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Research Article

Effects of ionizing radiation sources and dose levels on quality characteristics of meal ready to eat (Minced cow meat)

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Abstract

The increasingly busy routines of people in many countries have driven the demand for safe, convenient and ready-to-eat food. Food poisoning cases, on the other hand are constantly reported. Irradiation offers a potential to enhance food safety and quality by reducing microbial load while maintaining its nutritional values. Thus, the purpose of this study was to compare the effect of gamma, Electron Beam (EB) and X-Rays irradiation on the safety and quality of Meal Ready to Eat (MRE). MRE samples were prepared from minced cow meat and vacuum packed in 100 g pouches. The samples were irradiated by gamma rays, EB, and X-Rays at irradiation doses of 11, 12, and 13 kGy. The appearance of the irradiated samples was significantly different among the irradiation technologies and dose level ($p \leq 0.05$) as compared to the texture, taste, and overall acceptability ($p \leq 0.05$). The % crude fat and moisture contents differed significantly from control samples ($p \leq 0.05$), while in % crude protein and ash, no significant difference was observed. The irradiated samples showed zero Total Viable Counts (TVC) for the entire storage period. The un-irradiated sample was spoiled after 15 days due to microbial load. The study found that Gamma, EB and X-Rays irradiation processing techniques can be applied for ensuring the safety and quality of MREs food. This will potentially facilitate the availability of food for astronomers, troops during combat or field conditions and as emergency rations during natural calamities.

Keywords: EB; Gamma; Irradiation; MRE; X-Rays

Introduction

A hectic lifestyle has led to changes in the eating habits of people and forced food manufacturers to produce ready-to-eat food products. MRE food is prepared for special target groups like immune-compromised cancer patients, emergency and disaster victims of earthquakes and floods, etc. The food is sterilized with ionizing radiation, which kills the microbes causing spoilage of MRE **[1]**.

In the USA, microbial contamination has caused spoilage of approximately 56,000 metric tons of MRE during 1998-2002. There were 2500 cases of food poisoning reported annually, out of which 500 deaths with a 20%

mortality rate. Most of these cases testified to be caused by MRE food (Komolprasert, 2002). The National Center for Policy Analysis (NCPA) estimated that if half of the highest-risk food were irradiated, it would reduce foodborne illness by 900,000 cases with 352 fewer deaths **[2]**.

Food irradiation relies on gamma, EB or X-Rays ionizing irradiation technologies (Peter B & Roberts, 2014). X-Rays and EB are non-thermal, environment-friendly, food processing technologies that are slowly and steadily making a profound change in the quality and safety of food and food products around the world. X-Rays and EB are switch-on and switch-off technologies that can be customized for different food industry applications **[3]**.

Irradiation has been used for sanitizing meat & its products and ensuring a longer shelf-life with minimal effect on nutritional and sensory quality **[4]**. Irradiation has caused significant changes in microbial load and the color of meat & its products. In a comparative study of EB and gamma irradiation effects on beef, both irradiation sources were found effective to minimize the load of E. coli O157:H7, Salmonella typhimurium, and Pseudomonas fluorescens **[5]**.

Although effects of EB and gamma irradiation on the nutritional and sensory quality of meat were studied at lower doses, a little information on the comparative study of three sources (X-Rays, gamma, and EB) at higher doses is available. Therefore, the current study was carried out to evaluate the comparative effects of irradiation sources at different doses on MRE food for a storage period of three months (90 days) at ambient temperature.

Materials and Methods

Preparation of sample

Minced Cow meat was purchased from the local market and cooking was carried out in oil with onion, tomato, spices, and garlic at the temperature of 70 0C for 20 minutes. The cooking was done at 70 0C temperature and after cooking, the samples were cooled down to 25 0C. The temperature was monitored with a scientific thermometer (made of USA ACC2457). Cooked MRE samples were vacuum-packed (approximate 15 mm thickness) in tetra pack aluminum pouches using a vacuum sealer machine (HENKELMAN, Model: B100608477) according to the weight composition of 20 g meat, 5 g oil, 10 g onion, 10 g tomato, 2.5 g spices ad 2.5 g garlic and transferred for irradiation after cooling to room temperature.

Irradiation

Packed MRE samples were irradiated by Gamma Rays, X-Rays, s and Electron Beam at target doses of 11, 12, and 13 kGy at ambient temperature. Gamma radiation source (Hungarian Made ISSO GAMMA LL Type) installed at Nuclear Institute for Food and Agriculture (NIFA) Peshawar, Pakistan, having dose rate of 3.60 kGy/hr. was used. Irradiation time of the samples were 3 hr. and 3 min, 3hr and 20 min and 3hr and 37 min respectively for the mentioned doses at an ambient temperature of 28 0C. Routine Dosimetry was carried out of the irradiation source with PMMA Dosimetry System. X-Rays and EB irradiation were done with a DD type Electron-Beam-Accelerator (10 MeV, 5MV) Pak Electron Beam Irradiation (Pvt.) Ltd. Port Qasim, Karachi Pakistan. The beam intensity was 5.5, 6, and 6.5 mA for 11, 12, and 13 kGy accordingly. GEX Corporation USA dosimetry system (B6002 10 MeV Polystyrene) was used for the measurement of the above-mentioned doses of the samples.

Sensory evaluation

MRE samples were evaluated for their sensory attributes (appearance, texture, taste, and overall acceptance) by a panel of 10 judges during 90-day storage at ambient temperature. Each sample was evaluated using a 9-point hedonic scale [6]. Sensory evaluation was carried out on the 1st day and repeated at 30, 60 and 90-day intervals, accordingly.

Microbiological analysis

Samples were analyzed for the total viable count with an interval of 15 days for a period of 90-day storage at ambient temperature. Total Viable Counts (TVC) were determined by the dilution plate method using nutrient agar media [7].

Proximate compositional analysis of MRE

The % crude protein, ash, moisture, and fat were determined at a 30-day interval. Kjeldahl's method was used to determine the % protein in the irradiated samples of MRE [8]. The % ash was determined by AOAC 2005 method in the irradiated MRE samples. Samples were dried in an oven and determined the moisture content by the weight difference between dried and wet material [9]. The % fats of MRE samples were determined as a percentage of the weight before the solvent is evaporated [10].

Statistical analysis

Statistical analysis of data was carried out according to Steel et al., 1997 method [11]. A factorial design was used for the analysis of variance and means were interpreted by Latin Square Design.

Results and Discussion

Sensory evaluation

Although the sensory characteristics of MRE samples treated with different technologies (gamma, EB, and X-Rays s) decreased with storage, all samples were in the acceptable range after 90 days of storage at ambient temperature as shown in (Table 1). The mean values revealed that gamma (6.91b, 6.84a, and 6.80b) and X-Rays (6.88b, 6.81b, and 6.75b) treated MRE samples scored higher values for appearance as compared to EB (6.36c, 6.18d, and 6.19d) at irradiation dose levels of 11, 12 and 13 kGy respectively.

Moreover, in irradiated meat products, the level of change in color depends on the irradiation technologies, doses, and packaging types [12]. The decrease in color score in current research could be linked to the breakdown of nitrosyl hemochrome [13]. Furthermore, free radicals produced by radiation under a high dose rate might induce changes in the structure of myoglobin [14]. Therefore, variation in color of treated MRE samples is probably due to generative modifications in free radicals among various irradiation technologies. No significant difference in taste and texture among different technologies of the treated MRE samples was observed. Similar results were reported by Aguilera et al., 2016 & Lee et al; 2005 [15, 16] who did not observe any significant change in the hardness of patties made from beef pork due to radiation.

Table 1. Mean values of the sensory evaluation of the irradiated MRE samples

Parameters	Electron beam (kGy)			X -rays (kGy)			Gamma-rays (kGy)		
	11	12	13	11	12	13	11	12	13
Appearance	6.36^{c}	6.18^{d}	6.19^{d}	6.88^{b}	6.81^{b}	6.75^{b}	6.91^{b}	6.84^{a}	6.80^{b}
Texture	6.35^{a}	6.28^{a}	6.24^{a}	6.83^{a}	6.82^{a}	6.79^{a}	6.93^{a}	6.89^{a}	6.90^{a}
Taste	6.75^{a}	6.75^{a}	6.75^{a}	6.78^{a}	6.75^{a}	6.73^{a}	6.78^{a}	6.75^{a}	6.75^{a}
Overall Acceptability	6.78^{ab}	6.75^{ab}	6.75^{ab}	6.78^{ab}	6.75^{ab}	6.73^{b}	6.80^{a}	6.75^{ab}	6.75^{ab}

$^{a-f}$ Means in the same row with dissimilar letters are significantly different ($p \leq 0.05$).

Proximate compositional analysis

Crude protein% and ash%

Data depicted a non-significant difference ($p \leq 0.05$) in % crude protein and ash content between the irradiated samples by gamma, EB, and X-Rays at different dose levels for a storage period of 90 days at ambient temperature as shown in Figure 1 and Figure 2, respectively. Similar results were reported by Baptista et al. 2014 [17], who observed a non-significant difference in %crude protein and ash in irradiated ready-to-eat broiler breast fillets at high dose levels (48 kGy) stored at room temperature. Badr, 2005 irradiated chicken breast with 1.5 & 3 kGy and recorded no significant changes in % protein and % ash content in irradiated and non-irradiated samples of MRE [18].

% Crude moisture

Our results indicate that moisture content decreases with irradiation doses 11, 12, and 13 kGy having a decrease in values of water content by 0.1% and 0.3% for 12 and 13 kGy as compared to 11 kGy for the first month of storage at ambient temperature as shown in Figure 3. During the second-and third-month storage period the moisture content decreases with time for two months. No significant pattern in % moisture content was observed in the different irradiation technologies. Loss in moisture content% might be due to the poor water-holding ability of the irradiated MRE samples [19]. Riebroy et al. (2007) while working on som-fug reported that radiation at 6 kGy caused detrimental effects on water holding capacity, thus damaged the muscle fibers, which may have induced water loss [20]. In general, at higher irradiation doses, a decrease in the moisture occurs as the water content is ousted as drip and remains on the outer part of foods [21].

% Crude fat

The results of % crude fat is depicted in the Figure 4. Significant interactions were recorded among different radiation technologies (Gamma, EB, and X-Rays), dose levels, and storage period on % fat ($p \leq 0.05$). In particular, decrease (2%) in crude fat was observed in gamma irradiated MRE samples as compared to EB and X-Rays s for the irradiation doses of 11, 12, and 13kGy. The variation in the % fat of the irradiated samples was observed in the range of 0.13% to 0.50% for the second and third-month storage as compared to the first-month storage at room temperature as shown in Figure 4. An increase in lipid oxidation has been reported in the products of irradiated meat by several researchers [22]. Likewise, it was observed that more changes in lipids are due to high doses of irradiation because unsaturated fatty acids in the matrix are more subjected to oxidation [23]. Our findings shows that amount of decrease in % crude fat can be affected differently by different irradiation sources at the same level of irradiation dose.

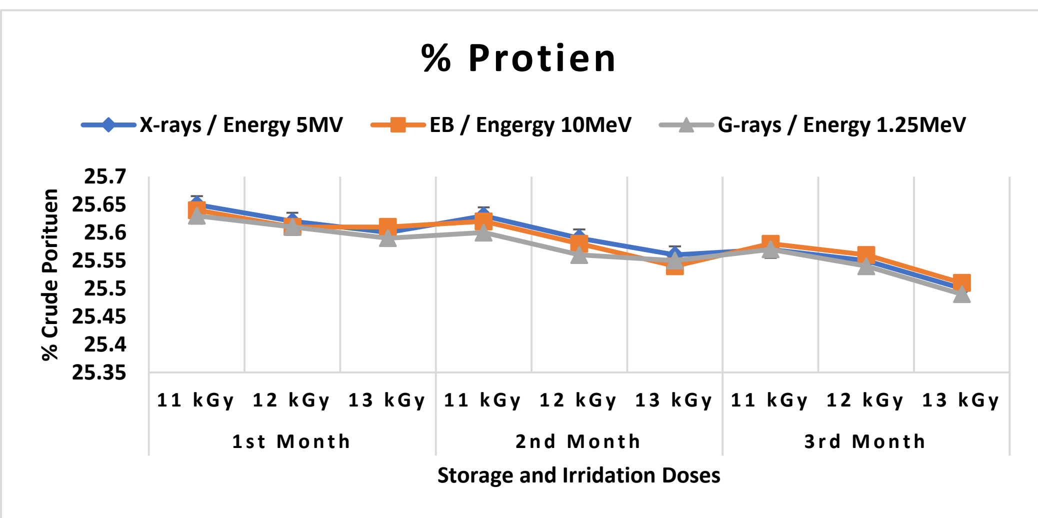

Figure 1. % Protein of irradiated MRE samples during the storage period

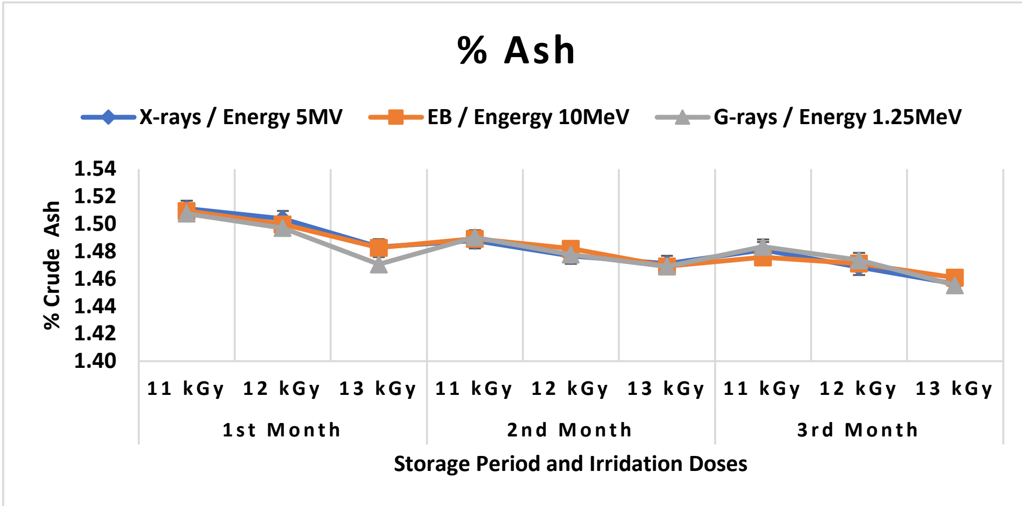

Figure 2. % ASH of irradiated MRE samples during the storage period

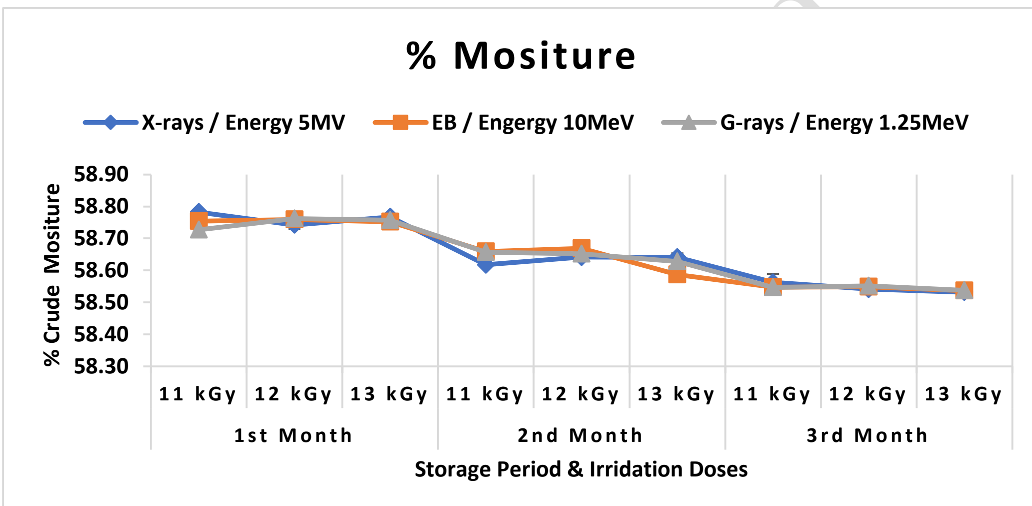

Figure 3. % Moisture of irradiated MRE samples during the storage period

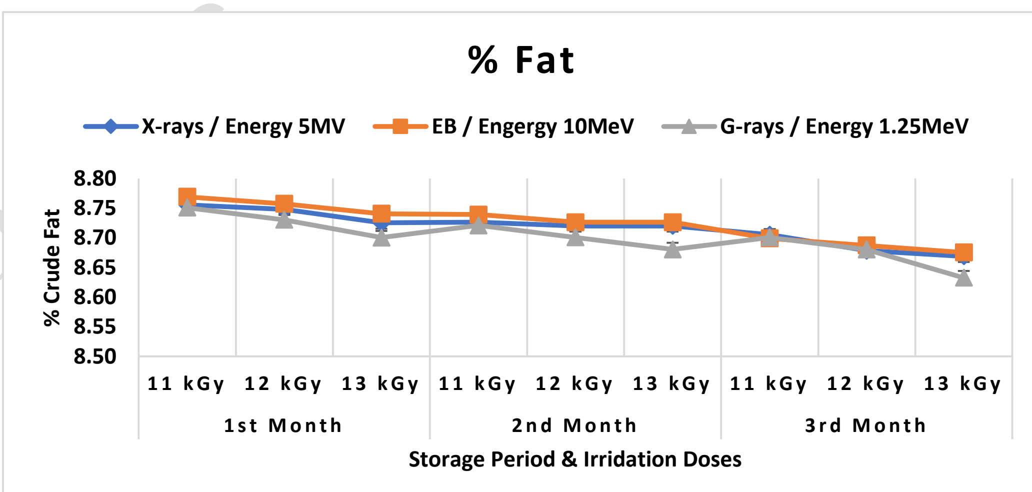

Figure 4. Fat% of irradiated MRE samples during the storage period

Microbiological analysis

Total viable count (TVC)

The TVC value after irradiation and days of intervals is shown in (Table 2). There was no microbial population detected in the irradiated MRE samples irrespective of dose levels and irradiation technologies for the storage period of 90 days at ambient temperature. In agreement with our results, at 40 kGy dose of Gamma irradiation to ready to eat chicken breasts no living cells were found in the irradiated samples. In cooked meat, the bacterial nucleic acid of microorganisms is impaired by ionizing radiation which is an effective process for decreasing microbial contamination of meat-based products [17]. However, the control sample was spoiled at a storage period of two weeks. Sample spoilage can be defined as the results of total bacterial populations (≤ 8 log CFU/g) [24-26].

Table 2. TVC of the control and irradiated samples of MRE

Storage Period (days)	Control	G-rays (kGy)			EB (kGy)			X-Rays (kGy)		
MRE	0kGy	11	12	13	11	12	13	11	12	13
0	3.21	--	--	--	--	--	--	--	--	--
15	8.45	--	--	--	--	--	--	--	--	--
30	*	--	--	--	--	--	--	--	--	--
45	*	--	--	--	--	--	--	--	--	--
60	*	--	--	--	--	--	--	--	--	--
75	*	--	--	--	--	--	--	--	--	--
90	*	--	--	--	--	--	--	--	--	--

*Indicates that the sample was spoiled and "--", indicates Not Detected

Conclusion

The preservation method used in this study was nominal in preserving the microbial population below the permitted level (≤ 8 log CFU/g) during the storage period of 90 days at 28±1 ^{0}C. The study concluded that high dose irradiation (11, 12, and 13 kGy) has great potential for the preservation of MRE products made from beef, to make available hygienic foods for consumption.

Authors' contributions

Conceived and designed the experiments: A Khan & MZ Shah, Performed the experiments: MZ Shah & Z Mehmood, Analyzed the data: M Khan & MA Irshad, Contributed reagents/ materials/ analysis tools: F Ahmad & MA Irshad, Wrote the paper: A Khan, MZ Shah & Z Mehmood.

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