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Evaluation of Gamma Irradiation and Moringa Leaf Powder on Quality Characteristics of Meat Balls under Different Packaging Materials

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Abstract

This study was carried out to investigate the effects of irradiation doses (0, 1.5 and 3kGy) on the physicochemical and microbial qualities of meat balls with or without moringa leaf powder (MLP) and 14 days under refrigerated storage. The results indicated that irradiation and storage caused significant changes on physicochemical attributes of meatballs and the decreasing trend in stability was observed in meatballs stored under aerobic packaging. Highest pH and TVBN were observed in samples treated with 3kGy at day 14 in aerobic packaging without MLP. The addition of MLP and higher doses of irradiation reduced the total aerobic bacteria and coliforms counts. Different treatments did not affect the sensory quality of chicken samples. Hence, it was concluded that irradiation dose at 1.5kGy with the addition of MLP and vacuum packaging may enhanced the safety, quality as well as stability of chicken meat during storage intervals.

Keywords. **Aerobic and vacuum packaging, g*amma irradiation, moringa leaf powder, quality attributes, sensory evaluation***

Practical application

The health benefits of meat and its products make them popular among the consumers. Hence, this study indicates the significance of irradiation (at low dose) in preserving the meat for long time without causing immense deteriorative changes in its quality. Moreover, the addition of moringa leaf powder (a natural antioxidant) and type of packaging (vacuum packaging) plays a vital role in maintaining the shelf life and stabilizing the safety of meat without causing major changes in its physicochemical, functional and sensory characteristics.

Introduction

Meat consumption is considered as highly esteem diet in most places around the world due to its high nutritional value. Meat is regarded as a rich source of zinc, essential amino acids, heme iron and bioavailable B vitamins (Pereira & Vicente, 2013). It is the first-choice source of animal protein for many people all over the world (Ekmekcioglu et al., 2018).

The need for ensuring meat products of high quality, consumer attractiveness and cost effectiveness has made the industrialists, meat processors, distributors and retailers to confirm the availability of these required features (Valdramidis & Koutsoumanis, 2016). It is not easy for meat-based products to make stable its shelf life in dynamic market due to its high perishability character without employing some appropriate preservation techniques. To enhance the shelf life of meat and its products various traditional preservation approaches have been utilized such as dehydration; heat processing, low temperature preservation, smoking and curing, but these conventional preservation methods have certain restrictions such as average shelf life, expansive and less stability. Moreover, numerous environmental and safety issues are also linked with the application of these methods that may develop serious environmental and health issues. Therefore, for safety enhancement of meat innovative techniques must be used in spite of these traditional methods that do not cause adverse effects on health (Troy et al., 2016). Thus, a wide range of novel processing, packaging and preservation methods has been emerging to increase the shelf stability and quality of meat products. These innovative techniques preserve the meat without disturbing the quality and sensory characteristics of muscle food (Feng et al., 2018).

Researchers have investigated a novel method that is the use of radiation for the decontamination of meat from different food and meat borne pathogens. It is quite efficient method as it has less residual effect on meat products in comparison to the use of different chemicals for decontamination (FAO, 2016). Radiation was first time applied in food materials at the institute of technology in Massachusetts. It was documented that irradiation can enhance the shelf life and eradicate the microorganisms of food product (Fadhel et al., 2016).

Irradiation preserves food products with minimal harm to the nutritional, functional and sensory attributes and has recently become one of the effective techniques for the preservation of food products. Irradiation is considered as preservation technology and gaining importance in muscle food worldwide (Bhat et al., 2016). All types of pathogenic microorganism in meat can be decontaminated by irradiation application but it also has negative effect as it reduces the quality due to change in oxidation reduction environment (Ahn et al., 2013). The gamma irradiation can also be applied on different fruits processing for enhancing the safety and shelf life (Panou et al., 2020).

Another major issue in maintaining the quality of meat is lipid oxidation (Feng & Ahn, 2016). Anti-oxidant addition can resolve the meat oxidation issue. The use of natural preservative is a promising technology to enhance the shelf-life of meat and meat products. Natural preservatives includes plants, herbs, fruits and vegetables powders or extracts have antimicrobial and antioxidant properties. *Moringa oleifera* is one of the naturally founded antioxidant which is also called as drumstick or horse radish tree is native to Southeast Asia, Arabia, Pakistan, Bangladesh, India, Africa and South America (Falowo et al., 2017). *Moringa oleifera L.* leaf extracts have been reported in literature as edible and promising sources of natural antioxidants (Bartolome et al., 2013). The leaves have unique concern in the preservation of food as they are highly enriched with proteins, essential amino acids such as cystine, tryptophan, methionine and lysine, minerals (particularly iron) and provitamin A, vitamins B and C (Oyeyinka & Oyeyinka, 2018) and also because of presence of bioactive substances such as, flavonoids, ascorbic acid, carotenoids and phenolics. It plays a significant role as a natural anti-oxidant and shelf life enhancer (Al-Juhaimi et al., 2016). The combination of gamma irradiation and moringa leaf powder has synergistic effect on the safety of meat products (Nisar et al., 2019).

Application of a novel and advance techniques are useless without applying proper packaging, it has an active role in, safety enhancement, preserving quality and sensory characteristics of the product. Plastics are usually used for meat as a packaging material, more specifically, laminates, in which good humidity barrier performance and polymer layers with oxygen-barrier properties like polyamide or polyethylene tetrapthalate. Packaging materials with good oxygen barrier attributes can be employed for low oxygen vacuum packaging. An air-permeable packaging is generally characterized as aerobic packaging, whereas vacuum packaging involves placing a product in a pack possessing low-oxygen permeability.

Considering the facts discussed above, the objective of this study was to determine the anti-microbial effect of irradiation with addition of moringa leaf powder as an antioxidant for safety enhancement of meat and meat products, to improve the shelf life of meat with gamma irradiation and to examine the stability of gamma treated meat under different storage conditions (Aerobic and Vacuum) and time intervals.

Material and methods

Procurement of raw material

This research study was conducted at Nuclear Institute for Food and Agriculture, Peshawar (NIFA) and Institute of Home and Food Sciences, Government College University, Faisalabad, Pakistan. The moringa leaf powder (MLP) and chicken meat were collected from the local market. Chicken was grinded and half of the meat was mixed with 2% MLP. Chicken samples were then placed in polythene bags and were transferred to NIFA for gamma irradiation. All reagents and chemicals used in this study were procured from Sigma Aldrich (Tokyo, Japan).

Irradiation dose

The chicken meat samples were placed in 12 packets (6 each for aerobic and vacuum packaging). The samples were than subjected to different irradiation doses (0, 1.5 and 3 kGy). After treatment the samples were placed in refrigerator storage at 4 °C up to 14 days. The physicochemical and functional analysis of treated samples was performed at 0, 7 and 14 days of interval.

Physicochemical analysis

pH

The pH was determined in a homogenate of the sample with distilled water (1→10) using a digital pH meter (Model 520A, Orion Research inc., Boston, USA) that was calibrated with standard pH buffers of 4.01, 7.00 and 10.01 at 25 °C. Three replicate measures were taken, and the mean value derived.

Total volatile basic nitrogen value

The TVBN value was determined as described by Qiao et al., 2017. Meat sample (5 g) was homogenized (Heiddph: 595-08000-00-2, Germany) with 45 mL of DW for 30 s; 5 mL of the homogenate was mixed with an equal volume of 10% trichloroacetic acid (TCA; w/v in distilled water). Thus, obtained TCA extract was used to determine the value of TVBN. One milliliter of TVBN reagent was added into the inner well of the Conway unit, and 1 mL TCA extract was added into the outer well, followed by the addition of 1 mL saturated potassium carbonate (K_2CO_3). The Conway unit was immediately sealed with an airtight ground glass plate, rotated clockwise and counter-clockwise, and incubated at room temperature for 3 h. The TVBN reagent in the inner well was back-titrated with 0.02 N sulfuric acid (H_2SO_4) until the blue coloring changed to pink. The TVBN value was calculated using the following equation

$$\text{“N”mg/mL of extract} = 14 \times a \times b$$

$$\text{TVBN value (mg/100mL)} = 100 \times N$$

14 = molecular weight of nitrogen, a= normality of H_2SO_4,

b = volume of H_2SO_4, (titration value)

Hunter color

Hunter colorimeter was used to determine the surface color values of the chicken samples, white calibration plate (L = 89.2, a = 0.921, and b = 0.783) is used as standardized measurements. An average of 3 random readings of color values (lightness (L), redness (a), and yellowness (b)) were obtained of each sample surface.

Heme pigment

The extraction of heme pigments from chicken meat samples were extracted following the protocol of Warriss (1979). Chicken sample (4 g) was homogenized (Heiddph: 595-08000-00-2, Germany) for 10 s at 13000 rpm with cold phosphate buffer (20 mL, 40 mM, pH 6.8). The resultant homogenate was stored for 1 hour at 4°C. The extract was then subjected to centrifugation for 30 min at 5000 rpm, the mixture was then filtered through Whatman No.1 filter paper. Ultraviolet–visible (UV/VIS) spectrophotometer (U-1800, Japan) was used to measure the absorbance of sample at different wavelength (525, 545, 565, and 572 nm). The method of Krzywicki et al, (1982) was followed to determine the relative concentration of heme pigments, such as myoglobin, oxymyoglobin and metmyoglobin. The relative concentrations (%) of Mb, MbO_2, and MMb were calculated using the following equations:

$$[Mb] = (0.369R_1 + 1.140R_2 - 0.941R_3 + 0.015) \times 100$$

$$[OxyMb] = (0.882R_1 - 1.267R_2 + 0.809R_3 - 0.361) \times 100$$

$$[MetMb] = (-2.541R_1 + 0.777R_2 + 0.800R_3 + 1.098) \times 100$$

Where R_1, R_2, R_3 are absorbance ratios A^{572}/A^{525}, A^{565}/A^{525}, A^{545}/A^{525}, respectively.

Microbial analysis

The determination of microbes (total aerobic bacteria and coliforms) in chicken samples were done according to the methodology described by Helrich, (1990). Total aerobic bacteria were spread on Plate Count Agar (Merck, Darmstadt, Germany) in petri dishes, which were then incubated at different time and temperature (35 °C for 24–48 hour and 25 °C for 3–5 days). Enumeration of coliform was performed with solid medium method by using double layer VRBA (Violet Red Bile Glucose Agar, Oxoid) and VRBA (Oxoid) with 4-methlyenebelliferyl-b-D-glucuronide (MUG). The plates were then incubated for 18-24 hour at 35 °C. The total coliforms were counted by the formation of dark red, lactase positive and 0.5–2 mm diameter colonies surrounded by a reddish zone.

Storage Study

The irradiated meat samples were kept in storage for 7 and 14 days at 4°C to study the changes in its physicochemical and functional analysis throughout the storage interval (Walkling-Ribeiro et al., 2009).

Sensory evaluation

The sensory evaluation of gamma and moringa leaf powder treated chicken meatballs sample was conducted at storage interval of 0, 7, and 14 by trained panelists using a 9-point hedonic scale where "0" being the lowest and "9" being the highest score (Meilgaard et al., 2007). The chicken meatballs were analyzed for different quality attributes (appearance, taste, texture, flavor, and overall acceptability).

Statistical analysis

All experiments were conducted in triplicate (n=3) and an ANOVA test using SPSS version 11.5 was used to compare the mean values of each treatment. Significant differences between the means of parameters were determined by using the Tukey test ($p < 0.05$) (Steel & Torrie, 2012).

Results and Discussion

Physicochemical parameters

The effect of different irradiation doses on the physicochemical parameters of meat samples including pH, hunter color and heme pigment of meat samples incorporated with or without moringa leaf powder were examined. Chemical composition and nutritional quality of meat and meat products are affected by several factors including processing and storage and are also influenced by species. Results for changes in physicochemical parameters (pH, hunter color and heme pigment) of untreated and processed meat samples kept at refrigerator in aerobic and vacuum packaging for a maximum period of 14 days are presented and described.

pH

pH is one of the important factor as it is closely related with the stability of the bioactive compounds in meat and meat products (Sánchez-Moreno et al., 2006). The pH value of meat samples with or without moringa leaf powder showed significant decrement ($p \leq 0.05$) with the increment of irradiation doses and storage days. The mean values of pH irradiated with different doses of gamma radiations, stored in aerobic and vacuum packaging are given in (table 1). The pH value in aerobic and vacuum packaging on 0 day after different treatments ranged from 5.61±0.01 to 5.76±0.01 respectively, whereas, the pH values in aerobic packaging during storage ranged from 5.70±0.01 to 6.02±0.01 and in vacuum packaging ranged from 5.71±0.02 to 6.06±0.01 respectively. The Higher pH (more acidic) was found with 1.5 kGy with the addition of 2% MLF on storage day 0 (5.61±0.01) in both aerobic and vacuum packaging; lower pH (6.06±0.01) was found with 1.5 kGy without MLF on storage day 14. This result is similar with the findings of Chouliara et al. (2008), who concluded that pH of irradiated meat samples kept in aerobic and modified atmospheric packaging tends to reduce slightly throughout the storage period of 25 days. Pelicia et al. (2014) also determined that pH tends to decrease in meat with the high dose of gamma irradiation kept in both aerobic and vacuum packaging.

The increment in pH level by irradiation processing may be because of the breakdown of lactic acid production and due to hydrolysis of glycogen which accumulates in meat (Kumar et al., 2017). The stability of pH level in irradiated samples with moringa leaf powder is because the radiations and antioxidants inhibit the growth of lactic acid bacteria which causes the rise in pH in meat samples (Miyagusku et al., 2008).

Total volatile basic nitrogen (TVBN) value

The TVBN value of meat samples with or without moringa leaf powder showed significant increment ($p \leq 0.05$) with rise of irradiation doses and storage period. The mean TVBN value of meat samples on storage day 0 varied from 2.25±0.01 to 4.15±0.02 mg/100mL among different applied treatments, whereas the TVBN value during storage in aerobic packaging ranged from 2.43±0.02 to 4.51±0.01 mg/100mL, while in vacuum packaging ranges from 2.37±0.01 to 4.42±0.01 mg/100mL respectively (Table 1). Higher TVBN value (4.51±0.01 mg/100mL) were found in meat samples (without MLF) treated with 3 kGy irradiation dose and stored in aerobic packaging for 14 days. The similar effect of high dose irradiation causing the increment in TBVN value of chicken kababs was examined by Al-Bachir et al. (2010). In another study by Kwon et al. (2011), it was determined that the TVBN level increases in raw and cooked chicken meat when exposed to gamma radiation dose of 0-5kGy.

However, it was also demonstrated that the increment in TVBN values were suppressed by irradiation during storage as compared to control and it was also observed that addition of moringa leaf powder also suppressed the production of volatiles in meat samples during storage. The amount of TVBN components also vary in type of packaging, meat samples stored in vacuum packaging showed less value of TVBN throughout the storage as compared to meat samples in aerobic packaging. This result is similar with the findings of Yun et al. (2014), who reported that volatile compounds were enhanced by irradiation process in ready to eat chicken breast, but they tend to increase slowly as compared to un-irradiated meat samples during the storage time period. Furthermore, Li et al. (2017) reported that the volatiles substances found to be increased in high dose irradiated pork samples as compared to low dose irradiated samples during storage. The role of antioxidants in suppressing the volatiles production induced by irradiation process during storage was demonstrated by Hwang et al. (2015). According to the author the mugwort extracts and ascorbic acids when added into meat samples inhibits the increment of volatile substances during storage.

The increment in TVBN level by irradiation processing may be because of the breakdown of nitrogenous compounds present in meat samples (Ahn et al, 2004). The stability of TVBN level in irradiated samples and samples with moringa leaf powder during storage might be due to the fact that irradiation and antioxidants both helps in controlling the production of spoilage bacteria which may causes high amount of TBVN value in meat samples (An et al., 2017). The results are in agreement with the findings of Arshad et al. (2019); Arshad et al. (2020).

Hunter color

Color is one of the most important sensory attribute of any product. The color value of meat samples with or without moringa leaf powder showed significant changes ($p \leq 0.05$) in all treatments and during storage. The lightness L^* value of meat samples increased till 1.5 kGy dose, whereas it showed decrement with the rise of irradiation dose. On the other hand, the a^* and b^* values increased significantly with the increment of irradiation dose (Table 2). According to the obtained data the higher L^*, a* and b* value was observed at 1.5 kGy with 2% MLF throughout storage in vacuum packaging that ranged from 70.00±1.00 to 78.66±0.57, 4.04±0.05 to 7.48±0.01 and 15.55±0.09 to 13.00±0.100 respectively, while minimum L*, a* and b* values were observed in control at 0 day.

According to our result the storage days do not show any variation in L*, a* and b* color values, but different irradiation treatments significantly affect the color values of meat samples. Moreover, we concluded that meat samples stored in vacuum packaging show minimally changes in color values as compared to meat samples stored in aerobic packaging. The incorporation of natural antioxidant (moringa leaf powder) resulted in the variation in L*, a* and b* color values of irradiated and non-irradiated samples throughout the storage period in both types of packaging. The similar effect of storage was determined in the study of Li et al. (2017), who examined that L*, a* and b* values of color parameters remain unchanged during storage for 14 days. However, the rise in irradiation doses enhanced the color values. Present results are in agreement with Zhao et al. (2017) on effect of irradiation on quality of vacuum packed chopped beef samples, also agrees with our finding. The authors concluded that color of meat samples changes with the increment of irradiation dose level irrespective of storage time and packaging. The change in color as observed in irradiated meat samples incorporated with moringa leaf powder is in favor of previous study by Liz and Getty, (2013), who demonstrated that antioxidants when mixed with meat samples transfers their natural color into the meat thus causing some variation in meat color.

Irradiation degrades the water molecules in meat that generates oxidizing and reducing compounds such as hydroxyl radicals, hydrogen atoms, etc. and lead to the changes in meat color (Thakur and Singh, 1994). The oxidizing compound can convert myoglobin to metmyoglobin and can also lead to lipid oxidation by removing ferric ion from heme, whereas the oxidation-reduction potential is lowered by reducing compounds in meat (Min et al., 2010).

Heme Pigment

The assessment of heme pigment especially myoglobin is used to observe the quality parameters of meat like color, microbial growth, shelf life and rancidity (Chaijan et al., 2007). The heme pigment value of irradiated meat samples with or without moringa leaf powder in aerobic and vacuum packaging showed significant changes ($p \leq 0.05$) among all treatments and storage days. The mean values of myoglobin, oxymyoglobin and metmyoglobin are shown in Table 3. The amount of myoglobin varied from 28.98±0.86 to 34.08±0.06 %, oxymyoglobin ranged from 8.98±0.15 to 11.77±0.06 % and metmyoglobin ranged from 42.12±0.31 to 45.05±0.04 % respectively, on storage day 0. The higher value of myoglobin was observed in 3 kGy samples with MLF on day 0 (35.65±0.03 %), higher value of oxymyoglobin was 20.61±0.12%, observed at 3 kGy with MLF on day 14, while the highest value of metmyoglobin (65.90±0.07 %) was observed on day 14 at 3 kGy without MLF in vacuum packaging.

According to present results, the myoglobin pigment decreased, whereas the oxymyoglobin and metmyoglobin pigments increased with the rise in irradiation dose level and storage days in both aerobic and vacuum packaging. This result correlates with the findings of An et al. (2017) who reported that heme pigments of irradiated smoked duck meat increased during storage except myoglobin which tends to decrease with the increase in storage days. Reddy et al. (2015), also reported that myoglobin pigment decreased during storage, whereas, oxymyoglobin and metmyoglobin increased as the storage day increases in irradiated samples of mutton kheema. In our study, we also found that the heme pigments level in the meat samples incorporated with moringa leaf powder though exhibited the same trend as meat samples without the antioxidant, but the level of heme pigments is greater in those samples as compared to ones without antioxidants. Cunha et al. (2018), also examined that addition of antioxidants in meat samples slightly inhibits the degradation of myoglobin during storage, thus provided better contents of heme pigments in meat samples.

The irradiation process through many different mechanisms causes the catabolism of myoglobin pigment into oxymyoglobin and metmyoglobin pigments thus resulting in decrement of myoglobin level and increment in other two pigment compounds. Myoglobin possess prooxidant capacities by many ways as it could act as a free radical by decomposing hydroperoxide. free radicals helps in lipid oxidation and produces hydroxyl radicals from water that converts myoglobin into metmyoglobin due to ionizing radiation (Aliakbarlu et al., 2015).

Microbial analysis

The effect of different irradiation doses on the microbes of irradiated and non-irradiated meat samples with or without moringa leaf powder were examined before and after storage under vacuum and aerobic packaging. Total aerobic bacteria and coliform values of irradiated meat samples with or without moringa leaf powder showed significant changes ($p \leq 0.05$) in all treatment and storage time interval (Table 4). The results of total bacterial count in meat samples after being exposed to irradiation processing, demonstrate that irradiation have the great potential in minimizing and eliminating the microbes from the meat and meat products. The highest value of TAB was found in control (9.81±0.04 log CFU/g) on day 14 in aerobic packaging, whereas the lowest TAB value was observed in 3 kGy treated sample w/ MLF (4.17±0.02 log CFU.g) on day 0. Coliforms were only discovered in control samples with or without MLF, whereas, they were absent in all irradiated meat samples. The similar effect of gamma irradiation eradicating the microbes from fried chicken dices was observed by Chen et al. (2016). Kanatt et al. (2010), also examined the effect of irradiation in controlling the growth of microorganism in different meat products. The gamma radiation eradicating the no of coliforms in smoked duck meat samples was also reported by An et al. (2017). Moreover, according to our result, the incorporation of Moringa leaf powder in meat samples act as a resistant against microbial growth, therefore, the no of bacterial count become more less in antioxidant meat samples after irradiation as compare to non-antioxidant irradiated meat samples. This examinations corelates with the observation of Cunha et al. (2018), who demonstrate that antioxidants play a vital role in preserving the different meat products.

Though irradiation reduced the amount of TAB but during storage their number tends to increase slightly. On the other hand, irradiation eradicates the coliforms from the meat samples which do not appear in storage days as well. These findings agree with the observations of Fallah et al. (2010) who examined that gamma radiation inactivates pathogenic bacteria from chicken meat samples, moreover very less amount of bacteria were found in irradiated samples when kept in storage for 25 days. In another study, Mantilla et al. (2011) reported that the shelf life of chicken breast fillets improves with the irradiation treatment and when kept in storage under vacuum packaging as compared to unirradiated samples in aerobic packaging. Henriques et al. (2013) and Arzina et al. (2012) also reported that irradiation dosage of 1.5-2.5kGy is enough to eradicate the pathogenic bacteria in refrigerated stored meat samples. The growth of microorganism is controlled by irradiation process as it kills them with its high doses of radiation (Montiel et al., 2013).

Sensory evaluation

Sensory assessment of a product correlates with consumer approach, believes and awareness. Product development requires an efficient hedonic evaluation for documentation and interpretation of sensory results perceived by the trained panelists. The mean sensory score of appearance, flavor, texture, taste and overall acceptability of formulated chicken meatballs in aerobic and vacuum packaging are shown in Tables 5 and 6, respectively. According to present results, different treatments did not affect the sensory result, but it showed variation with storage days and type of packaging. the highest value of appearance (8.25±0.70), flavor (7.5±1.35), texture (7.1±0.77), taste (7.3±1.03), overall acceptability (7.5±0.81) was awarded to control (0 kGy) on day 0 in both aerobic and vacuum packaged meatballs samples. Whereas the lowest value of appearance (6.1±1.43 in aerobic packaging), flavor (6.1±0.90 in vacuum packaging), texture (5.7±1.20 in aerobic packaging), taste (6.0±0.90 in vacuum packaging) and overall acceptability (6.2±0.90 in vacuum packaging) is also at 0 kGy but on storage day 14.

The sensory attributes showed decrement in their value throughout the storage time. These findings are in accordance with Fallah et al. (2010) who concluded that appearance score of both irradiated and non-irradiated samples were good at day 1, but after storage day 15 the non-irradiated barbecued chicken exhibit less sensory score as compared to irradiated one. Al-Bachir et al. (2010) also reported that the flavor of prepared chicken kababs was well accepted by the panelist without irradiation treatment on day 1, all irradiated chicken kababs were also had good sensory score on day 1 and throughout the storage period, but non-irradiated samples start losing their acceptability of flavor as the storage days increases. Regarding texture, Benerjee et al. (2016), reported that the hardness, chewiness and gumminess in mutton patties were lower in control on day 0, as compared to irradiated mutton patties. Furthermore, Gertzou et al. (2017) reported that sensory attributes are better with combination of vacuum packaging and ozonation. In another study by Kanatt et al. (2005), it was observed that un-irradiated meat products exhibited good taste on day 1 but when kept in storage their taste become less accepted due to bacteria which altered the taste as compared to irradiated meat products which inhibited the growth of pathogenic bacteria. Irradiation facilitated the lipid oxidation which cause changes in sensory attributes and made the product less acceptable, but overall acceptability was in the range of acceptance.

Conclusion

This study indicated that irradiation preserves food products with minimal harm to the nutritional, functional and sensory attributes at lower doses. Phytochemicals originating from moringa leaf powder play an important role in stabilizing and protecting the fat, amino acid and other physicochemical and functional components in meat and meat products. The type of packaging helped in extending the shelf life of meat and meat products. The irradiation doses minimize the total aerobic bacteria and eliminates the coliform from the meat samples during storage. Different treatments did not affect the sensory quality of chicken meatballs, but the variation was observed with the storage period.

Authors' contributions

The contribution of the each author for this manuscript was as follows, MSA and MY designed the experimental plan and MFS conducted the analysis and drafted the manuscript. MKK and MA helped in execution of the project. MARS helped in revising the manuscript and SS helped in data analysis. It is also confirmed that all the authors read and approved the final manuscript.

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Table 1. pH and TVBN in aerobic and vacuum packaged meat samples during storage

		pH		TVBN (mg/100mL)	
		Aerobic	**Vacuum**	**Aerobic**	**Vacuum**
0kGy	0	5.76±0.01^{f}	5.76±0.01^{g}	2.76±0.02^{a}	2.76±0.02^{a}
	7	5.88±0.01^{cd}	5.82±0.01^{e}	3.20±0.01^{b}	3.01±0.02^{b}
	14	5.97±0.01^{b}	5.93±0.01^{bc}	3.54±0.02^{c}	3.27±0.02^{b}
	0	5.70±0.01^{g}	5.70±0.01^{ef}	3.70±0.02^{c}	3.70±0.02^{c}
1.5kGy	7	5.82±0.01^{e}	5.97±0.01^{b}	3.89±0.02^{d}	3.82±0.02^{d}
	14	5.95±0.01^{b}	6.06±0.01^{a}	3.97±0.01^{e}	3.78±0.01^{c}
	0	5.77±0.01^{f}	5.77±0.01^{hi}	4.15±0.02^{e}	4.15±0.02^{b}
3kGy	7	5.90±0.01^{c}	5.81±0.04^{ef}	4.44±0.01^{f}	4.36±0.01^{e}
	14	6.02±0.01^{a}	5.91±0.01^{cd}	4.51±0.01^{e}	4.42±0.01^{ef}
	0	5.67±0.01^{gh}	5.67±0.01^{i}	2.25±0.01^{a}	2.25±0.01^{a}
0kGy + 2% MLF	7	5.74±0.01^{f}	5.76±0.03^{fg}	2.43±0.02^{a}	2.37±0.01^{a}
	14	5.82±0.01^{e}	5.86±0.01^{de}	2.51±0.02^{a}	2.45±0.01^{a}
	0	5.61±0.01^{i}	5.61±0.01^{gh}	3.36±0.01^{c}	3.36±0.01^{c}
1.5kGy + 2% MLF	7	5.70±0.01^{g}	5.89±0.01^{cd}	3.58±0.02^{bc}	3.50±0.02^{bd}
	14	5.86±0.01^{d}	5.99±0.01^{b}	3.71±0.01^{c}	3.59±0.02^{c}
	0	5.67±0.01^{h}	5.67±0.01^{j}	3.67±0.01^{c}	3.67±0.01^{c}

3kGy + 2% MLF	7	5.77±0.01[f]	5.71±0.02[gh]	3.78±0.01[d]	3.70±0.01[d]
	14	5.88±0.01[cd]	5.86±0.02[de]	3.89±0.01[d]	3.77±0.01[d]

Results are means of triplicates (±SD). Values with different letters in columns are significantly different (Tukey's test, $p \leq 0.05$). MLF; Moringa Leaf Powder

Table 2. Hunter color in aerobic and vacuum packaged meat samples during storage

Results are means of triplicates (±SD). Values with different letters in columns are significantly different (Tukey's test, $p \leq 0.05$). MLF; Moringa Leaf Powder

Treatments	Storage Days	Aerobic			Vacuum		
		L*	**a***	**b***	**L***	**a***	**b***
0kGy	0	54.00±1.00^{def}	4.04±0.06^{h}	13.00±0.100^{i}	54.00±1.00^{ef}	4.04±0.05^{f}	13.00±0.100^{g}
	7	53.00±1.00^{ef}	4.05±0.01^{h}	12.96±0.01^{i}	58.00±1.00^{f}	4.24±0.01^{f}	13.38V0.03^{g}
	14	51.33±1.52^{f}	4.08±0.01^{h}	12.85±0.05^{i}	56.66±0.57^{f}	4.29±0.01^{f}	13.77±0.02^{fg}
1.5kGy	0	61.00±1.00^{b}	5.57±0.04^{f}	14.23±0.15^{de}	61.00±1.00^{b}	5.57±0.04^{d}	14.23±0.15^{c}
	7	62.66±0.57^{b}	5.56±0.01^{f}	14.18±0.03^{def}	71.33±0.57^{b}	5.90±0.01^{d}	14.83±0.05^{c}
	14	62.00±1.00^{b}	5.60±0.01^{f}	14.35±0.02^{d}	73.00±1.00^{b}	5.97±0.01^{d}	14.94±0.02^{bc}
3kGy	0	53.00±1.00^{ef}	5.09±0.07^{g}	14.00±0.10^{efg}	53.00±1.00^{c}	5.09±0.07^{c}	14.00±0.10^{c}
	7	52.00±1.00^{ef}	5.11±0.02^{g}	13.96±0.01^{fgh}	66.66±0.57^{c}	5.57±0.01^{c}	14.63±0.06^{cd}
	14	54.33±0.57^{de}	5.08±0.02^{g}	13.98±0.07^{efgh}	66.00±1.00^{c}	5.62±0.01^{c}	14.73±0.02^{cd}
0kGy + 2% MLF	0	57.66±0.57^{c}	6.72±0.07^{e}	13.73±0.05^{h}	57.66±0.57^{d}	6.72±0.07^{e}	13.73±0.05^{ef}
	7	56.66±0.57^{cd}	6.79±0.02^{de}	13.76±0.01^{gh}	61.33±0.57^{d}	6.85±0.01^{e}	13.99±0.05^{ef}
	14	56.66±0.57^{cd}	6.71±0.03^{e}	13.79±0.01^{gh}	62.66±0.57^{de}	6.90±0.01^{e}	14.29±0.44^{de}
1.5kGy + 2% MLF	0	70.00±1.00^{a}	7.15±0.04^{b}	15.13±0.20^{bc}	70.00±1.00^{a}	7.15±0.04^{a}	15.13±0.20^{a}
	7	69.33±0.57^{a}	7.53±0.15^{a}	15.26±0.05^{ab}	77.66±0.57^{a}	7.43±0.01^{a}	15.44±0.05^{a}
	14	68.00±1.00^{a}	7.12±0.01^{bc}	15.40±0.01^{a}	78.66±0.57^{a}	7.48±0.01^{a}	15.55±0.09^{a}
3kGy + 2% MLF	0	63.00±1.00^{b}	6.94±0.08^{d}	14.93±0.15^{c}	63.00±1.00^{b}	6.94±0.08^{b}	14.93±0.15^{ab}
	7	63.66±0.57^{b}	6.89±0.01^{d}	14.88±0.03^{c}	73.33±0.57^{b}	7.22±0.01^{b}	15.31±0.05^{ab}

14	63.00±1.00^{b}	6.95±0.01^{cd}	14.96±0.01^{c}	73.33±1.52^{b}	7.28±0.01^{b}	15.26±0.04^{ab}

Table 3. Heme pigment in aerobic and vacuum packaged meat samples during storage

Results are means of triplicates (±SD). Values with different letters in columns are significantly different (Tukey's test, p ≤ 0.05). MLF; Moringa Leaf Powder

Treatments	Storage Days	Aerobic			Vacuum		
		Mb (%)	**OxyMb (%)**	**MetMb (%)**	**Mb (%)**	**OxyMb (%)**	**MetMb (%)**
0kGy	0	33.36±0.43[a]	8.98±0.15[l]	42.12±0.31[l]	34.44±0.14[c]	9.12±0.06[l]	42.86±0.07[k]
	7	26.30±0.13[e]	10.86±0.04[jk]	51.51±0.49[g]	26.26±0.32[h]	13.75±0.19[g]	53.71±0.22[g]
	14	18.13±0.09[j]	13.78±0.14[g]	57.28±0.25[d]	19.58±0.34[m]	15.59±0.05[e]	61.79±0.13[d]
1.5kGy	0	30.73±1.18[b]	10.96±0.01[jk]	44.64±0.14[i]	33.93±0.06[c]	11.05±0.01[j]	44.89±0.02[j]
	7	22.63±0.20[gh]	12.84±0.16[h]	54.56±0.19[e]	26.71±0.19[h]	14.45±0.08[f]	52.80±0.13[h]
	14	16.71±0.21[k]	15.64±0.25[e]	59.45±0.16[b]	18.50±0.04[n]	17.51±0.20[c]	63.84±0.14[c]
3kGy	0	28.98±0.86[c]	10.47±0.35[k]	43.90±0.07[j]	32.38±0.20[d]	10.99±0.01[j]	44.63±0.05[j]
	7	19.43±0.06[i]	14.55±0.19[f]	53.60±0.16[f]	24.57±0.06[i]	13.58±0.14[g]	55.80±0.10[f]
	14	15.84±0.03[k]	17.63±0.09[c]	57.30±0.10[d]	17.64±0.24[o]	16.35±0.11[d]	65.90±0.07[a]
0kGy + 2%	0	34.08±0.06[a]	9.07±0.05[l]	42.96±0.02[k]	34.08±0.06[b]	9.07±0.05[k]	42.96±0.02[k]
MLF	7	28.68±0.24[cd]	11.75±0.25[i]	50.83±0.01[h]	28.68±0.24[f]	12.62±0.05[h]	51.79±0.14[i]
	14	23.81±0.16[f]	16.67±0.29[d]	56.922±0.01[d]	22.65±0.16[k]	15.59±0.14[e]	60.73±0.13[e]
1.5kGy + 2%	0	33.17±0.08[a]	11.77±0.06[i]	45.05±0.04[i]	36.34±0.07[a]	11.96±0.03[i]	44.99±0.01[j]
MLF	7	27.50±0.04[d]	15.70±0.38[e]	54.70±0.30[e]	29.57±0.10[e]	15.48±0.11[e]	53.67±0.30[g]

	14	21.52±0.19[h]	18.58±0.13[b]	61.62±0.31[a]	23.54±0.26[j]	18.50±0.14[b]	64.63±0.31[b]
3kGy + 2% MLF	0	31.26±0.08[b]	11.22±0.06[ij]	44.97±0.01[i]	35.65±0.03[b]	11.72±0.03[i]	44.79±0.03[j]
	7	22.72±0.22[fg]	16.89±0.07[d]	50.76±0.12[h]	27.67±0.16[g]	16.48±0.10[d]	59.90±0.07[f]
	14	15.71±0.13[k]	19.48±0.07[a]	58.74±0.33[c]	20.59±0.15[l]	20.61±0.12[a]	64.81±0.09[b]

Table 4. Mean values of microbial load in aerobic and vacuum packaged meat samples during storage

Treatments	Storage Days	Aerobic		Vacuum	
		TAB (log CFU/g)	Coliform (log CFU/g)	TAB (log CFU/g)	Coliform (log CFU/g)
0kGy	0	7.03±0.01[d]	5.23±0.02[d]	7.03±0.01[e]	5.23±0.02[b]
	7	8.53±0.01[b]	6.35±0.01[b]	7.62±0.01[b]	5.71±0,28[a]
	14	9.81±0.04[a]	7.12±0.01[a]	8.15±0.01[a]	5.98±0.10[a]
1.5kGy	0	5.15±0.02[h]	ND	5.15±0.02[j]	ND
	7	5.36±0.02[g]	ND	5.68±0.01[h]	ND
	14	5.98±0.02[f]	ND	5.98±0.01[g]	ND
3kGy	0	4.23±0.02[m]	ND	4.23±0.02[n]	ND
	7	4.52±0.01[l]	ND	4.65±0.01[l]	ND
	14	4.67±0.01[k]	ND	4.77±0.02[k]	ND
0kGy + 2% MLF	0	6.74±0.02[e]	4.86±0.04[f]	6.74±0.02[f]	4.86±0.04[c]
	7	7.02±0.01[d]	5.17±0.01[e]	7.03±0.01[d]	4.90±0.01[b]
	14	7.24±0.02[c]	5.35±0.01[c]	7.31±0.09[c]	4.97±0.01[b]
1.5kGy + 2% MLF	0	5.04±0.01[i]	ND	5.04±0.01[k]	ND
	7	5.12±0.01[h]	ND	5.03±0.01[j]	ND
	14	5.38±0.01[g]	ND	5.20±0.01[i]	ND
3kGy + 2% MLF	0	4.17±0.02[n]	ND	4.17±0.02[o]	ND

	7	4.46±0.03[l]	ND	4.24±0.02[n]	ND
	14	4.74±0.01[j]	ND	4.31±0.04[m]	ND

Results are means of triplicates (±SD). Values with different letters in columns are significantly different (Tukey's test, $p \leq 0.05$). MLF; Moringa Leaf Powder

Table 5. Sensory scores of meatballs stored in aerobic packaging

Treatments	Storage Days	Appearance	Flavor	Texture	Taste	OA
0kGy	0	8.25±0.70[a]	7.5±1.35[a]	7.1±0.77[ab]	7.3±1.03[a]	7.5±0.81[ab]
	7	7.15±1.30[b]	6.7±1.03[b]	6.8±0.95[b]	6.9±1.16[b]	6.8±0.97[b]
	14	6.1±1.43[c]	6.2±0.91[c]	5.7±1.20[c]	6.1±1.42[c]	6.3±1.10[c]
1.5kGy	0	7.86±0.71[ab]	7.2±1.30[b]	6.9±0.80[b]	7.2±0.90[a]	7.2±0.67[c]
	7	7.1±0.71[b]	6.5±1.10[b]	6.2±0.90[b]	6.5±1.20[b]	6.4±0.82[b]
	14	6.8±0.74[c]	5.9±.080[c]	5.8±1.40[c]	6.3±1.25[c]	6.1±1.02[c]
3kGy	0	7.5±0.53[ab]	7.3±1.15[a]	7.0±0.90[a]	7.1±1.01[a]	7.3±0.77[ab]
	7	7.2±1.30[b]	6.8±0.95[b]	6.7±1.52[b]	6.9±1.19[b]	6.9±0.77[b]
	14	6.5±1.52[c]	6.5±0.90[c]	6.1±1.20[c]	6.5±1.04[c]	6.4±1.03[c]
0kGy + 2% MLF	0	8±0.65[a]	7.4±1.32[a]	7.0±1.10[ab]	7.2±0.98[a]	7.4±0.74[a]
	7	7.5±0.70[b]	6.9±1.14[b]	6.7±0.99[b]	6.7±1.06[b]	6.9±0.77[b]
	14	7.1±1.20[c]	6.4±1.01[c]	6.2±1.30[c]	6.4±1.10[c]	6.5±1.32[c]
1.5kGy + 2% MLF	0	7.8±0.77[ab]	7.3±1.16[ab]	7.0±0.87[a]	7.3±1.15[a]	7.4±0.93[abc]
	7	7.2±0.82[b]	6.6±0.70[b]	6.7±1.03[b]	6.4±1.07[b]	6.7±0.85[b]

	14	6.9±0.90^{c}	6.4±0.74^{c}	6.3±0.93^{c}	6.3±1.03^{c}	6.4±1.05^{c}
3 kGy + 2% MLF	0	7.6±0.80^{b}	7.4±1.43^{ab}	7.0±0.90^{ab}	7.1±0.88^{a}	7.3±1.01^{bc}
	7	6.8±1.30^{b}	6.5±1.33^{b}	6.6±0.90^{b}	6.2±0.98^{b}	6.5±0.98^{b}
	14	6.76±1.42^{c}	6.3±1.21^{c}	6±1.10^{c}	6.2±1.07^{c}	6.1±1.10^{c}

The values are mean ± SD of ten independent determinations. The means carrying different letters in a column differed significantly. OA: Overall Acceptability; MLF: Moringa Leaf Powder

Table 6. Sensory scores of meatballs stored in vacuum packaging

Treatments	Storage Days	Appearance	Flavor	Texture	Taste	OA
0kGy	0	8.25±0.70^{ab}	7.5±1.35^{b}	7.1±0.77^{ab}	7.3±1.03^{a}	7.5±0.81^{a}
	7	7.3±0.72^{b}	6.4±1.21^{b}	6.9±1.18^{b}	6.8±1.16^{b}	6.8±0.88^{b}
	14	6.4±0.80^{c}	6.1±0.90^{c}	6.0±1.36^{c}	6.0±0.90^{c}	6.2±0.90^{c}
1.5kGy	0	7.86±0.71^{d}	7.2±1.30^{ab}	6.9±0.80^{ab}	7.2±0.90^{a}	7.2±0.67^{a}
	7	6.9±0.71^{b}	6.7±1.21^{b}	6.8±1.10^{b}	6.4±1.13^{b}	6.7±0.80^{b}
	14	6.8±0.82^{c}	6.4±1.02^{c}	6.3±1.32^{c}	6.2±1.43^{c}	6.3±0.77^{c}
3kGy	0	7.5±0.53^{b}	7.3±1.15^{b}	7.0±0.90^{a}	7.1±1.01^{a}	7.3±0.77^{a}
	7	7.3±0.77^{b}	6.2±1.22^{b}	6.9±0.98^{b}	6.8±1.07^{b}	6.8±0.84^{b}
	14	6.8±0.85^{c}	6.3±1.10^{c}	6.2±1.08^{c}	6.4±1.41^{c}	6.3±0.77^{c}
0kGy + 2% MLF	0	8±0.65^{a}	7.4±1.32^{a}	7.0±1.10^{b}	7.2±0.98^{a}	7.4±0.74^{a}
	7	7.5±0.99^{b}	6.9±0.94^{b}	6.5±0.90^{b}	6.6±1.33^{b}	6.8±0.91^{b}

	14	$7±1.01^{c}$	$6.4±0.74^{c}$	$6.1±1.41^{c}$	$6.3±1.21^{c}$	$6.1±1.01^{c}$
1.5kGy + 2% MLF	0	$7.8±0.77^{bc}$	$7.3±1.16^{a}$	$6.9±0.87^{ab}$	$7.2±1.15^{a}$	$7.4±0.93^{a}$
	7	$7.2±1.10^{b}$	$6.9±1.30^{b}$	$6.8±1.17^{b}$	$6.3±1.10^{b}$	$6.8±0.85^{b}$
	14	$6.7±0.77^{c}$	$6.4±1.04^{c}$	$6.4±1.10^{c}$	$6.2±1.15^{c}$	$6.3±0.74^{c}$
3 kGy + 2% MLF	0	$7.6±0.80^{cd}$	$7.4±1.43^{b}$	$6.8±0.90^{ab}$	$7.1±0.88^{a}$	$7.3±1.01^{a}$
	7	$7.1±0.71^{b}$	$6.3±1.25^{b}$	$6.7±1.18^{b}$	$6.3±1.23^{b}$	$6.6±0.84^{b}$
	14	$6.6±0.74^{c}$	$6.2±1.17^{c}$	$6.1±1.30^{c}$	$6.1±1.20^{c}$	$6.2±0.91^{c}$

The values are mean ± SD of ten independent determinations. The means carrying different letters in a column differed significantly. OA: Overall Acceptability; MLF: Moringa Leaf Powder