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Irradiated luncheon meat: microbiological, chemical and sensory characteristics during storage

M. Al-Bachir[a,*], A. Mehio[b]

[a]Radiation Technology Department, Syrian Atomic Energy Commission, PO Box 6091, Damascus, Syria
[b]Department of Food Technology, Agriculture Faculty, Aleppo University, Aleppo, Syria

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Abstract

To investigate the effect of gamma irradiation on the shelf-life of luncheon meat, packs were exposed to doses of 0, 1, 2, 3 and 4 kGy in a ^{60}Co package irradiator. Irradiated and non-irradiated samples were stored at refrigeration temperatures (1–4°C). Microbial population, chemical changes and sensory properties were evaluated every 2 weeks during 14 weeks of storage. The results indicated that gamma irradiation reduced the counts of microorganisms and increased the shelf-life of luncheon meat from 10 weeks for the control to 14 weeks for irradiated samples. Total acidity, lipid oxidation and the volatile basic nitrogen (VBN) increased after 2 weeks of irradiation. However, after 10 weeks of storage, the total acidity and volatile basic nitrogen were less than the control. Sensory evaluation indicated that no significant differences ($P > 0.05$) were found between irradiated and non-irradiated samples in taste, and flavour.

Keywords: Irradiation; Luncheon meat; Shelf-life

1. Introduction

Foods of animal origin, such as unprocessed meat, usually contain large numbers of spoilage micro-organisms as well as possible pathogens.

Irradiation is one possible method to help assure meat safety, when combined with good manufacturing practices (Gants, 1996; WHO, 1981). Treatment with low doses of ionizing radiation is considered as an effective procedure for meat decontamination and shelf-life extension at refrigeration temperatures (Urbain, 1986).

The microbiological safety of irradiated meat and their products is affected by most of the factors observed with any other food processing technology (Thayer, 1993). The advantages of irradiation in controlling microorganisms in different kinds of meat such as pork (Lebepe, Molins, Charoen, Farrar, & Skowronsdi, 1990; Mattison, Kraft, Olson, Walker, Rust, & James, 1986; Thayer, 1993; Thayer, Fox, & Lakritz, 1993, 1995), chicken (Luchsinger et al., 1996), and ground beef (Murano, 1995), are well known, but information about the effect of ionizing irradiation on the safety and storability of luncheon meat is still unclear.

A major concern in irradiating meat, however, is its effect on meat quality, mainly because of free radical reactions resulting in the possibility of odour generation during irradiation. Ionizing radiation generates hydroxyl radicals in aqueous (Thakur & Singh, 1994) or oil emulsion systems (O'Connell & Garner, 1983). Hydroxyl radicals may also be produced in irradiated meat because a significant portion of the muscle cells (75%) are water surrounded by lipid bilayers. Thus, it may lead to lipid oxidation (Thakur & Singh, 1994). However, the volatile compounds responsible for off-odours produced by changes in the protein and lipid molecules in irradiated meat are different from those of lipid oxidation (Merritt, 1966).

Irradiation was found to have no detrimental effect on flavour in vacuum-packed raw or cured meat (Shahidi, Pegg, & Shamsuzzaman, 1991; Shamsuzzaman, Chuagiu-Offermann, Lucht, McDougall, & Borsa, 1992), and there is little information available on lipid oxidation, free fatty acids and volatiles production in irradiated cooked meat, especially when low irradiation doses (10 kGy), are employed. Luncheon meat is considered an important industrial product, and it is used for fast meals. However, no information is available on using irradiation to improve its quality and storability. Therefore, the objective of this study was to investigate

* Corresponding author.

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the effect of using gamma radiation on shelf-life, sensory and chemical properties of luncheon meat.

2. Materials and methods

2.1. Preparation and formulation of luncheon meat

Beef was obtained from a commercial supplier, and ground through a 3–4 mm grinder plate. The ground beef was mixed for 5 min with 2% salt. The preblend was held for 6 h at 4°C. The preblend was then mixed for 5 min with 7% egg, 4% flour, 3% dried milk, 4% soybean, 1% spices, 1% ground garlic, ascorbic acid (0.4 g/kg meat), and $Na_3HP_2O_7$ (1.5 g/kg meat). The new mixture was ground with 20% ice for 5 min. The pastes were stuffed into round bottom tubes 5-cm diameter, 15-cm long, fibrous casings (about 300 g each) and cooked for 90 min at 90–95°C using steam as the heat source. The fibrous casings were removed after cooking as per domestic market. Every piece was individually packed with aluminum foil and stored under refrigeration (1–4°C) for 10 h.

2.2. Gamma irradiation and storage trial

Packed luncheon meat samples were exposed to gamma radiation doses of 0, 1, 2, 3, and 4 kGy in a ^{60}Co package irradiator (dose rate 730 Gy/h). The absorbed dose was determined using an alcoholic chlorobenzene dosimeter (Cserep et al., 1971), After processing non-irradiated and irradiated meat samples (30 for each treatment) were stored at 1–3°C for 14 weeks. Microbiological, chemical, and sensory analyses were performed on samples of each treatment, immediately after irradiation, and at different periods of storage.

2.3. Microbiological analysis

To accelerate spoilage, inoculated meat bags were incubated at 27°C for 10 h. One bag from each treatment was aseptically opened. Ten grams of luncheon meat were used to prepare serial dilutions according to standard methods (AOAC, 1986). Aerobic plate counts (APCs) were enumerated after plating with double case agar (PCA) and incubated at 37°C for 48 h to determine the total plate counts for mesophilic bacteria. Three replicates were used for each treatment.

2.4. Chemical analysis

Approximately 150 g of luncheon meat was blended for 15 s in a laboratory blender. This sample was used in all the chemical analyses. Each sample was homogenized and later analyzed in triplicate, to determine moisture, fat (as extractable component in Soxhlet apparatus), and protein (as Kjeldahl nitrogen), using standard methods (AOAC, 1990).

2.5. Total acidity

The total acidity was obtained by direct titration with (0.1 M) NaOH and phenolphthalein as indicator (Egan, Kirk, & Sawyer,1987). Ten grams of each sample were magnetically stirred in a total volume of 100 ml distilled water for 30 min, and filtered. Ten millilitres filtrate was titrated with (0.1 M) NaOH using three drops of phenolphthalein as indicator. The total acidity was calculated as 1.0 ml of (0.1 M) NaOH = 0.0090 g lactic acid.

2.6. Total volatile basic nitrogen (VBN)

A sample (10 g) was minced with 100 ml distilled water and washed into a distillation flask with 100 ml distilled water; then 2 g of magnesium oxide and an antifoaming agent were added. The mixture was distilled using the microKjeldahl distillation apparatus. Distillate was collected for 25 min into 25 ml 4% boric acid and five drops of Tashero indicator. The solution was titrated using (0.1 M) HCl to calculate the total volatile basic nitrogen in the sample in terms of mg VBN/100 g luncheon meat (Pearson, 1976).

2.7. Lipid oxidation

Lipid oxidation in terms of mmol O_2/g luncheon meat was determined by the modified method of Buege and Aust (1978). A luncheon meat sample of 1 g was placed in a 250 ml test flask and homogenized with a 20-ml solution of acetic acid (50% acetic acid, 50% chloroform). The mixture was vortexed, incubated in a hot water bath at 50°C for 30 min, and the samples filtered. The filtrate was received into 0.5 ml of potassium iodide (50%), held in a dark place for 2 min. Distilled water [100 ml] and three drops of starch 1% as indicator were added, and the mixture was titrated by sodium thiosulfate-pentahydrate (0.01 M) added drop wise until the end point.

2.8. Sensory evaluation

Pieces of (50×2) mm were prepared as steaks for sensory evaluation and placed in numerically-coded glass Petri dishes. A sensory test, using a consumer-type panel, comprised of 20 staff members from different departments, was employed to detect sensory differences between irradiated and non-irradiated samples. Each member independently evaluated the 2-mm thick slice (50-mm diameter) for taste and flavour on a 5-point scale (1 = very bad, 2 = bad, 3 = accepted, 4 = good, 5 = very good), according to Lavrova and Krilova (1975).

2.9. Statistical analysis

The experiment consisted of five treatments in a completely randomized design with three replicates. The data were subjected to analysis of variance (ANOVA) using the **SUPERNOVA** computer package. A separation test on treatment means was conducted using Fisher's least significant differences PLSD at the 95% confidence level.

3. Results and discussion

3.1. Effect of gamma irradiation on microbiological load

Treated luncheon meat (with 1, 2, 3 and 4 kGy of gamma irradiation) had significantly ($P<0.05$) lower counts of micro-organisms than the non-treated (control) over the experimental period (Table 1).

The effect of gamma irradiation on microbial load and shelf-life has not previously been investigated, but similar observations on sausage were reported by Oztasiran, Akin, Ersen, Cerci, and Dincer, 1993. They found that doses of 1, 2 and 4 kGy, of gamma irradiation, reduced the count of all micro-organisms in the Turkish fermented sausage to levels lower than those, which could cause public health concern. Robert and Wees (1998) found that fresh ground beef [initial APC of 10^2 (CFU/g), treated with 3 kGy] was acceptable ($<10^7$ CFU/g) for 42 days at 4°C, whereas the non-irradiated control samples of ground beef spoiled within 7 days. Lebepe et al. (1990) reported that irradiation of refrigerated vacuum-packaged pork loins at a dose of 3 kGy and stored at 2–4°C can extend shelf-life of the product up to 91 days without microbial spoilage. Prachasitthisak and Bunnak (1994) found that irradiated Nham (fermented pork sausage, (with 2 kGy) can be kept for 9 weeks in refrigerated conditions (5±2°C).

However, if the 10^6 microbe/g spoilage level defined by Banwart (1987) for ground beef was adopted in this study, the luncheon meat samples would have been considered spoiled after 10 and 14 weeks of storage for non-irradiated and irradiated samples respectively.

The dramatic increase in micro-organism load after 10 weeks, in the irradiated luncheon meat could be attributed to the extent and nature of the irradiation effect on the activity and ability of micro-organisms to regenerate their multiplication and make use of the suitable growth media. Diehl (1990) suggested that, in different species of micro-organisms, the substances within cells may modify indirect effects of radiation differently. Most importantly, however, the deoxyribonucleic acid (DNA) in different species is aligned during replication and repair enzymes can carry out DNA degradation or DNA synthesis. They can thus excise a damaged sequence of nucleotides and resynthesize the missing sequence.

3.2. Effect of gamma irradiation on chemical characteristics

Mean luncheon meat characteristics in this study were: fat content (8.58±0.6)%, protein content (23.1±0.1)%, moisture content (67.4±0.2)%. Results of the proximate analysis of luncheon meat showed that moisture content decreased ($P<0.05$) when the luncheon meat was irradiated. Immediately after irradiation, the moisture percentages were 66.15, 66.15, 66.13, 66.22, and 66.69% for samples treated with 0, 1, 2, 3 and 4 kGy, respectively. But no difference ($P>0.05$) between irradiated and non-irradiated samples was found in moisture content at the end of the storage period.

3.3. Total acidity

Irradiated luncheon meat, stored at refrigerated temperature for 1 week, had higher total acidity compared with non-irradiated samples stored at the same temperature (Table 2). However, the total acidity was not different from the non-irradiated controls at the 4, 6 and 9th week of storage. Throughout the storage period, the total acidity of the control samples increased, whereas no changes were observed in irradiated samples. After 10 weeks of storage, all samples dosed with gamma irradiation had significantly ($P<0.05$) lower total acidity than the non-irradiated samples.

Table 1
Effect of gamma irradiation on microbial load of luncheon meat stored at 1–4°C (cfu/ g)

Treatment (kGy)	Storage period (week)						
	0	2	4	6	10	12	14
0	2×10^3b[a]	2×10^3b	2×10^3b	2×10^4b	$>10^6$b	R[b]	R
1	<10 a	<10 a	<10 a	<10 a	<10 a	5×10^4 b	2×10^4 a
2	<10 a	<10 a	<10 a	<10 a	<10 a	2×10^5 c	2×10^5 b
3	<10 a	<10 a	<10 a	<10 a	<10 a	3×10^5 d	–
4	<10 a	<10 a	<10 a	<10 a	<10 a	1×10^4 a	1×10^6 c

[a] Values within a column followed by the same letter are not significantly different at the 95% confidence level.
[b] R, rejected.

Kanatt, Paul, Dsouza, and Thomas (1997) and Paul, Dsouza, and Thomas (1998) reported that the free fatty acid (FFA) content in meat decreased after irradiation. Fu, Sebranek, and Murano (1995) indicated that pork meat irradiated with 2 kGy was not significantly different in acidity from the control. However, higher acidity of meat is a positive indicator of storability. This is due to the inhibition of microbial growth by acids, which may have improved the storability of irradiated luncheon meat.

Bell, Marshall, and Anderson (1986), Mendonca, Molins, Kraft, and Walker (1989) reported that submerging fresh beef in acetic acid solution (1.2%) reduced the number of bacteria.

3.4. Volatile basic nitrogen (VBN)

The VBN analysis of luncheon meat (Table 3) showed no significant differences between irradiated and non-irradiated luncheon meat at 0, 2, and 3 weeks of storage.

After 6 and 10 weeks of storage, all doses of gamma irradiation (1, 2, 3 and 4 kGy) significantly decreased ($P<0.05$) the content of VBN.

Throughout storage, the VBN increased in non-irradiated samples and decreased in irradiated ones. After 10 weeks of storage, the VBN in irradiated samples was significantly lower than those of the non-irradiated controls (Table 3). Naik, Pushpa, Chawla, Sherikar, and Nair (1994) found that fresh buffalo meat, irradiated with a 2.5 kGy dose and stored at 0–3°C had a shelf-life of 4 weeks with low total volatile basic nitrogen values and acceptable sensory score.

Little information on production of volatiles is available for cooked irradiated meat with low doses (<10 kGy) (Ahn, Olson, Lee, Jo, Wu, & Chen, 1998).

However, the decrease of the VBN by irradiation, may be considered as an indicator of storability improvement of luncheon meat by gamma irradiation.

3.5. Lipid oxidation

Table 4 shows that 1 and 2 kGy of gamma irradiation increased, though not significantly, the peroxidation values compared with control samples after 2 weeks of storage. However, the peroxide values of luncheon meat irradiated with 2, 3 and 4 kGy were lower than those of the control after 4 and 6 weeks of storage.

The fibrous casings of luncheon meat were removed before irradiation, so that the product was in contact with oxygen. The effect of oxygen exposure may be an important factor to increase the oxidation of irradiated samples.

Ahn, Wolfe, Sim, & Kim (1992); Ahnm Ajuyah, wolfe, and Sim (1993) reported that preventing oxygen exposure after cooking was more important than package, irradiation, or storage of raw meat to maintain low thiobarbituric acid values (TBARS).

Mattison et al. (1986), and Lebepe et al. (1990) reported that TBA values were stable for up to 27 days of refrigerated storage in vacuum-packaged pork loins;

Table 2
Effect of gamma irradiation on total acidity (% Lactic acid) of luncheon meat

Treatment (kGy)	Storage period (week)							
	0	1	4	6	9	10	12	14
0	0.321 a[a]	0.303a	0.242 a	0.242 a	0.264 a	0.435 b	R[b]	R
1	0.319 a	0.312 ab	0.250 a	0.246 a	0.246 a	0.285 a	0.250 b	0.231 a
2	0.339 a	0.323 bc	0.252 a	0.242 a	0.248 a	0.263 a	0.233 ab	0.249 b
3	0.315 a	0.359 d	0.254 a	0.248 a	0.252 a	0.257 a	0.271 a	0.255 b
4	0.312 a	0.338 c	0.253 a	0.248 a	0.270 a	0.261 a	0.233 ab	0.264 b

[a] Values within a column followed by the same letter are not significantly different at the 95% confidence level.
[b] R, rejected.

Table 3
Effect of gamma irradiation on volatile basic nitrogen (VBN percent) of luncheon meat

Treatment (kGy)	Storage period (week)							
	0	2	3	6	8	10	12	14
0	0.024 ab[a]	0.026 a	0.020 ab	0.019 b	0.014 c	0.078 c	R[b]	R
1	0.021 a	0.028 c	0.019 a	0.016 a	0.013 b	0.019 b	0.015 c	0.013 b
2	0.027 b	0.027 ab	0.022 b	0.016 a	0.017 e	0.018 a	0.015 c	0.014 c
3	0.025 ab	0.026 ab	0.021 ab	0.016 a	0.015 d	0.017 a	0.011 a	0.013 b
4	0.024 ab	0.027 bc	0.021 ab	0.016 a	0.013 a	0.019 c	0.013 b	0.011 a

[a] Values within a column followed by the same letter are not significantly different at the 95% confidence level.
[b] R, rejected.

thereafter, values in irradiated samples slowly increased, while they decreased after 34 days in controls. This suggested that malonaldehyde (used as a measure for lipid oxidation) was metabolized by spoilage bacteria, decreasing the TBAR in the non-irradiated controls.

Lambert, Smith and Dodds (1992) reported no differences in TBA values between irradiated pork under 100% N_2 and under 20% O_2 until 7 days storage. In their work, 20% O_2 samples had higher TBA values than 100% N_2 samples. Nawar (1985) reported that irradiation in the presence of oxygen accelerated the auto-oxidation of fats by one of the three possible reactions: (1) formation of free radicals which combine with oxygen to form hydroperoxides; (2) breakdown of hydroperoxides; or (3) destruction of antioxidants.

Kanatt et al. (1997) found that irradiated meat showed a slight increase in lipid peroxidation in terms of (TBA) number on storage as compared with non-irradiated meat.

Peter, Murano, Murano, and Olson (1998) reported no difference in lipid oxidation within the first week of storage between ground beef patties irradiated with 2 kGy and non-irradiated sample.

3.6. Sensory evaluation

The consumer panel data (Tables 5 and 6), indicated that no significant differences ($P > 0.05$) in taste and flavour were observed between irradiated (1, 2, 3 and 4 kGy) and control luncheon meat. The effects of gamma irradiation on the sensory characteristics of luncheon meat are not yet known. But there is contradicting information about such effect on other kinds of meat. Luchsinger et al. (1997) observed that irradiation with 2

Table 4
Effect of gamma irradiation on lipid peroxide (mmol O_2/g) of luncheon meat

Treatment (kGy)	Storage period (week)						
	0	2	4	6	10	12	14
0	4.13 a[a]	3.42 b	1.96 a	1.96 ab	R[b]	R	R
1	5.35 a	3.50 b	1.92 a	1.65 a	3.30 d	1.57 a	0.98 a
2	5.74 a	3.34 b	1.65 a	2.32 b	2.75 c	1.53 a	1.14 a
3	–	2.48 a	1.88 a	2.16 ab	2.12 b	2.40 b	0.94 a
4	2.44 a	3.26 b	1.45 a	1.96 ab	1.49 a	2.20 b	1.14 a

[a] Values within a column followed by the same letter are not significantly different at the 95% confidence level.
[b] R, rejected.

Table 5
Effect of gamma irradiation on the taste of luncheon meat[a]

Treatment (kGy)	Storage period (week)				
	0	2	4	6	7
0	3.085 a[b]	2.267 a	2.818 a	2.490 a	2.825 a
1	3.085 a	2.355 a	2.345 a	2.310 a	3.050 a
2	2.785 a	2.564 a	2.310 a	2.450 a	2.100 a
3	2.962 a	2.391 a	2.550 a	2.250 a	2.720 a
4	2.992 a	2.383 a	2.580 a	2.600 a	3.175 a

[a] Data represent a 5-point scale ranging from 1 (very bad) to 5 (very good).
[b] Values within a column followed by the same letter are not significantly different at the 95% confidence level.

Table 6
Effect of gamma irradiation on the flavour of luncheon meat[a]

Treatment (kGy)	Storage period (week)				
	0	2	4	6	7
0	3.423 ab[b]	2.871 a	2.768 a	2.186 a	2.500 a
1	3.331 ab	2.700 a	2.646 a	2.336 a	2.967 a
2	3.100 ab	2.729 a	2.650 a	1.907 a	1.783 a
3	2.908 a	2.243 a	2.142 a	2.029 a	2.033 a
4	3.308 ab	2.021 a	2.608 a	1.964 a	2.150 a

[a] Data represent a 5-point scale ranging from 1 (very bad) to 5 (very good).
[b] Values within a column followed by the same letter are not significantly different at the 95% confidence level.

and 3.5 kGy had minimal effects on flavour, texture, and aroma of raw and precooked beef patties. Alur, Kamat, Doke, and Nair (1998) reported that a trained taste panel gave high score for irradiated meat products with 4 kGy in terms of odour, colour and texture, so 4 kGy was conceded to be an optimum radicidation dose for meat products. Prachasitthisak and Bunnak (1994) found that sensory quality evaluation showed no significant differences in colour, odour, flavour and texture between non-irradiated and irradiated Nham (fermented pork sausage) with 1, 2 and 3 kGy doses. Saovapong and Nouchpramool (1996) reported that the 2 kGy dose appeared to be sufficient for improving bacteriological quality and increasing the shelf-life of beef balls without affecting sensory quality. Hashim, Resurreccion, and MacWalters (1995) reported sensory improvement in irradiated poultry with respect to flavour and tenderness. Lynch, Macfie, and Mead (1991) reported that irradiation of turkey breast fillets in air resulted in 54% of panellists assessing the flavour of the samples as acceptable, compared with 66% acceptable in non-irradiated controls. A study, carried out by Hanis, Jelen, Klir, Mnukora, and Pesek (1989) with irradiated chicken packaged under air, showed differences in flavour between irradiated samples and non-irradiated controls.

4. Conclusion

Irradiation improved the storability of luncheon meat by reducing the level of spoilage micro-organisms. The doses of gamma irradiation used in this study increased the shelf-life of luncheon meat from 10 weeks for the control to 14 weeks for the irradiated ones, with no differences ($P > 0.05$) in taste and flavour, as indicated by sensory evaluation and chemical analyses (lipid oxidation, VBN and total acidity).

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