Effect of Maillard Reaction Products (MRPs) on lipid oxidative profile of irradiated meat products

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I. ABSTRACT

Optimized concentration of glucose-lysine (90 millmolar/2h) MRPs were incorporated with meat products prepared from goat meat and subjected for irradiation at 1, 2 & 3 kGy in LDPE pouches in a Gamma Chamber 5000, with Co^{60} source. The samples along with control were stored at 5±2°C. Investigations on total carbonyls, Thiobarbituric acid reactive substances (TBARS), Non heme iron, Total volatiles, Peroxide value, Total fatty acid profile by Gas liquid Chromatography and sensory characteristics as per standard procedures have been carried out for 6 months. Data obtained were subjected to ANOVA and Duncan's multiple range tests ($p<0.01$) to establish the statistical significance of the treatment at various dosages. A dose dependent increase in oxidative rancidity was observed. MRPs at 90mM/2h inhibited oxidative deterioration significantly ($p<0.01$) during irradiation and storage. A positive correlation ($r^2=0.98$) existed between peroxide value and other parameters. MRPs produced significant reduction ($p<0.01$) in the catalytic activity of non heme iron. 3kGy irradiation without MRPs significantly reduced ($p<0.01$) the unsaturated fatty acids. Incorporation of MRPs significantly reduced ($p<0.01$) the production of irradiated volatiles. Sensory evaluation of the product revealed an overall acceptability score of 7.9±0.2 on a 9-point hedonic scale for 3kGy product with MRPs after 6m of storage at 5±2°C. From the studies it could be concluded that early MRPs from glucose-lysine exhibited good antioxidant potential during irradiation and storage. 3kGy irradiation coupled with MRPs could extend the shelf life upto 6m at 5±2°C. It could be effectively employed in the development of RTE irradiated meat and meat products with good shelf stability.

Keywords: Maillard Reaction Products (MRPs), Irradiated meat, Lipid oxidation.

II. INTRODUCTION

Radiation processing of meat is a novel alternative to traditional preservation methods and is an emerging meat preservation technique**.** Microbial contamination of meat is a serious concern for both meat producers and consumers. Radiation processing has emerged as an alternate technology to eliminate microbial contamination [1]. Several countries have approved irradiation of meat and meat products [2]. Wide acceptability of radiation processed meat products will depend upon quality parameters such as oxidative changes, colour stability and organoleptic attributes. Irradiation is known to accelerate lipid peroxidation of meat and meat products [3, 4]. Products of lipid peroxidation adversely affect the colour, flavour, texture and nutritive value of meat. So it is necessary to control these changes in irradiated meat products for better development.

Ionizing radiation generates free radicals that may induce lipid peroxidation and other oxidative changes as well as influencing sensory quality of meat [5, 6]. The susceptibility of irradiated meat to oxidative rancidity is related to the nature, proportion, packaging, storage, and degree of unsaturation in fatty acids and the composition of phospholipids in cell membranes [4, 7]. As lipids oxidize, they form hydro peroxides, aldehydes, ketones and various other products that adversely affect flavour, taste, nutritional quality and overall acceptability.

Antioxidants are one of the principal ingredients that protect meat quality by preventing oxidative deterioration of lipids [8, 37]. Effect of natural antioxidants like chitosan [7], mint [9] and tocopherol

in combination with sesamol [10] were evaluated on lamb and pork meats during radiation processing and storage to establish the antioxidant potential and found to give positive effects in controlling the oxidation of lipids.

MRPs formed through a reaction of amino acids or peptides with reducing sugars are known to have antioxidative effects in food systems [11, 44, 38]. Some of the early MRPs are known to have antioxidative properties [39, 40].

Model studies carried out in methyl linoleate system on the antioxidative potential of early MRPs formed from glucose and lysine revealed strong antioxidant activity of the Amadori compounds [12]. Application of these MRPs in different species of meat [13] as well as in fluidised bed dried meat products [14] clearly established the inhibition of lipid peroxidation.

In view of this, studies have been undertaken to establish the effect of early MRPs in controlling/inhibiting the lipid peroxidation and other quality changes during irradiation and storage of meat products.

III. MATERIALS AND METHODS

A. Preparation of Maillard Reaction Products (MRPs)

MRPs were prepared by refluxing 90mM concentration of glucose in the presence of similar concentration of lysine in 100ml of water for 2h over a sand bath maintained at 100-110°C [12]. Losses in water content were periodically restored for maintaining the final volume.

B. Meat Product Preparation

Fresh mutton (goat meat) leg portion, 2-3h post mortem were purchased from the local market, washed thoroughly under running water, deboned, cut into small pieces (1cm x 1cm) and used for processing.

Various green spices, e.g. onion, garlic, ginger, green chillies and turmeric, pepper, cloves, cinnamon, cardamom and cumin, were obtained from the local market. Wet masala paste was prepared and fried in vegetable oil and divided into two equal parts. Deboned and cut mutton samples were divided into two equal parts and one portion was subjected for cooking along with MRPs and masala. The other portion cooked with masala only was treated as control sample. After cooking each sample was divided into 4 equal parts and irradiated in LDPE (Low Density Poly Ethylene) pouches at 3 different dosage levels in a Gamma Chamber 5000 with Co^{60} source.

C. Sample Code

0a – Non irradiated, 0b – Non-irradiated with MRP

1a – 1kGy irradiated, 1b – 1kGy with MRP
2a – 2kGy irradiated, 2b – 2kGy with MRP
3a – 3kGy irradiated, 3b – 3kGy with MRP

The samples were subjected for initial analysis, and stored at 5°C for a period of 6m to evaluate the physico-chemical characteristics. Peroxide value [15], Fat content [16]. TBARS [17], Total carbonyl expressed in terms of n-hexanal per 100g fat [18], the catalytic activity of non-heme iron [19] and Total volatile content [20] were determined as per the standard methods. Sensory characteristics of the product were evaluated initially and during storage for its quality attributes like colour, aroma, texture and overall acceptability on a 9 point hedonic scale by a panel of judges keeping 9 for excellent and 1 for very poor [21]. Total fatty acid analysis was carried out by Gas chromatographic method by esterifying the samples. [22].

D. Total Fatty Acid Analysis by Gas Chromatography

Analysis of total fatty acids was carried out by Ceres – 800, Chemito model Gas chromatograph fitted with BPX 70 column (25 m, 0.32mm ID) and flame ionisation detector. Temperature gradient programming was employed from 150 to 220^0 C. Split ratio was adjusted to 1:25 and capillary flow of carrier 2 ml/min. Injector and detector port temperatures were adjusted as 230 and 240 respectively. For FID, Hydrogen and oxygen were used and the flow was adjusted as 45 ml/min and 450 ml/min respectively. Along with samples standard esters of fatty acids were also injected and the fatty acids were detected by comparing the retention time of the standard esters of fatty acids. The quantification

of the fatty acids was carried out by evaluating with the standard fatty acid esters area corresponding to each peak in the chromatogram. Iris–32 software is used to integrate and evaluate the chromatogram in the analysis.

E. Statistical Analysis

Data obtained were subjected to analysis of variance (ANOVA) and Duncan's multiple range tests to evaluate the statistical significance of the treatments and significance was established at P<0.01.

IV. RESULTS AND DISCUSSION

A. Effect of irradiation dosage and MRPs on the oxidative deterioration of lipids

Evaluation of TBARS and Total Carbonyls

Variation in the parameters like TBARS and total carbonyls in the presence of MRPs at various irradiation dosages (1 to 3 kGy) was studied to monitor the lipid oxidative profile of meat products. The data generated by carrying out storage studies for 6 months has been depicted in Figs. 1 & 2 for TBARS and total carbonyls respectively. All the eight samples were subjected for TBARS and total carbonyls evaluation initially and during storage with an interval of 2 months. From the data it could be observed that lipid oxidation is increasing during irradiation and storage and it is dependent on the dosage level. The control samples in each group, i.e. 0a, 1a, 2a and 3a (0, 1, 2 and 3 kGy) without MRPs showed maximum oxidative deterioration during storage. After 6 months of storage the initial and 6 month reading was significantly different (p<0.01) for 0 kGy control and significantly different (p<0.01) for 1, 2 and 3 kGy control samples. The negative effect of irradiation on the lipid deterioration of meat by producing free radicals was reported [43, 23]. The MRPs treated samples (0b, 1b, 2b and 3b) exhibited good lipid stability during irradiation and storage as indicated by the TBARS and total carbonyls values depicted in Figs.1&2. The values of both parameters of all the four samples were not significantly different (p>0.01)

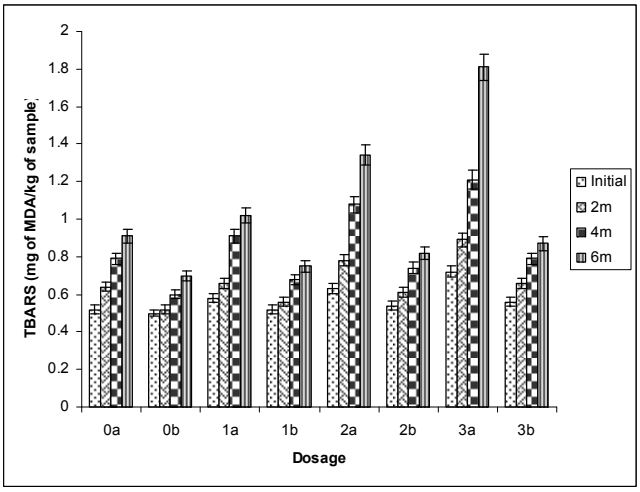

Fig.1.TBARS values of irradiated meat products with MRPs

Values are expressed as mean ± SD (n=5)

after 6 months of storage. This clearly indicates the ability of MRPs formed from glucose and lysine to inhibit the free radical mechanism and thus controlling the oxidation of lipids during irradiation and storage. MRPs were found to be effective at all the three irradiation dosages. The effectiveness of employing these MRPs in dehydration process and inhibiting the WOF development of meat species was earlier reported [13]. Studies were conducted on the antioxidative effect of MRPs and its effect on lipid oxidation and colour in meat products during frying and refrigerated storage [24]. Effectiveness of other Natural antioxidants like chitosan [7] and mint [9] were evaluated on lamb meat and reported as effective in controlling lipid oxidation during irradiation and storage. MRP treated samples even at 3 kGy dosage of irradiation and storage after 6 months the samples did not show any significant increase (p>0.01), indicating the strong antioxidative activity of MRPs in controlling the lipid oxidation even at higher dosage levels. All the MRP treated samples (0b, 1b, 2b and 3b) did vary significantly (p<0.01) initially and 2, 4 and 6 months of storage (p<0.01) in the values of TBARS and total carbonyls with respect to the 0a, 1a, 2a and 3a samples. A study on the ability of MRPs to contain free radicals and its possibility to interact with the peroxy radicals causing an inhibition of the lipid oxidation was reported [39, 25].

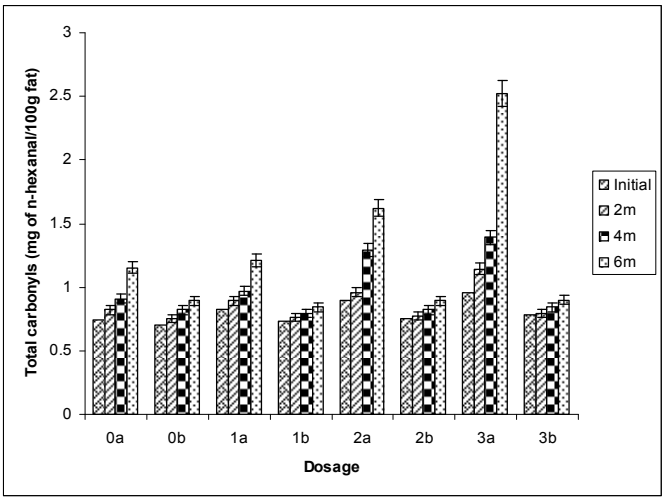

Fig.2. Total carbonyls in irradiated meat products with MRPs. Values are expressed as mean ± SD (n=5)

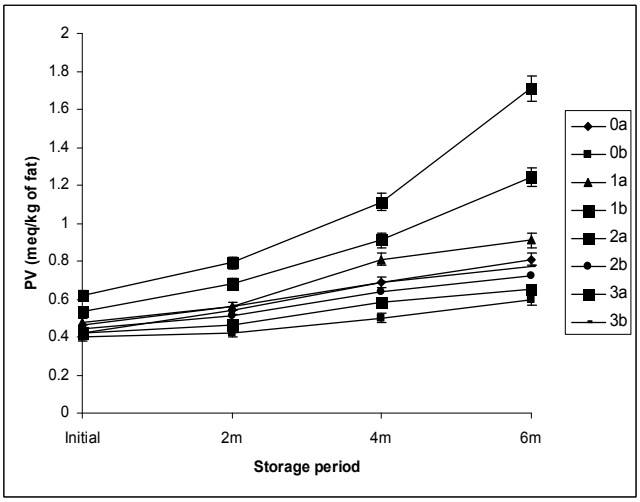

Fig.3.Peroxide values of irradiated meat products with MRPs Values are expressed as mean ± SD (n=5)

B. *Effect of irradiation and MRPs on the peroxide value of meat products*

Peroxide value, which is also a good indicator of lipid oxidation has been determined for all the treatments of different irradiation dosages of 0 1, 2 and 3 kGy and shown in Fig.3. All the eight samples were evaluated for peroxide value initially and during storage for 6 months at an interval of 2 months. It could be interpreted from the data that the peroxide value increases with irradiation dosage and storage period and was significantly different ($p<0.01$) for all the control samples (0a, 1a, 2a and 3a), after 6 months of storage. Between the initial and 2, 4 and 6 months data for the peroxide value for the control group of 0a, 1a, 2a and 3a exhibited significant difference ($p<0.01$). The formation of peroxides during irradiation was reported earlier [26, 27]. The usage of MRPs to inhibit the formation of peroxides during irradiation and storage yielded positive results as reflected from the data obtained and depicted in Fig.3. The values of peroxides for the MRP treated samples at all irradiation dosages, did not exhibit any significant difference ($p>0.01$) initially and during storage, indicating the ability of MRPs to arrest/inhibit the formation of peroxides, which are the main cause for the lipid oxidation and deterioration of quality of meat products [28]. Reports are there on the strong scavenging activity of MRPs against hydroxyl and superoxide anion [38].

MRPs treated with meat product were thus found to be effective in controlling lipid deterioration due to oxidative changes and thus able to enhance the shelf-life of the products. The results for the peroxide values were showing similar trend and correlating positively ($r^2 = 0.98$) with the data of TBARS and total carbonyls exhibited in Figs. 1 and 2 indicating the correlation of all these oxidative rancidity parameters for the results obtained in the irradiation experiments.

C. Effect of irradiation and MRPs on the catalytic activity of non heme iron in lipid oxidation

Transition metals such as iron, copper and cobalt may catalyze the initiation and enhance the propagation steps involved in lipid auto oxidation [41]. The ferrous iron released during cooking has been reported to accelerate lipid oxidation during storage [29]. So the release of non-heme iron in the presence of antioxidants like MRPs during irradiation at various dosage levels was estimated to understand the catalytic activity of non-heme iron in promoting the oxidation of lipids in irradiated meat product.

All the eight samples were subjected for non-heme iron estimation at various storage periods of 0, 2, 4 and 6m at different dosage levels of irradiation (0, 1, 2 and 3 kGy) and presented in the Fig.4. From the studies and data evaluation it could be ascertained that

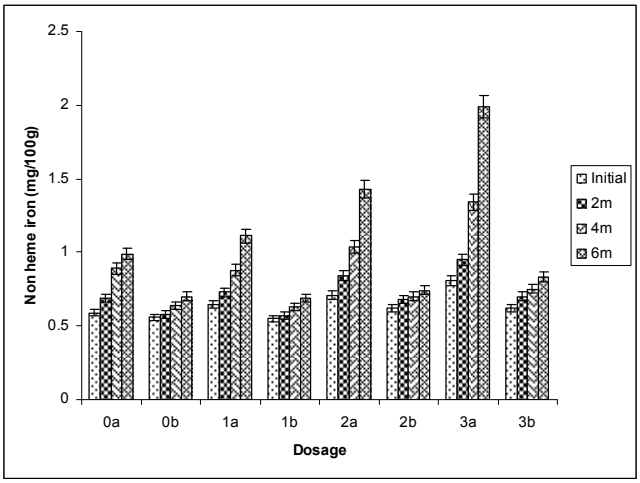

Fig.4. Changes in non- heme iron values of irradiated meat products with MRPs
Values are expressed as mean ± SD (n=5)

MRPs do have the ability to control the release of non-heme iron and thus inhibiting its catalytic activity to promote lipid oxidation. From the values it could be observed that, all the control group (0a, 1a, 2a and 3a), significant difference (p<0.01) in non-heme iron was observed initially and after 6m of storage. In samples 1a, 2a and 3a the values exhibited significant difference (p<0.01) between 2, 4 and 6 months stored samples. The release of non-heme iron was found to be dosage dependent, which could be seen from the values of 0a, 1a, 2a and 3a. As in the case of previous investigations of oxidative deterioration in terms of TBARS, total carbonyls and peroxide value, the antioxidant treatment of MRPs did have a significant impact in controlling the release of non-heme iron during irradiation and storage. Model MRPs were reported to produce metal chelating and antioxidant activity [30]. The MRP treated samples 0b, 1b, 2b and 3b did not exhibit any significant increase (p>0.01) with reference to irradiation dosage and also during storage of these irradiated products at 5±2°C. This clearly elucidates the ability of these MRPs in inhibiting the catalytic activity of non-heme iron in irradiated meat product and to enhance the shelf-life and overall acceptability by interfering in the lipid oxidation mechanism. Studies were conducted on the interaction between the Maillard reaction and lipid oxidation in model systems during high temperature treatment and reported to slow down the rate of lipid oxidation due to the presence of MRPs [31].

D. Gas chromatographic evaluation of the total fatty acid profile of the product with MRPs at various irradiation dosages

The individual fatty acids concentration of all the irradiated meat products were evaluated to study the effect of MRPs treatment and various irradiation dosage on the stability of various saturated, monounsaturated and polyunsaturated fatty acids during refrigerated storage of the samples at 5°C. The data pertaining to the study carried out by gas chromatographic analysis are reflected in Tables 1, 2, 3 and 4. From the tables it could be observed that the samples contains a mixture of fatty acids, both saturated and unsaturated. Unsaturated fatty acids constitutes both monounsaturated (MUFAs) and polyunsaturated (PUFAs). MUFAs are the dominant unsaturated fatty acid and they account for approximately 40%. Oxidation of lipids is one of the primary causes of deterioration in meat systems during cooking and storage, leading to development of off flavour, decrease in nutritive value, loss of colour and texture etc. [32]. The substrate for the lipid oxidation reaction is mainly unsaturated fatty acids [42]. So the degradation of unsaturated fatty acids present in meat samples with reference to different dosages of irradiation and in the presence of MRPs have been investigated by GC analysis during storage at refrigerated temperature. From the data it could be interpreted that out of the saturated fatty acids, Myristic and Lauric are present in very small quantities and palmitic and stearic contributes the major saturated fatty acids percentage. The major MUFA being the oleic acid ($C_{18:1}$) and palmitoleic acid also to a smaller extent contributes towards the MUFA percentage. Linoleic ($C_{18:2}$) and linolenic ($C_{18:3}$) are essential fatty acids, and it is further elongated and desaturated to longer chain derivatives like arachidonic acid ($C_{20:4}$) etc. Out of the polyunsaturated fatty acids, linoleic acid is present in around 12-13% and other PUFAs like linolenic and arachidonic in smaller percentages.

Table 1: Initial fatty acid composition of 0 & 1 kGy irradiated meat samples.

Fatty acid	Initial			
	0kGy		1kGy	
	a	b	a	b
Lauric ($C_{12:0}$)	0.83 ± 0.07[a]	0.90 ± 0.05[a]	0.89 ± 0.08[a]	0.92 ±0.09[a]
Myristic ($C_{14:0}$)	4.18 ± 0.11[a]	4.38 ±0.20[a]	4.59± 0.08[a]	4.25 ±0.08[a]
Palmitic ($C_{16:0}$)	17.99 ± 0.38[a]	18.23 ± 0.29[a]	18.18 ± 0.18[a]	17.98 ± 0.22[a]
Palmitoleic ($C_{16:1}$)	3.39 ± 0.13[a]	3.36 ±0.26[a]	2.93 ±0.11[a]	3.23 ±0.15[a]
Stearic ($C_{18:0}$)	16.89 ± 0.18[a]	16.62 ± 0.56[a]	16.48 ± 0.32[a]	16.70 ± 0.20[a]
Oleic ($C_{18:1}$)	34.59 ± 0.83[a]	34.33 ± 0.36[a]	33.82 ± 0.29[a]	34.29 ± 0.33[a]
Linoleic ($C_{18:2}$)	11.92 ± 0.23[a]	13.29 ± 0.19[a]	12.56 ± 0.36[a]	12.68 ± 0.33[a]
Linolenic ($C_{18:3}$)	3.32 ± 0.11[a]	3.50 ±0.12[a]	2.99 ±0.11[a]	3.19 ±0.12[a]

Values are mean ± S.D (n=3)
In the rows values with different letters vary significantly *(P<0.01)*
values with same letter did not vary significantly *(P>0.01).*

From the studies it was observed that saturated fatty acids did not vary significantly (p>0.01) throughout the storage period at all the three irradiation dosages of 1, 2 and 3 kGy. Even the samples without MRPs also did not exhibit any significant changes (p>0.01) indicating the good stability of these saturated fatty acids in meat samples during irradiation and storage. In the case of MUFAs and PUFAs upto 1 kGy all the samples a, b and c exhibited good stability and no significant difference (p >0.01) has been noticed in the fatty acid values. 2 kGy and 3 kGy irradiation of the samples without MRPs i.e., 2a and 3a in the case of MUFAs and PUFAs showed significant difference (p<0.01) immediately after irradiation indicating the effect of irradiation in deteriorating the unsaturated fatty acid and to promote oxidation of lipids. Literature pertaining to the enhancement of lipid peroxidation connected with irradiation process of meat was reported [4, 33]. The treatment of MRPs did have a clear positive effect in stabilizing the unsaturated fatty acids percentage during irradiation and storage. As reflected in the tables the values of MRPs treated samples did not show any significant difference (p>0.01) during irradiation and storage. All the unsaturated fatty acids both MUFAs and PUFAs exhibited good stability profile with MRPs during irradiation and storage. From the values obtained from the GC analysis of fatty acids, initially the fatty acids ratio was calculated and it was found to be 1:0.93:0.45 for 0 and 1 kGy samples (0a, 0b, 1a & 1b) and 2b and 3b samples. But the ratio was 1:0.82:0.39 and 1:0.77:0.35 in the case of samples 2a and 3a respectively. So from the comparison of the ratio it was clear that the samples 2a and 3a without MRPs at 2 kGy and 3 kGy irradiation did have an impact on the percentage of MUFAs and PUFAs. The corresponding ratios for 6 months stored samples were found to be

Table 2: Initial fatty acid composition of 2 & 3 kGy irradiated meat samples

Fatty acid	Initial			
	2kGy		3kGy	
	a	b	a	b
Lauric ($C_{12:0}$)	0.81 ± 0.06[a]	0.88 ± 0.08[a]	0.79 ± 0.09[a]	0.83 ±0.12[a]
Myristic ($C_{14:0}$)	4.18 ± 0.12[a]	4.41 ±0.14[a]	4.53± 0.12[a]	4.19 ±0.15[a]
Palmitic ($C_{16:0}$)	16.99 ± 0.22[a]	17.38 ± 0.18[a]	18.11 ± 0.52[a]	18.22 ± 0.62[a]
Palmitoleic ($C_{16:1}$)	2.71 ± 0.11[b]	3.23 ±0.16[a]	2.23 ±0.14[b]	3.23 ±0.01[a]
Stearic ($C_{18:0}$)	16.16 ± 0.28[a]	16.49 ± 0.28[a]	16.18 ± 0.23[a]	16.41 ± 0.23[a]
Oleic ($C_{18:1}$)	32.43 ± 0.29[b]	33.99 ± 0.18[a]	31.89 ± 0.38[b]	31.29 ± 0.33[a]
Linoleic ($C_{18:2}$)	11.49 ± 0.22[b]	12.89 ± 0.20[a]	10.09 ± 0.28[b]	12.83 ± 0.23[a]
Linolenic ($C_{18:3}$)	2.58 ± 0.14[b]	3.20 ±0.09[a]	2.26 ±0.13[b]	3.04 ±0.12[a]

Values are mean ± S.D (n=3).
In the rows values with different letters vary significantly *(P<0.01).*
Values with same letter did not vary significantly *(P>0.01).*

Table 3: Fatty acid composition of 0 & 1 kGy irradiated meat samples stored for 6months

Fatty acid	6m stored			
	0kGy		1kGy	
	a	b	a	b
Lauric ($C_{12:0}$)	0.79 ± 0.08[a]	0.88 ± 0.06[a]	0.75 ± 0.08[a]	0.80 ±0.09[a]
Myristic ($C_{14:0}$)	4.10 ± 0.13[a]	4.32 ±0.13[a]	4.10± 0.11[a]	4.32 ±0.09[a]
Palmitic ($C_{16:0}$)	17.58 ± 0.36[a]	17.99 ± 0.23[a]	17.62 ± 0.24[a]	18.31 ± 0.32[a]
Palmitoleic ($C_{16:1}$)	3.18 ± 0.11[a]	3.52 ±0.16[a]	2.89 ±0.09[a]	3.34 ±0.18[a]
Stearic ($C_{18:0}$)	16.48 ± 0.28[a]	16.62 ± 0.16[a]	16.19 ± 0.18[a]	16.53± 0.21[a]
Oleic ($C_{18:1}$)	33.08 ± 0.28[a]	34.15± 0.29[a]	32.21 ± 0.23[a]	34.22 ± 0.13[a]
Linoleic ($C_{18:2}$)	11.89 ± 0.38[a]	12.89 ± 0.16[a]	11.29 ± 0.16[a]	12.44 ± 0.22[a]
Linolenic ($C_{18:3}$)	2.90 ± 0.09[a]	3.22 ±0.12[a]	2.69 ±0.18[a]	3.22 ±0.14[a]

Values are mean ± S.D (n=3).
In the rows values with different letters vary significantly (p<0.01).
0 and 1 no significant difference (p>0.01)

Table 4: Fatty acid composition of 2 & 3 kGy irradiated meat samples stored for 6months

Fatty acid	6m stored			
	2kGy		3kGy	
	a	b	a	b
Lauric ($C_{12:0}$)	0.73 ± 0.08[a]	0.80 ± 0.08[a]	0.68 ± 0.05[a]	0.81 ±0.07[a]
Myristic ($C_{14:0}$)	3.92 ± 0.05[a]	4.23 ±0.07[a]	3.82± 0.08[a]	4.12 ±0.18[a]
Palmitic ($C_{16:0}$)	17.38 ± 0.14[a]	18.22 ± 0.16[a]	17.19 ± 0.22[a]	18.14 ± 0.24[a]
Palmitoleic ($C_{16:1}$)	2.26 ± 0.08[b]	3.33 ±0.07[a]	2.09 ±0.08[b]	3.26 ±0.08[a]
Stearic ($C_{18:0}$)	16.14 ± 0.17[a]	16.52 ± 0.29[a]	15.82 ± 0.42[a]	16.46± 0.42[a]
Oleic ($C_{18:1}$)	31.23 ± 0.29[b]	34.62± 0.51[a]	30.22 ± 0.31[b]	33.18 ± 0.29[a]
Linoleic ($C_{18:2}$)	10.01 ± 0.26[b]	12.58 ± 0.24[a]	9.04 ± 0.22[b]	12.34 ± 0.41[a]
Linolenic ($C_{18:3}$)	2.10 ± 0.09[b]	3.11 ±0.16[a]	1.99 ±0.23[b]	3.18 ±0.08[a]

Values are mean ± S.D (n=3).
In the rows values with different letters vary significantly (p<0.01).
Values are expressed as mean ± standard deviation (SD) (n=3)
Within the column values superscripted with different letters are significantly different (p<0.01)

1:0.90:0.42, for samples 0a, 0b, 1a, 1b, 2b and 3b, 1:0.71:0.33 for sample 2a and 1:0.65:0.26 for 3a. These results were in accordance with the earlier studies of lipid oxidation in terms of parameters like TBARS, total carbonyls, PV etc, where the ability of MRPs was clearly demonstrated to inhibit the oxidation of lipids. So the protecting effect of MRPs towards unsaturation and stabilizing unsaturated fatty acids is reflected in this study.

E. Effect of irradiation on the total volatile characteristics of mutton samples treated with MRPs

The effect of irradiation and treatment with MRPs on the total volatile profile of Mutton samples have been evaluated initially and storage after 6 months at 5°C and the data obtained is shown in the Table. 5. From the table it could be observed that irradiation process at 1, 2 and 3 kGy increases the total volatile content. The values for 1a, 2a and 3a where no treatment was given, was significantly different (p<0.01), from the initial values of non irradiated samples (0a, 0b and 0c) and also between the samples indicating the production of irradiated volatiles and its correlation with the irradiation dosage. During storage loss in volatiles was noticed both in irradiated and non irradiated samples. The treatment with MRPs significantly reduced (p<0.01), the total volatiles during irradiation as reflected from the values depicted in the Table-5.

Volatile compounds responsible for off-odour in irradiated meat are produced by the impact of radiation on protein and lipid molecules and are distinctly different from those characteristics of lipid oxidation. Recent findings in this area [34] support and extend this concept. These investigators studied odour volatiles in irradiated mutton and found that dimethyl trisulfide is the most potent off-odour compound. Studies were conducted on the impact of irradiation on the total volatiles of pork and reported the greater number of volatiles than the non irradiated pork [35]. Lipid oxidation coupled with radiolysis of proteins played an important role in the production of off-odour volatiles in irradiated meat [36]. MRPs at all dosages were able to control the production of off-odour volatiles during irradiation in meat samples.

Table 5. Effect of irradiation and MRPs on the total volatile (mg/kg) characteristics of irradiated meat products with MRPs

Dosage	Total Volatiles	
	0m	6m
0_a	108.62 ± 1.86^a	91.23 ± 1.20^b
0_b	110.43 ± 2.04^a	104.99 ± 1.31^a
1_a	131.53 ± 2.91^b	119.19 ± 1.85^c
1_b	117.28 ± 1.68^a	113.52 ± 1.81^c
2_a	154.62 ± 1.52^c	141.12 ± 1.85^d
2_b	121.08 ± 1.23^a	115.52 ± 2.09^c
3_a	179.64 ± 3.09^d	166.28 ± 1.98^f
3_b	124.61 ± 1.24^b	119.89 ± 1.26^c

Values with same letters are not significantly different ($p>0.01$)
2 and 3 kGy samples significant difference ($p>0.01$) with 0 and 1 kGy samples. ($p<0.01$)

F. SENSORY PROFILE OF IRRADIATED MEAT SAMPLES

Sensory evaluation of the product treated with MRPs and irradiated at 3 different dosage levels (1, 2 &3 kGy) were evaluated during storage for 6 months along with control samples for its flavour, taste, colour and other related aspects on a 9 point hedonic scale. The overall acceptability score of each sample during storage has been depicted in Table 6. From the table it could be visualized that initially all the samples had a good overall acceptability score. Non-irradiated samples (0a & 0b) were not subjected for sensory evaluation during storage. 1, 2 & 3kGy irradiated samples without MRPs exhibited a significant difference ($p<0.01$) after 2 months of storage. 1 & 2 kGy irradiated samples with MRPs showed a significant difference ($p<0.01$) after 4 months of storage but the samples irradiated at 3 kGy with MRPs produced a good organoleptic score after 6 months of storage indicating the protective effect of MRPs on the quality deterioration of meat products during irradiation and storage.

Table.6. Sensory profile of irradiated meat samples expressed as overall acceptability score[a, b] during storage at $5 \pm 2\ ^0$C conditions

	Storage period (months)			
Sample	0	2	4	6
0a	8.3 ± 02	-	-	-
0b	8.4 ± 0.3	-	-	-
1a	8.0 ± 0.2^a	7.8 ± 0.2^a	7.1 ± 0.1^b	-
1b	8.1 ± 0.3^a	7.8 ± 0.2^a	7.5 ± 0.2^a	6.6 ± 0.2^b
2a	7.8 ± 0.4^a	7.5 ± 0.3^a	6.9 ± 0.2^b	6.3 ± 0.3^b
2b	8.0 ± 0.3^a	7.7 ± 0.2^a	7.7 ± 0.1^a	7.0 ± 0.2^b
3a	7.6 ± 0.2^a	7.2 ± 0.1^a	6.2 ± 0.2^a	5.6 ± 0.2^b
3b	8.0 ± 0.2^a	8.0 ± 0.3^a	7.9 ± 0.2^a	7.9 ± 0.2^a

a- Values are mean ± SD (n=12)
b- Within the rows values superscripted with different letters are significantly different ($p<0.01$), Values with same letters are not significantly different ($p>0.01$).

V. CONCLUSION

Studies established a dose dependent increase in oxidative rancidity parameters. Incorporation of preformed MRPs from glucose + lysine significantly inhibited/retarded the oxidative deterioration during irradiation and storage. Chemical markers like TBARS, Total carbonyls, PV, Non heme iron, Total fatty acid profile and total volatiles gave a clear picture of the positive effect of MRPs in inhibiting the lipid oxidation during irradiation at different dosages and on storage. MRPs significantly reduced ($p<0.01$) the catalytic effect of non heme iron. 2 kGy and 3 kGy irradiation without MRPs produced deterioration in the PUFA's reflecting the effect of higher irradiation dosage on unsaturated fatty acids. MRPs treatment significantly reduced ($p<0.01$) the irradiated volatiles production. 3kGy irradiation coupled with MRPs exhibited good sensory score and good shelf life at 5°C for 6m. Early MRPs generated from glucose and lysine will have great potential in inhibiting the oxidative deterioration of meat and meat products during irradiation and storage. These findings will be of much help in developing RTE shelf stable meat products for services and civilian sector.

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