Shattuck, G.E. (1983) Competitive groeth of chicken skin microflora and *Clostridium botulinum* type E after an irradiation dose of 3 kGy. J. Food Prot., 46, 12-18
21. Cho H.O., Lee, M.K., Byun, M.W., Kwon, J.H. and Kim, J.K. (1985) Radurization of the microorganisms contaminated in chicken. Korean J. Food Sci. Technol., 17, 170-174
22. Kwak, H.J., Chung, C.K. and Kang, I.J. (2001) Microbiological and genotoxicological safety of gamma-irradiated chicken. Korean J. Soc. Food Cookery Sci., 17, 617-624
23. Kwak, H.J., Lee, S.O. and Jung, I.C. (2002) Irradiation of chicken for the improvement of hygiene. Korean J. Culin. Res., 8, 249-257
24. Chuang, J.T., Yi, Y.H. and Chen, T.C. (1990) Microbial quality and TBA values of chicken patties as affected by irradiation and storage temperature. Korean J. Food Sci. Technol., 22, 290-295
25. Lee, K.A. and Kim, M.J. (2004) Physico chemical properties of irradiated chicken. Korean J. Living Sci., 13, 91-95
26. Gomes, H.A., Silva, E.N., Cardello, H.M.A.B. and Cipolli, K.M.V.A.B. (2003) Effect of gamma radiation on refrigerated mechanically deboned chicken meat quality. Meat Sci., 65, 919-926
27. Zhu, M.J., Lee, E.J., Mendonca, A. and Ahn, D.U. (2003) Effect of irradiation on the quality of turkey ham during storage. Meat Sci., 66, 63-68
28. Yoon, K.S. (2003) Effect of gamma irradiation on the texture and microstructure of chicken breast meat. Meat Sci., 63, 273-277
29. Angelini, P., Merritt, C.Jr., Mendelshon, J.M. and King, J.F. (1975) Effect of irradiation on volatile constituents of stored haddock flesh. J. Food Sci., 40, 197-199
30. Du, M., Ahn, D.U., Nam, K.C. and Sell, J.L. (2000) Influence of dietary conjugated linoleic acid on volatile profiles, color and lipid oxidation of irradiated raw chicken meat. Meat Sci., 56, 387-395
31. Ahn, D.U., Jo, C. and Olson, D.G. (2000) Analysis of volatile components and the sensory characteristics of irradiated raw pork. Meat Sci., 54, 209-215
32. Thayer, D.W. and Murry, A.C. (1987) Toxicology studies of irradiated sterilized chicken. J. Food Prot., 50, 278-234
33. World Health Organization (WHO). (1999) High dose irradiation: wholesomeness of food irradiated with doses above 10 kGy. WHO Technical Report Series 890, Geneva

(접수 2004년 12월 10일, 채택 2005년 1월 14일)