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[1]Department of Animal Science, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh;

***Corresponding Author:**
MA Hashem
E-mail: hashem_as@bau.edu.bd

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Research Article

Effect of irradiation with black cumin (*Nigella sativa*) on the biochemical properties and microbial population of beef at different days of interval at ambient temperature

M Sadakuzzaman[1], MAH Bosunia[1], MRU Amin[1], MA Hashem[1*]

Abstract

This study explored how combining gamma irradiation with black cumin (*Nigella sativa*) extract affects the biochemical makeup and microbial levels of beef stored at ambient temperature over time. Fresh, boneless beef samples were first treated with a 2% solution of black cumin extract, then exposed to gamma radiation at doses of 0 (as a control), 3, 5, and 7 kGy using a cobalt-60 (^{60}Co) irradiator. Biochemical analyses such as peroxide value (POV), free fatty acids (FFA), and thiobarbituric acid reactive substances (TBARS) were performed on treated samples at 0, 3, 5, and 7 days. Microbial analyses included total coliform count (TCC), total viable count (TVC), total yeast and mould count (TYMC), and the existence of *Salmonella spp.* and *Staphylococcus spp*. Results demonstrated significant ($p<0.01$) increases in POV, FFA, and TBARS values with both greater radiation exposure and prolonged storage which enhanced lipid oxidation. Microbial counts were equally affected by both treatment and time, with large increases in TCC, TVC, and TYMC, whereas Staphylococcus spp. exhibited a general decline and Salmonella spp. varied depending on the treatment. The factorial experimental design indicated considerable interactions ($p<0.01$) between radiation dose and storage term on most biochemical and microbiological markers. These observations show that irradiation in association with black cumin (*Nigella sativa*) extract can influence both oxidative stability and microbiological safety of beef and that optimization of dose and storage conditions are important to ensure product quality under ambient temperature.

Introduction

Beef, defined as the edible muscle tissue of cattle, is a nutritionally rich food source that offers a concentrated and digestible form of high-quality protein compared to many plant-based diets (Sayeed et al., 2023; Azad et al., 2022). Despite its nutritional significance, beef, like other meat products, is highly perishable, primarily due to oxidative deterioration and microbial growth that compromise its safety, quality, and shelf life (Dave & Ghaly, 2011). These vulnerabilities are of particular concern in regions lacking reliable cold chain infrastructure, such as many developing countries. In this context, irradiation has emerged as a promising preservation technique that significantly enhances microbial safety and extends shelf life (Rima et al., 2019; Sadakuzzaman et al., 2023). Globally, more than half a million tonnes of food are irradiated annually, underlining its growing acceptance and effectiveness in reducing spoilage and ensuring food security (Eustice & Bruhn, 2012).

However, while irradiation can successfully reduce pathogens like *Salmonella* and *E. coli* (Indiarto et al., 2023), and maintain acceptable sensory traits at moderate doses (Dimov & Popova, 2022), it is not without limitations. Several studies report that higher irradiation doses and extended storage durations are associated with increases in biochemical degradation markers such as free fatty acids (FFA), peroxide value (POV), and thiobarbituric acid reactive substances (TBARS) (Sadakuzzaman et al., 2024; Rima et al., 2019; Hashem et al., 2022; Arshad et al., 2020). For instance, beef irradiated up to 6 kGy and stored at –20 °C showed increased oxidative changes, even though microbial loads decreased and key physicochemical properties such as color and ether extract content were preserved (Haquea et al., 2017). Similarly, higher levels of POV, TBARS, and TVBN were reported in frozen duck meat irradiated at 7 kGy (Arshad et al., 2020).

To mitigate these oxidative effects, the use of antioxidants—especially from natural sources—has become increasingly important. Traditionally, synthetic antioxidants were employed, but due to health-related concerns and regulatory restrictions, there has been a shift toward plant-based alternatives (Kalogianni et al., 2020; Sadakuzzaman et al., 2021). Natural antioxidants such as ginger and tulsi have been shown to enhance shelf life and improve sensory qualities by lowering oxidative markers like FFA, POV, and TBARS (Hossain et al., 2021; Siddiqua et al., 2018). In addition to preserving chemical integrity, some plant-derived molecules have also been found to positively influence meat flavor, color, and tenderness, occasionally performing better than synthetic options (Velasco et al., 2011; Kumar et al., 2015).

Moreover, emerging evidence suggests that combining irradiation with natural antioxidants may offer synergistic benefits, balancing microbial safety with oxidative stability.

For example, a 2 kGy dose successfully maintained microbiological safety and prolonged the shelf life of Black Bengal goat meat (Khan et al., 2017), while edible coatings incorporating plant extracts extended the shelf life of meat products by up to six days (Smeti et al., 2025). The microbial profile of meat, including total viable count (TVC), total coliform count (TCC), and total yeast and mold count (TYMC), has also been shown to rise with age and storage but remains significantly reduced under irradiation (Rima et al., 2019).

Further advancements in meat quality assessment—such as near-infrared spectroscopy and artificial intelligence—offer rapid, nondestructive alternatives for evaluating meat safety and quality under various storage conditions, aligning with industry trends for efficiency and traceability (Sarker et al., 2024a). Physicochemical traits like pH, L value, and water-holding capacity also remain key indicators of meat quality, with structural and genetic factors (e.g., *Calpain*, *Myostatin*, *Calpastatin*) offering molecular insights into tenderness and texture variations across primal cuts (Sarker et al., 2024b; Khatun et al., 2025).

In this study, the combined effects of gamma irradiation at doses of 3, 5, and 7 kGy and black cumin (*Nigella sativa*) extract on the microbial safety and oxidative stability of beef stored at room temperature are investigated. Specifically, changes in microbial counts (TVC, TCC, TYMC) and oxidative indicators (FFA, POV, TBARS) are analyzed to evaluate the efficacy of this dual preservation strategy. Given the urgent need for affordable, accessible, and effective meat preservation solutions in developing nations such as Bangladesh, the findings from this research could provide vital guidance for both local producers and international meat safety initiatives.

Materials and Methods

Research samples and chemical reagents

The chemical reagents were used for this experiment are beef, Black cumin (*Nigella sativa*) extract, peptone, potato dextrose, Mak Conkey agar, sulphuric acid, chloroform, sodium hydroxide, Copper Sulphate, phenopthelin,starch solution, buffer solution etc.

Apparatus and equipments

A variety of apparatus and equipment were used throughout the research, including a spectrophotometer, homogenizer, Soxhlet apparatus, centrifuge machine, and Kjeldahl apparatus for analytical work. Tools such the chopping board, knife, meat grinder, microwave oven with grill, and plastic pots were utilized for sample preparation. Supporting equipment comprised a digital shaking bath, muffle furnace, magnetic stirrer with hot plate, and a micro-grinder with screen mesh. Essential lab materials such as burettes, pipettes, conical flasks, crucibles, and tissue paper were also used. Measurements were conducted using a scale and balance, weighing balance, and Hanna pH meter, while observations were supported by a microscope and Minolta colorimeter. Storage and preservation were handled with a refrigerator and water distillation unit. Additional devices like a polythene bag, water pump, incubator, oven, autoclave, and a computer with printer and scanner helped expedite the overall procedure. All tools were thoroughly washed with pure water and detergent powder, then sterilized in an autoclave and dried correctly before use.

Sample preparation with experimental design

About 3 kilograms (kg) of fresh, boneless beef was collected for each experiment from local livestock at a market. The 500 g chunks of beef, each representing three replications, were marinated in 2% black cumin (*Nigella sativa*) extract before being placed in zip-locked bags. With three replications for each treatment, the study used a 4x4 factorial design in a completely randomised design (CRD). At BINA, the Bangladesh Institute of Nuclear Agriculture, Mymensingh, packed beef samples were exposed to at dosages of 0 (control), 3, 5, and 7 kGy by using used a cobalt-60 (^{60}Co)irradiator while they were at room temperature (15–20°C). Post-irradiation, the samples were kept at room temperature, and on days 0, 3, 5, and 7, biochemical and microbiological analyses were performed.

Irradiation of the experimental samples

After collecting the beef samples, the beef was marinated in 2% extract from black cumin seeds (*Nigella sativa*), a naturally occurring antioxidant. Following that, the marinated meat was separated into four groups and placed in zip-locked bags, three of which were to receive radiation therapy and one of which was to serve as a control. At BINA, the Bangladesh Institute of Nuclear Agriculture, Mymensingh, the samples were exposed to gamma radiation at dosages of 0 (control), 3, 5, and 7 kGy using a Cobalt-60 Gamma Chamber-5000 (Activity: 10,473 Ci). 500 g of meat was exposed for 3 kGy for 54 seconds, 5 kGy for 1 minute 30 seconds, and 7 kGy for just over 2 minutes. Each treatment's absorbed dosage was determined. After being irradiated at the room temperature (15–20°C), all samples were taken to the Meat Science Laboratory for evaluation.

Biochemical properties

This study's biochemical properties included peroxide value (POV), free fatty acid (FFA), and thiobarbituric acid reactive substance (TBARS).

Determination of peroxide value (POV) (meq/kg)

The Sallam et al. (2004) method was used to calculate the peroxide value (POV). First, the fat was melted by slowly heating 3 g of the sample to 60°C for 3 minutes. To properly dissolve the fat, it was then combined with 30 millilitres of a 3:1 acetic acid–chloroform solution and agitated for an additional three minutes. 0.5 ml of saturated potassium iodide and a few drops of starch solution were added after the mixture had been filtered through Whatman No. 1 paper to get rid of any particles. After that, 0.01 N sodium thiosulphate was used to titrate the solution.

The POV value was measured and expressed as milli equivalent per kilogram of sample following this equation:

$$\text{POV (meq/kg)} = \frac{S \times \text{N}}{W} \times 1000$$

Where S is the volume of titration (ml), N is the normality of sodium thiosulfate solution (n = 0.01) and W is the sample weight (g).

Determination of free fatty acid (FFA) (%)

The FFA value was calculated using Rukunudin et al. (1998) as a guide. Using an IKA T25 computerised Ultra-Turrax homogeniser (IKA, Königswinter, Germany) set to 10,000 rpm for one minute, the 5 g sample was dissolved in 30 ml of chloroform. Meat particles were eliminated from the sample by vacuum-filtering it with Whatman filter paper number 1. The filtrate was titrated with 0.01 N ethanolic potassium hydroxide after five drops of 1% ethanolic phenolphthalein were added as an indicator. The measurement of FFA value following this equation:

FFA (%) = Titrate required (ml) × Normality of KOH × 28.2 Sample weight (g)

Determination of thiobarbituric acid reactive substances (TBARS)

Schmedes and Holmer's (1989) 2-thiobarbituric acid (TBARS) technique was used to measure the lipid oxidation in triplicate. Samples (5 g) were mixed in a homogeniser (IKA) for 30 seconds using 25 ml of a 20% trichloroacetic acid solution (200 g/l of tricholoroacetic acid in 135 ml/l phosphoric acid solution). Two milliliters of the filtrate were added to two milliliters of 0.02 M aqueous TBA solution (3 g/l) in a test tube after the homogenised sample had been filtered using Whatman filter paper number 4. After 30 minutes of incubation at 1000 C, the test tubes were cooled with tap water. Using a UV-VIS spectrophotometer (UV-1200, Shimadzu, Japan), the absorbance was determined at 532 nm. Malonaldehyde milligrammes per kilogram of material is the TBARS value.

Microbial population

Microbial population was decided by Ikhlas et al. (2012). The following describes the microbial evaluation methods for total coliform count (TCC), total viable count (TVC), total yeast-mold count (TYMC), *Salmonella spp.* and *Staphylococcus spp.*:

Enumeration of total coliform count (TCC)

Three MacConkey agar plates were loaded with 0.1 ml of each dilution. After that, the plates were incubated for 24 to 48 hours at 35°C. Colonies (between 30 and 300) were enumerated after incubation, and the TCC was computed by multiplying the average colony count by the dilution factor. The outcome was measured in colony-forming units per gramme (CFU/g) of the sample.

Enumeration of total viable count (TVC)

0.1 cc of each dilution was put into three PCA agar plates.Colonies were counted following a 24- to 48-hour incubation period at 35°C. The TVC, which was then represented as CFU/g of the sample, was computed by multiplying the average count by the dilution factor.

Enumeration of total yeast-mould count (TYMC)

0.1 cc of each dilution was applied to three PDA agar plates and the plates were cultured for 48 to 72 hours at 25°C. Following incubation, TYMC was computed using the dilution factor and the colonies were counted. CFU/g of the sample was used to express the outcome.

Enumeration of total *Salmonella spp*.

To isolate Salmonella, 0.1 ml of each dilution was applied to three XLD agar plates. For 48 to 72 hours, these plates were incubated at 25°C. Following the counting of colonies with black centres, the results were reported as CFU/g of material.

Enumeration of total *Staphylococcus spp.*

To isolate Staphylococcus, three MSA plates were coated with 0.1 ml of each dilution, and the plates were then incubated at 25°C for 48 to 72 hours. Following colony counting, the data were expressed as CFU/g of the sample.

Statistical analyses

The entire experiment was conducted in triplicate. A factorial experiment consisting of four treatments, two variables, and a 4-day interval that was replicated three times using a completely randomised design (CRD), the data was analysed using SAS 9.1.3 software. All statistical investigations evaluated the interaction effects of the component content change using two-way analyses of variance (ANOVA). As a post-hoc test, Duncan's multiple-range test for mean comparison was employed. The significance of differences in treatment means at values ($p<0.01$) was assessed using the mean values and standard errors of the means (Mean±sem).

Results and Discussion

Effect on biochemical properties of beef

Table 1 shows how exposure to black cumin extract affects the biochemical characteristics of beef, including POV, FFA, and TBARS levels. These qualities reflect the rancidity of beef sample which is connected with grade of beef. The average values of POV, FFA and TBARS were discovered 4.37, 0.96, 0.45; 4.62, 1.06, 0.49; 4.83, 1.20, 0.54 and 5.28, 1.33, 0.59, respectively in T_0, T_1, T_2 and T_3 treatment groups which had showed significant ($p<0.01$) effect among four treatment groups. During storage period average values of POV, FFA and TBARS were detected 1.26, 0.12, 0.11; 0.81, 0.06, 0.26; 7.15, 1.67, 0.77 and 9.88, 2.69, 0.93, respectively which had showed significant ($p<0.01$) effect for 0, 3, 5 and 7 days of interval. For POV, FFA, and TBARS, the interaction between therapy and days of interval had a significant ($p<0.01$) impact.

No studies were found on the effect of irradiation with black cumin extract or other natural antioxidant on biochemical analysis of beef at ambient temperature except one study in our lab. Sadakuzzaman et al. (2021) worked on a study of irradiation with BHA in beef samples at ambient temperature and found that the inclusion of black cumin retarded oxidation effectively up to 3 days. But after 3 days of storage time started oxidation process and oxidative values were found higher at 5 and 7 days at ambient condition. Irradiation induced lipid oxidation up to 3 days of storage time and after that spoilage started with extended

storage time. According to Javanmard et al. (2006), the lipid hydroperoxides would not react with oxygen to create secondary oxidation products in storage for up to three days if the POV values were within the range of 5 meq/kg. But in our study after 5 and 7 days of interval POV values were within 7.15 and 9.88 meq/kg which indicates putrification started with oxidative rancidity. The FFA, POV and TBARS found significantly ($p<0.01$) increased both in treatments groups and days of interval. These findings were in close agreement with those reported by Quattara et al. (2002), Haque et al. (2017) and Al-Bachir & Zeinou, (2014). The peroxide value was increased by increasing the electron beam (EB) irradiation dose using leek extract (Kim et al., 2013), which was agreed with the current study.

Table 1. Effect on biochemical properties of beef

Parameters	Storage time (days)	Dose (kGy)				Mean	Level of significance		
		T_0	T_1	T_2	T_3		Treat.	DI	T*DI
POV (meq/kg)	**0**	1.16±0.10	1.30±0.06	1.29±0.04	1.29±0.09	1.26^{c}±0.06	p<0.01	p<0.01	p<0.01
	3	0.74±0.04	0.83±0.05	0.90±0.00	0.77±0.01	0.81^{d}±0.01			
	5	6.48±0.31	6.85±0.10	7.27±0.26	8.00±0.42	7.15^{b}±0.27			
	7	9.10±0.28	9.51±0.15	9.88±0.22	11.05±0.21	9.88^{a}±0.21			
	Mean	4.37^{c}±0.18	4.62^{bc}±0.04	4.83^{b}±0.13	5.28^{a}±0.04				
FFA (%)	**0**	0.11±0.00	0.13±0.00	0.11±0.00	0.15±0.01	0.12^{c}±0.00	p<0.01	p<0.01	p<0.01
	3	0.06±0.00	0.06±0.00	0.06±0.00	0.06±0.00	0.06^{c}±0.00			
	5	1.58±0.09	1.63±0.04	1.74±0.04	1.75±0.06	1.67^{b}±0.16			
	7	2.10±0.12	2.43±0.22	2.88±0.16	3.37±0.25	2.69^{a}±0.01			
	Mean	0.96^{c}±0.04	1.06^{bc}±0.06	1.20^{ab}±0.06	1.33^{a}±0.03				
TBARS (mg-MA/kg)	**0**	0.09±0.00	0.13±0.02	0.12±0.00	0.13±0.00	0.11^{d}±0.01	p<0.01	p<0.01	p<0.01
	3	0.28±0.07	0.31±0.01	0.24±0.02	0.21±0.00	0.26^{c}±0.02			
	5	0.65±0.01	0.66±0.01	0.81±0.04	0.95±0.01	0.77^{b}±0.06			
	7	0.79±0.04	0.86±0.01	0.38±0.02	1.08±0.07	0.93^{a}±0.02			
	Mean	0.45^{c}±0.01	0.49^{c}±0.01	0.54^{b}±0.01	0.59^{a}±0.01				

There are significant variations ($p<0.05$) between the superscripts in the different interval days and treatment groups. T_0= Control group, T_1= 3 kGy gamma ray, T_2= 5 kGy gamma ray, T_3= 7 kGy gamma ray, DI=Days of Interval, Treat= Treatment, T*DI=Interaction of Treatment and Days of Interval

Effect on microbial population of beef

The effect of black cumin extract irradiation on the biomicrobial population of beef, including TCC, TVC, TYMC, total Salmonella spp., and total Staphylococcus spp., is presented in Table 2. In T_0, T_1, T_2, and T_3 treatment groups, the mean log (CFU/g) of TCC, TVC, TYMC, Salmonella spp., and total Staphylococcus spp. were 2.87, 5.07, 2.82, 3.53, 4.05; 2.98, 5.29, 2.94, 3.87, 3.53; 3.11, 5.43, 3.14, 4.06, 3.55, and 3.16, 5.62, 3.18, 3.90, 3.78, respectively. For all four treatment groups, the effects were statistically significant ($p<0.01$). The average log (CFU/g) values of TCC, TVC, TYMC, Salmonella spp., and Staphylococcus spp. during storage were 2.37, 3.38, 1.73, 3.56, 3.61; 2.65, 3.70, 2.12, 3.69, 3.71; 3.38, 6.78, 3.13, 3.83, 3.87, and 3.72, 7.54, 5.09, 4.29, 3.72, respectively. There was a substantial ($p<0.01$) effect for 0, 3, 5, and 7 days, with the exception of Staphylococcus species. For TVC, TYMC, and Staphylococcus species, there was no significant ($p>0.05$) interaction effect; however, for TCC and Salmonella species, there was a significant ($p<0.01$) influence between treatment and interval days.

A few investigations have been carried out on the impact of irradiating beef at room temperature with black cumin extract or other natural antioxidants. Sadakuzzaman et al. (2021) analyzed the effects of BHA irradiation on the microbial community in beef samples kept at room temperature. The bacterial counts were discovered a rising tendency during storage time reported by Khare et al. (2017) and Sadakuzzaman et al. (2021) The findings showed that irradiation dosages of 3, 5, and 7 kGy, as well as longer storage times at room temperature, significantly ($p<0.01$) raised TCC, TVC, and TYMC levels in comparison to the control group. According to Ferawati et al. (2015), the irradiation samples had lower overall microbial burdens than the control. Present findings were not in agreement to those published by Reddy et al. (2017), Inamura et al. (2012), and Afrin et al. (2017) who stated that microbial loads were lowered with the rise of irradiation doses. They found that adding leek (Allium tuberosum Rottler) extract to the irradiation dose resulted in a considerable drop in the overall aerobic bacterial count. The current research did not support these findings. With increasing irradiated doses in beef, the number of *Staphylococcus spp*. significantly ($p<0.01$) decreased and *Salmonella spp.* was substantially ($p<0.01$) higher than in the control group.As storage time extended, both Salmonella and Staphylococcus species significantly increased ($p<0.01$). Several studies showed that, in contrast to the current experiment, gamma irradiation at modest doses (2, 4, and 6 kGy) decreased the amounts of yeasts, moulds, coliforms, E. coli, and Staphylococcus aureus in ground beef samples to safe levels. (Ayari et al., 2016; Song et al., 2018).

Table 2. Effect on different microbial population of beef

Parameters	Storage time (days)	Dose (kGy)				Mean	Level of significance		
		T_0	T_1	T_2	T_3		Treat.	DI	T*DI
TCC (logCFU/g)	**0**	1.92±0.02	2.18±0.06	2.72±0.07	2.68±0.06	2.37^{d}±0.08	p<0.01	p<0.01	p<0.01
	3	2.71±0.03	2.72±0.07	2.61±0.06	2.59±0.04	2.65^{c}±0.03			
	5	3.30±0.19	3.29±0.06	3.44±0.05	3.49±0.05	3.38^{b}±0.11			
	7	3.55±0.11	3.75±0.04	3.69±0.03	3.88±0.05	3.72^{a}±0.06			
	Mean	2.87^{c}±0.08	2.98^{b}±0.05	3.11^{a}±0.05	3.16^{a}±0.07				
TVC (logCFU/g)	**0**	2.95±0.15	3.50±0.03	3.52±0.05	3.57±0.07	3.38^{d}±0.08	p<0.01	p<0.01	p>0.19
	3	3.60±0.11	3.68±0.05	3.72±0.09	3.82±0.07	3.70^{c}±0.10			
	5	6.55±0.28	6.51±0.07	6.82±0.04	7.24±0.15	6.78^{b}±0.19			
	7	7.20±0.17	7.47±0.17	7.65±0.08	7.84±0.06	7.54^{a}±0.12			
	Mean	5.07^{c}±0.17	5.29^{b}±0.15	5.43^{b}±0.26	5.62^{a}±0.11				
TYMC (logCFU/g)	**0**	1.65±0.04	1.73±0.03	1.79±0.04	1.77±0.11	1.73^{d}±0.07	p<0.01	p<0.01	p>0.91
	3	1.88±0.06	2.03±0.04	2.22±0.06	2.37±0.24	2.12^{c}±0.13			
	5	2.89±0.15	3.15±0.31	3.21±0.16	3.26±0.10	3.13^{b}±0.12			
	7	4.85±0.29	4.48±0.23	5.35±0.23	5.33±0.24	5.09^{a}±0.24			
	Mean	2.82^{b}±0.13	2.94^{ab}±0.15	3.14^{a}±0.12	3.18^{a}±0.17				
Salmonella spp. (logCFU/g)	**0**	3.37±0.14	3.51±0.19	3.67±0.27	3.67±0.23	3.56^{c}±0.20	p<0.01	p<0.01	p<0.01
	3	3.13±0.01	4.01±0.06	4.08±0.07	3.53±0.22	3.69^{bc}±0.09			
	5	3.32±0.05	3.74±0.20	4.18±0.06	4.09±0.07	3.83^{b}±0.09			
	7	4.29±0.12	4.22±0.20	4.33±0.10	4.31±0.05	4.29^{a}±0.11			
	Mean	3.53^{b}±0.08	3.87^{a}±0.16	4.06^{a}±0.12	3.90^{a}±0.14				
Staphylococcus spp. (logCFU/g)	**0**	3.67±0.17	3.67±0.12	3.53±0.18	3.58±0.23	3.61^{a}±0.17	p<0.01	p>0.38	p>0.51
	3	4.18±0.23	3.41±0.16	3.59±0.23	3.67±0.29	3.71^{a}±0.22			
	5	4.19±0.20	3.44±0.24	3.75±0.33	4.08±0.07	3.87^{a}±0.21			
	7	4.18±0.18	3.58±0.14	3.32±0.16	3.80±0.09	3.72^{a}±0.14			
	Mean	4.05^{a}±0.19	3.53^{b}±0.16	3.55^{b}±0.22	3.78^{ab}±0.17				

Significant differences exist in the superscripts of various treatment groups and interval days ($p<0.05$). T_0= Control group, T_1= 3 kGy gamma ray, T_2= 5 kGy gamma ray, T_3= 7 kGy gamma ray, DI=Days of Intervals, Treat= Treatment, T*DI=Interaction of Treatment and Days of Interval

Conclusion

This study concluded that combining irradiation with black cumin (*Nigella sativa*) extract considerably affected the biochemical and microbiological quality of beef maintained at room temperature. Indicators of lipid oxidation (FFA, POV, TBARS) increased with stronger irradiation and longer storage. Microbial counts (TCC, TVC, TYMC) also rose, with increasing Salmonella spp. and decreasing Staphylococcus spp. as irradiation levels grew. Significant relationships between treatment and storage time were identified for many parameters. The findings emphasise how crucial it is to adjust irradiation dosages and storage settings to guarantee both meat safety and quality. Overall, this study suggests that black cumin (*Nigella sativa*) treatment and irradiation influence both oxidative stability and microbial profiles of beef during ambient temperature, appropriate dose and storage management are key to maintaining product quality and safety.

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