PRESERVATION OF MEAT CUTLET EMPLOYING GAMMA RADIATION UNDER DIFFERENT PACKAGING SYSTEMS

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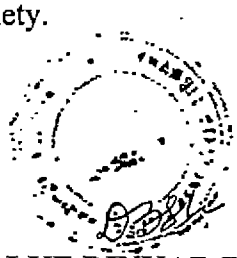
DECLARATION

I hereby declare that this thesis entitled **"PRESERVATION OF MEAT CUTLET EMPLOYING GAMMA RADIATION UNDER DIFFERENT PACKAGING SYSTEMS"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.



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CERTIFICATE

Certified that this thesis, entitled "**PRESERVATION OF MEAT CUTLET EMPLOYING GAMMA RADIATION UNDER DIFFERENT PACKAGING SYSTEMS**" is a record of research work done independently by **SALKE DINKAR BABANRAO,** under my guidance and supervision and it has not previously formed the basis for the award of any degree, diploma, associateship or fellowship to him.

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Dinkar

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INTRODUCTION

Meat and poultry industry play an important role in Indian economy with the livestock sector contributing around 6.8 per cent to Gross Domestic Product. The total meat production in our country from a registered sector is 5.7 million tones. India ranks eighth in world meat production of which about 51 per cent is buffalo and cattle meat, 12.3 per cent is sheep and goat meat, pig 8.5 per cent and poultry 25.6 per cent. (FAO, 2005)

Convenience and food safety are of paramount importance in meat industry. The commercial distribution of refrigerated unfrozen meat products requires shelf life for a couple of weeks rather than in days, which are assessed in terms of microbiological and organoleptic qualities. Any preservation technology has one or other disadvantages like low shelf life, early spoilage, flavour and textural changes and exorbitant energy charges or processing cost. Even modern minimal processing technique, such as modified atmosphere packaging and sous-vide cooking, each of which gives small changes in sensory quality, add to production cost and can carry microbiological hazards. Wholesomeness and quality of meat products can be maintained by multihurdle intervention strategies. Currently processors are employing a variety of intervention technologies but are still unable to eliminate contamination of final product by pathogens.

Cutlet is a cooked, spiced and molded ethnic Indian meat product. Contamination of ready-to-pack or fry cutlet occurs during processing, molding and or packaging. The primary objective of traditional and newly developed food preservation processes is the inhibition or inactivation of microorganism and to achieve shelf stability to food without affecting the organoleptic qualities.

In recent decades, food irradiation has become one of the most discussed technology for the food safety and extension of shelf life. Irradiation has become

popular since all other methods either add something to meat or remove some meat constituents, whereas irradiation method of preservation kills susceptible microorganism by direct effect on DNA or indirectly by ionization of water molecules. It is being widely used to increase storage life, reduce post harvest losses and to eliminate food poisoning microorganism.

The Prevention of Food Adulteration Act, 1954 made amendments in 1998 by extraordinary gazette and permitted, irradiation of meat and meat products including chicken employing gamma irradiation at a dose of 2.5 to 4.0 kGy for extending shelf life and to destroy pathogens. Wholesome meat production in India is far from satisfactory as a result of unhygienic practices and poor health of animals. For export potential there is a need to improve the quality and provide clean, wholesome and safe meat.

The purpose of packaging is to protect the meat product from microbial contamination, light, physical damage or chemical changes. Vacuum packaging has been more beneficial for irradiated long term storage of meat products as it minimises oxidative change and aerobic packaging may be useful for short term storage of irradiated meat products as irradiation off-odour can be reduced during the storage period. (Ahn *et al.*, 2000)

Irradiation can be combined with packaging systems to minimise sensory changes with extended keeping quality. On considering the potential and scope of application of gamma irradiation process in meat industry, the present study was undertaken:

- To asses the shelf life of gamma irradiated beef cutlets packaged under aerobic and vacuum packaging systems and stored at room temperature and chiller conditions.
- To asses the quality changes in beef cutlet due to different packaging and low dose gamma irradiation.

REVIEW OF LITERATURE

Cutlet is a cooked ready-to-fry or eat snack popular throughout India. It is prepared as vegetable or non-vegetable cutlet and it contains sufficient quantity of potato as binder, which is a highly perishable item. In order to prevent post preparation, packaging contamination and multiplication of microorganisms the final product has to be stored in deep freezer. Even this storage will not destroy bacteria and fungi. There is no other method available to destroy such microorganisms. Only gamma irradiation at a low dose destroys pathogens and spoilage organism without affecting the qualities. Irradiation in combination with packaging systems is more effective to maintain the quality of food items and it also plays an important role in safe guarding health of the public and reduces meat borne diseases.

2.1. RADIATION PRESERVATION OF FOOD

2.1.1. Food Safety

The FAO / IAEA / WHO / Joint Committee on irradiated foods at its meeting in Geneva in 1980 came to a conclusion that foods irradiated in the range of up to 10 kGy are toxicologically as well as microbiologically safe and nutritionally adequate and that no health hazard results from consuming such irradiated foods (WHO, 1981).

The use of ionizing radiation as a method of food preservation has been studied since 1940. The major applications of food irradiation include sterilisation, pasteurisation, disinfections, disinfestations, shelf life extension and product development (Nagai and Moy, 1985).

Dempster (1985) stated that low dose irradiation or radurisation eliminates most of the parasites in pork and very particularly, salmonella organisms in poultry and red meat. It will increase the shelf life of poultry meat, red meat and meat products significantly.

In a study conducted by Katusin–Razem *et al.* (1992) they stated that radiation induced chemical changes in irradiated foods are generally very small and usually difficult to observe in egg products. They also stated that irradiation at 2.5 kGy can be used for microbial decontamination in eggs and egg products which are more feasible than heat pasteurisation.

Irradiation is a safe, efficient, environmentally clean, not tainted with chemical residue and energy efficient process being particularly valuable as end product decontamination procedure (Frakas, 1998).

Food irradiation is one set of processing technology that increases microbial safety and enhance shelf life of food and in combination with other process enhance the safety of minimal processed foods, hence food irradiation if properly carried out is a safe process (Lee, 2004).

Smith and Pillai (2004) reported that irradiation of food is a beneficial technology to control pathogens, increase shelf life and maintain food quality. It can be used in food without posing any human health hazard.

Kuttinarayanan *et al.* (2006a) stated that the treatment of meat with ionizing radiation is an effective method to reduce or eliminate several food borne pathogens and larvae of parasites (Thayer, 1993). They also stated that lower doses of irradiation could reduce the growth of spoilage organisms, which helps in increasing the shelf life of meat.

2.1.2. Approval of Irradiation in Food

The meeting of the Joint Expert Committee (JEC), convened in 1976, recommended the unconditional acceptance of irradiated food items, including chicken. This paved the way for the development of Draft International General Standards on Irradiated Foods and a Draft International Code of Practice for the Operation of irradiation facilities used for the treatment of foods through the Codex Alimentarius Commission (WHO, 1977).

In 1990, Food and Drug Administration and in 1992, United States Department of Agriculture approved irradiation at the dose range of 1.5 to 3.0

kGy for destroying pathogenic bacterial organisms. The USDA approved the dose up to 4.5 kGy in 1999 (WHO, 1999).

In December 1997, FDA approved irradiation for red meat to control food borne pathogens and to extend shelf life. In February 1999, USDA allowed the proposal of irradiation of raw meat and meat products (Buzby and Morrison, 1999).

United States Department of Agriculture (USDA) approved medium dose irradiation (1.0 to 10.0 kGy) for decontamination of raw meat and poultry (Olson, 1998).

In India, the Ministry of Health and Family Welfare amended the Prevention of Food Adulteration Act, 1954 through a special Gazette notification dated August 9, 1994, permitting irradiation of onion, potato and spices. In 1998, meat and meat products including chicken were permitted for irradiation at dose of 2.5 to 4.0 kGy to extend shelf life and to control pathogens (PFA, 1998).

About 55 countries have approved and are using food irradiation technologies to ensure food safety and 29 countries have given clearance for irradiation of raw poultry and meat. Countries such as Belgium, China, France, Indonesia, the Netherlands, Thailand and United States have implemented irradiation of meat into commercial use (http://nucleaus.iaea.org., 2003).

2.2. SHELF LIFE STUDIES OF IRRADIATED MEAT PRODUCTS

2.2.1 Room Temperature

Bhagirathi *et al.* (1983) observed rapid proliferation of bacteria and onset of spoilage changes of mutton carcass by 6 to 8 h by exposing to natural atmospheric temperature.

Vijaya Rao *et al.* (1983) studied the bacterial load and spoilage changes in mutton stored at 25 ± 2°C at different intervals of storage. Total viable count at the onset was 5.0 log CFU per g, which increased to 8.0 log CFU per g after 24 to 36 h of storage. Developments of off odour were evident within 24 to 36 h with corresponding total viable count of 10^8 CFU per g of meat.

Narsimharao and Shreenivasmurthy (1986) recorded the total plate count of meat stored at 30°C on 0, 6, 12, 18, and 20 h of storage as 3.6, 4.2, 4.9, 6.2 and 7.2 log CFU per g respectively. Unacceptable odour was noticed at about 20 h of storage.

Shay *et al.* (1988) stated that doses of 2.5 kGy destroyed vegetative bacteria and were effective in reducing the population of pathogens and spoilage organisms. They opined that a dose of 45.0 kGy must be used to destroy *Clostridium botulinum* spores so that the meat could be stored at ambient temperature. They also noted that excluding oxygen and irradiating meat at low temperature could minimize irradiation odour and colour.

Lambert *et al.* (1990) in the study of effect of storage temperature, modified atmosphere and irradiation on toxicity and sensory evaluation of fresh pork inoculated with *Clostridium botulinum* showed that, at 25°C for sample with initial atmosphere 20, 10, 10 and 0 per cent oxygen, irradiation dose 0.5, 0, 1.0 and 0.5 kGy showed rejection time of 3, 2, 2 and 3 days, respectively. Sample stored at 15°C were not rejected until 7 day. They also observed that colour deteriorated more rapidly than odour.

The effect of irradiation (2.0 kGy) on the growth and toxin production of *Staphylococcus aureus* and *Bacillus cereus* in roast beef and gravy during storage at temperature (15 and 22°C) was assessed by Grant and Patterson (1992) and noted a 3.4 log reduction in number of these pathogens.

Zhao *et al.* (1996) showed that combination of irradiation and elevated carbon dioxide levels permanently eliminated salmonella and provided safety, whereas in unirradiated sample stored at 25°C the count has gone upto 6.5 log CFU per g within day one in aerobic and anaerobic packaging conditions.

Bhide (1999) observed evidence of spoilage of mutton and chevon by 12 hours at 25-30°C, whereas organic acid (1 % propionic acid, 2 % lactic acid and 2 % acetic acid) treatment delayed the spoilage by 18 h. When organic acid treated samples were irradiated at 1, 2 and 3 kGy the samples showed the shelf life of 18,

24 and 30 h respectively. The combination of treatment had lengthened the spoilage by 6 h at room temperature.

Pexara *et al.* (2002) showed an accelerated growth of lactic acid bacteria on cooked pork sausage at 10°C packed under modified atmosphere packaging with a greater discoloration at 10°C than 4°C.

2.2.2. Packaging and irradiation

Niemand *et al.* (1981) reported a doubling in the shelf life of vacuum packaged beef cuts irradiated at 2.0 kGy when compared to nonirradiated samples. The control had an acceptable shelf life of approximately three weeks, whereas the irradiated samples had a shelf life of more than eleven weeks when stored at 4°C.

Lee *et al.* (1983) reported vacuum packed veal chucks generally exhibited more surface discoloration and greening including exudates at 3 and 7°C than those packed in nitrogen over 70 days storage. However, there was increased incidence of off odours such as sour and slightly sulfide in either packaging treatment as storage period was extended or temperature increased.

Smith *et al.* (1983) reported that vacuum packaging was superior to modified atmosphere packaging for maintaining desirable appearance of wholesale loins; however neither appearance nor palatability of cooked lamb chops was dependent on packaging method during wholesale storage of loin at 0 to 28 days.

Dempster (1985) noticed that low dose irradiation destroyed microorganisms of public health significance and extended the shelf life of meat products.

Paul *et al.* (1990) reported that the lamb meat chunks irradiated at 1.0 kGy and 2.5 kGy remained in acceptable condition for 3 and 5 weeks respectively, whereas the shelf life of irradiated minced meat at 1.0 kGy and 2.5 kGy was 2 and 4 weeks respectively at 0 to 3°C storage. In contrast, unirradiated meat chunks and mince were spoiled within one week at the same storage condition.

Monk *et al.* (1995) studied use of vacuum packaging and irradiation of fresh ground beef at 1.5 and 2.5 kGy showing that vacuum packaging extend shelf life of more than 15 and 21 days, respectively compared to shelf life of only 4 days for nonirradiated.

Thayer (1993) showed that shelf life of poultry and beef can be significantly extended by ionizing radiation in combination with vacuum packaging or modified atmosphere packaging.

Lee *et al.* (1995) suggested that the application of gamma radiation up to a dose level of 10.0 kGy could eliminate a number of food spoilage microorganisms.

Patterson (1996) observed that packing pork chops in an atmosphere of 25 per cent carbon dioxide and 75 per cent nitrogen followed by irradiation at 1.75 kGy was effective in controlling microbial growth. Treated samples had a shelf life of 12 days at 4°C when compared to 3 days in nonirradiated samples.

Murano *et al.* (1998) studied the shelf life of irradiated ground patties irradiated at 2 kGy and packed using oxygen impermeable polyethylene or oxygen permeable polyolefin and reported that shelf life was extended 55 days at 4°C and a reduction of 3 log count was detected immediately after irradiation.

In a study conducted by Roberts and Weese (1998) observed extended chiller storage of 14, 21 and 42 days for ground beef patties when irradiated at 1.0, 3.0 and 5.0 kGy, respectively.

According to Lacroix *et al.* (2000) vacuum packaged fresh pork loins irradiated at a dose of 6.0 kGy, irrespective of packaging treatment and dose rate of radiation, all pork samples could be stored at 4 ± 1°C without bacterial spoilage for 43 days.

Johnson *et al.* (2004) recommended irradiation (1 to 3.0 kGy) to increase the shelf life of frankfurters. Irradiated frankfurters did not have a detrimental affect on consumer acceptance and sensory characteristics and were acceptable up to 32 days under refrigeration compared to 14 days in case of nonirradiated.

Irradiated spices, packaging material (10.0 kGy) and luncheon meat (2.0 kGy) kept in refrigerator (1-4°C) for 12 months showed that gamma irradiation decreased the microbial count of spices, packaging material and packed products and increased the shelf life. However, taste, odour, appearance and texture scores of irradiated product were significantly lower than nonirradiated samples (Al-Bachir, 2005).

Kanatt *et al.* (2005) found that 3 kGy was optimal for shelf life extension of some ethnic Indian meat products like chicken chilly, mutton shammi kababs and pork salami. The shelf life extended by more than 2 weeks at 0 to 3°C compared to corresponding nonirradiated samples.

Balamatsia *et al.* (2006) opined that the low dose irradiation (0.5 kGy and 1.0 kGy) in combination with aerobic packaging extended the shelf life of fresh chicken fillets by 4 to 5 days whereas irradiation at 2.0 kGy extended the shelf life by 15 days at 4°C.

Jenifer (2006) reported that irradiation process preserved the minced beef for 8 to 10 days, 22 to 25 days and 32 to 33 days at 1.0, 2.0 and 3.0 kGy, respectively.

2.3. PHYSICAL QUALITIES

Modified atmosphere packaging such as flushing of nitrogen and carbon dioxide at different proportion or vacuum packaging suppress the normal spoilage flora and thereby extend retail shelf life (Cann *et al.*, 1965; Eyles and Warth, 1981; Stier *et al.*, 1981; Fey and Regenstein, 1982)

Seideman *et al.* (1979) observed beef roast stored in modified atmospheres containing high level of oxygen exhibited a greater incidence of off odour, surface discoloration, lower overall appearance ratings, shorter retail case life and lower overall palatability rating than roast stored under vacuum or modified atmosphere containing 20 per cent carbon dioxide and 80 per cent nitrogen.

According to Narshimharao and Shreenivasmurthy (1986) unacceptable odour in fresh meat develop at 6 days of refrigerated storage (4 ± 1°C) when the

shelf life of meat was assessed by considering sensory parameter such as discolouration and odour.

Paul *et al.* (1990) observed freshly ground mutton irradiated at 2.5 kGy had a better colour, odour and microbiological acceptability than nonirradiated or irradiated mutton at 1.0 kGy. The meat chunks irradiated at 1.0 and 2.5 kGy remained in acceptable condition for 3 and 5 weeks, respectively whereas the shelf life of irradiated mince was 2 and 4 weeks. In contrast, unirradiated meat chunks and mince spoiled within one week of storage.

Grant and Patterson (1991) reported that microbiological population of irradiated pork was mainly composed of lactic acid bacteria, which produced 'sour' or 'dairy' odours.

Rosdriguez *et al.* (1993) suggested that low dose gamma irradiation (2.0 kGy) could be a reliable preservation method to obtain an organoleptically stable retail fresh beef products, by reducing naturally occurring spoilage microflora and enhancing the shelf life under refrigeration.

Zhao *et al.* (1996) reported that pork in air permeable packages the odour scores were high initially then decreased after 2 weeks of storage. The odour scores between irradiated and nonirradiated samples were not different after 2 weeks of storage.

Vacuum packaging was better than aerobic packaging for irradiation and subsequent storage of meat because it minimised oxidative change in patties and produced minimal amount of volatile compounds that might be responsible for off odour during storage (Ahn *et al.*, 2000).

Pexara *et al.* (2002) observed that increased TVC (8 log CFU per g) was due to lactic acid bacteria in vacuum and modified atmosphere packaging (80% CO_2 / 20% N_2) during two weeks of storage. The product appeared unacceptable due to higher drip loss and slime when lactic acid bacteria count reach 10^7CFU per g and sour odour developed at a count of 10^8 CFU per g at 4°C.

Badr (2004) reported that panelist preferred both irradiated and nonirradiated rabbit meat samples, as the samples were having high acceptance as judged by appearance and odour until rejection. Nonirradiated samples were rejected due to appearance of mould growth, slime formation and off odours by day 6 while irradiated sample showed off odour and mould growth by 12 to 21 days of storage.

The keeping quality of irradiated beef fry was studied by Kuttinarayanan *et al.* (2006b) and reported an enhanced shelf life of 28 to 32 days in irradiated samples, whereas control spoiled organoleptically by 7 to 9 days of storage in the chiller.

2.4. PHYSICOCHEMICAL QUALITIES

2.4.1. Proximate Composition

Sakala *et al.* (1987) reported that carbohydrates, lipid, proteins and amino acids were affected to a minimal degree as a result of low to medium dose of irradiation.

Heath *et al.* (1990) showed that there was no difference in moisture content of nonirradiated (65.0 %) and irradiated (64.0 %) chicken meat at 100, 200, 300 krads.

In study conducted by Katta *et al.* (1991) found that chicken carcass irradiated at various dose levels ranging from zero to 3.0 kGy using gamma radiation and stored in refrigerator conditions did not show any variation in their fatty acid profile.

Wheeler *et al.* (1999) conducted study on the proximate composition of ground beef patties and found that fat and moisture percentage were not affected by irradiation. They also observed no significant difference in the values of proximate composition between irradiated and nonirradiated patties up to 5 weeks in chiller storage.

Du *et al.* (2001a) studied the cooked patties prepared from chicken meat and packed in oxygen permeable or impermeable bags, irradiated at 0 or 3 kGy

and on analysis it was found that average moisture fat and pH were not affected by irradiation.

Daoud *et al.* (2002) studied effect of gamma irradaiation (0, 3, 5, 7 and 9 kGy) on the chemical and microbial qualities of chilled minced beef and noted that irradiation with different doses resulted in slight changes in chemical composition. Moisture content was decreased. Protein content decreased with the progress of storage, whereas fat and ash per cent increased with storage and irradiation doses. pH values of irradiated samples were lower than those of unirradiated samples.

Lee (2004) reviewed the trace components of food such as essential amino acid, essential fatty acids, minerals and elements are unaffected under practical irradiation conditions although some vitamins such as vitamin C and Vitamin B1 have partially lost.

Smith and Pillai (2004) reported that macronutrient (protein, lipid and carbohydrate) and mineral content were unaffected by irradiation.

Luncheon meat which was irradiated at 2 kGy and kept for 12 months in refrigerator storage (1-4°C) showed no significant difference in moisture, protein, fat, pH value, total acidity, lipid oxidation and volatile (Al-Bachir, 2005).

Rana Raj (2006) observed irradiation at different doses did not significantly affect proximate composition like moisture, ether extract, protein, crude fiber, ash, nitrogen free extract, gross energy, calcium and phosphorous content of intermediary moisture pet food.

2.4.2. pH

Niemand *et al.* (1981) reported that a dose of 2.0 kGy had little effect on the lactobacilli and the metabolites produced from these bacteria lowered the pH.

Irradiation did not influence the pH of fillet americain, but pH values of samples stored at 3°C increased slightly by 0.2 to 0.4 pH units (Tarkowski *et al.*, 1984)

Basker *et al.* (1986) found that pH of untreated chicken leg meat generally increased on storage at 4°C by perhaps 0.5 units in a month, probably as a result of microbiological activity. Irradiation at 2 and 3 kGy did not retard increase of pH, whereas 3.75 and 4.5 kGy did.

Lefebvre *et al.* (1994) opined that irradiation contributed to a diminution of pH in ground beef samples at 1.0, 2.5 and 5.0 kGy. Gram negative bacteria, which increase the pH by the production of ammonia and amines, were more sensitive to irradiation than that of gram positive bacteria.

Lee *et al.* (1996) did not observe any difference in pH upto 7 days of storage in irradiated (2.0 kGy) and nonirradiated beef samples, irrespective of storage temperature at 15°C and 30°C. However, after 14 days, pH of the irradiated samples stored at 30°C was lowest, because of growth of lactic acid bacteria after 7 days.

Karthikeyan *et al.* (2000) found out that there was no significant difference in the pH values between the control, acidulant and humectant treated chevon keemas, whereas storage at room temperature gradually increased the pH of treated keema and there was a decrease in the pH of untreated keema.

The pH values were not found to be significantly affected by the addition of sodium chloride either in the case of minced beef or pork, although the values were slightly lowered with the increase in sodium chloride concentration in both types of meats (Medynski *et al.*, 2000).

Porcella *et al.* (2001) reported that in vacuum packaged choriza (raw sausage), pH values decrease significantly ($P<0.05$) as storage time increased. The mean pH value of control sample fall from 6.20 to 5.88 and in soy protein isolate added sample from 6.22 to 5.96 with an increase in storage time from 0 to 20 day.

Nam *et al.* (2001) studied that irradiation had no effect on pH of vacuum packaged normal, PSE and DFD pork *longissimus dorsi* muscle at dose of 0 or 2.5 or 4.5 kGy. Original ultimate pH of all three pork types was maintained during 10 days of storage.

Pexara *et al.* (2002) noted a drop in pH during storage in cured, cooked and smoked turkey breast fillets at 4 and 10°C. The decrease in pH occurred more rapidly in samples stored at 10°C. They also showed decrease in pH of sausage was less than in fillets due to low fermentable carbohydrate in sausage than in fillets.

Sakala *et al.* (2002) observed that the pH of five pieces from five beef samples vacuum packaged and stored at 2°C was 5.62 ± 0.04 at the start of storage and 5.12 ± 0.07 after 6 weeks of storage.

Irradiation did not show any significant effect on the pH of vacuum packaged turkey breast meat samples at 1.5 kGy on day 0, but increased slightly after 10 days of storage at 4°C (Nam and Ahn, 2002a).

Irradiation of luncheon meat at 2 kGy has not revealed any significant difference in pH value of 1 to 4°C for 12 months (Al- Bachir, 2005).

Kudra *et al.* (2007) reported that pH value of irradiated meat products like beef patties, pork chops and frankfurters were similar in both vacuum and modified atmosphere packed items.

Vivek (2006) showed that pH was highest immediately after slaughter and the decline was drastic in zero to 6 h, followed by 6 to 12 h and 12 to 24 h. The control and irradiated meat samples from stressed cattle did not show any significant difference in the decline.

2.4.3. Thiobarbituric Acid Reacting Substances (TBARS)

Dempster *et al.* (1985) reported that doses of 1.03 and 1.54 kGy irradiation of vacuum packaged beef burger gave significantly higher peroxide value than for raw control.

In an experiment, Ahn *et al.* (1998) found that under oxygen permeable packaging conditions, the TBARS of patties from *longissmus dorsi* muscle of pork increased by 10 fold from day 0 to day 14 at 4°C. Even though irradiation cause accelerated lipid oxidation, oxygen exposure was an important factor than irradiation in catalyzing lipid oxidation of raw meat patties during storage.

According to Murano *et al.* (1998) ground beef patties irradiated (2 kGy) and stored under air and those irradiated under vacuum and stored under air, showed a higher degree of lipid oxidation (TBA value) compared with samples irradiated and stored under vacuum or nonirradiated.

Du *et al.* (2001a) reported that TBARS value of aerobic-packed cooked chicken meat patties after 5 days of storage were higher than that of day 0. Irradiation effect on TBARS of both vacuum and aerobic packaged cooked meat was not as significant and consistent as that of day 0, indicating that irradiation had only a minor impact on the oxidation of cooked meat lipid during storage.

Du *et al.* (2001b) reported that at day 0, the TBARS of aerobically packaged turkey and pork patties was significantly higher than those of vacuum packaged, but not for beef. Aerobic packaging significantly increased TBARS in cooked turkey, pork and beef patties after seven day storage, but vacuum packaging was very effective in preventing lipid oxidation irradiation had only a minor effect.

Nam and Ahn (2002b) reported that under vacuum condition, lipid oxidation of irradiated (1.5 kGy) raw turkey breast patties did not increase during 10 day storage, while lipid oxidation in nonirradiated increased during storage.

According to Quattara *et al.* (2002), the TBARS and free sulfydryl contents were stabilized during post irradiation storage for samples containing ascorbic acid coated with protein based film and immobilized spice powders in ground beef.

Du *et al.* (2003) conducted a study on quality characteristics of irradiated chicken breast roll and stated that after irradiation the total amount of volatiles in chicken rolls doubled compared with the initial values. Volatiles induced by irradiation include alkenes, aldehydes and sulphur compounds.

Houser *et al.* (2003) reported that irradiated cooked ham (4.5 kGy) had a significantly higher TBARS value of 0.13 mg of malonaldehyde / kg (mg mal / kg) than nonirradiated 0.094 mg mal / kg.

Aerobic packaging and irradiation both increased the lipid oxidation of turkey breast patties, but presence of oxygen was a more critical factor than irradiation on lipid oxidation during storage. The TBARS of meat was highest with aerobic packaging, lowest with vacuum packaging and in the middle with double packaging (Nam and Ahn, 2003).

Irradiated ready-to-eat ham had a higher TBARS values than nonirradiated at 0 day, but difference disappeared after 7 and 14 days of storage in 1 and 2 kGy irradiated respectively and TBARS change was non significant in vacuum packed sample (Zhu *et al.*, 2003).

Irradiation (2 kGy) and storage of turkey breast rolls (vacuum packaged shortly after cooking) increases the TBARS value from 0.104 to 0.175 mg mal / kg, while in nonirradiated it increased from 0.029 to 0.183 mg mal / kg at 0 to 28 days, respectively because of presence of residual oxygen or oxygen permitting packaging material during storage. However, due to vacuum packaging TBARS did not change significantly at day 0 or 14 days of refrigerated storage (Zhu *et al.*, 2004).

Ahn and Olson (1995) reported that changes of TBARS values in irradiated cooked pork sausage with different packaging conditions and storage time indicated that storage time had no effect on TBARS of vacuum packaged sausage but had significantly ($P<0.05$) higher values in aerobically packaged sausage.

Kanatt *et al.* (2005) showed that nonirradiated control samples showed lower TBARS than irradiated samples. Increase in TBARS were dose dependent in case of mutton shammi kabab and pork salami. However, in case of chicken chilly the increase in TBARS values of irradiated samples was not significant probably due to spices used in the preparation that are known to have antioxidant activity.

Irradiated restructured pork loins treated with rosemary and tocopherol packed by double packaging had a lower TBARS values than vacuum packaged

control after 10 days of refrigerated storage. The rosemary tocopherol combination, however, had no effect on production of sulfur volatiles responsible for the irradiation off odour, and colour changes in irradiated pork (Nam *et al.*, 2006).

2.4.4. Tyrosine Value (TV)

Jones *et al.* (1982) observed proteolysis measured in terms of tyrosine equivalent and total amino acid content, proceeded more rapidly in breast muscle from vacuum packs than from oxygen permeable packs, may be due to difference in proteolytic activity between two types of microflora.

The mean tyrosine values were higher in electrically stimulated mutton samples than their controls on chiller storage (Kuttinarayanan, 1988). The mutton carcasses obtained from old sheep over 7 years had the lowest mean values of 7.79 mg per 100 g of meat compared to that of 3 to 5 years age group with mean values of 12.43 mg per 100 g of meat when stimulated at 220 V.

In plate frozen meat cuts and minced meat, tyrosine values were slightly decreased during storage, since the proteolytic reaction due to bacteria or endogenous enzymes was ceased during frozen storage (Ziauddin *et al.*, 1993).

The irradiation of meat at 1 to 10 kGy could be useful in retaining quality since proteolysis by endogenous enzymes would be diminished (Lawrie, 1998).

A higher protein degradation was observed by Karthikeyan *et al.* (2000) in keema when stored at ambient temperature. The unusual higher tyrosine values noted in treated keema was due to proteolysis of added soy protein isolates and skim milk powder when compared to that of untreated keema.

Dushyanthan *et al.* (2001) observed that mutton packed in multilayered material under vacuum revealed lower mean tyrosine values of 20.54 mg and 21.35 mg per 100g of meat, respectively. Anaerobic environment and barrier property of multilayered material for oxygen led to lower proteolysis and hence the lowest tyrosine values.

There was no significant difference between aerobic (8.89 mg / 100g), vacuum (9.25 mg / 100g) and modified atmospheric (8.59 mg / 100g) packaging methods when the samples were stored at 4 ± 1°C (Jayanthi, 2003).

Kuttinarayanan *et al.* (2005) reported that proteolytic changes as estimated by tyrosine value have not shown any significant change between control and irradiated turkey breast samples initially. As the period enhanced from 0 to 25th day it was noticed a non significant increase with respect to tyrosine value during storage period as normal biochemical change as it is expected in refrigerated meats.

Balamatsia *et al.* (2006) found that volatiles amines, both trimethyl amine nitrogen (TMA-N) and total volatile basic nitrogen (TVB-N) values for aerobically packed nonirradiated chicken increased steeply, while aerobically packed irradiated sample showed lower TMA-N and TVB-N values ($P<0.005$) during refrigerated storage of 21 days at 4°C.

Jenifer (2006) reported that irradiation treatment of minced beef had no significant effect on tyrosine values compare to control samples at day 0. As storage days increased, tyrosine value increased with significant change among the treatments.

2.5. MICROBIOLOGICAL ANALYSIS

2.5.1 Aerobic Plate Count

Niemand *et al.* (1981) reported that aerobic bacteria were reduced by 99.99 per cent in irradiated vacuum packaged beef cuts at dose of 2 kGy. However, at 4°C storage there was a rapid increase in bacterial numbers in control and radurized samples for 5 weeks thereafter control samples maintain level of approximate log 8 bacteria / g whilst the number in radurized samples slowly increased until it reach unacceptable by 11 weeks.

Basker *et al.* (1986) showed that irradiation of raw whole chicken carcass by 2 to 4.5 kGy reduce the initial total aerobic mesophilic count by a factor of 10^3

to 10^4, during subsequent storage at 4°C for 30 days the total count gradually rose to the initial value of unirradiated samples.

Thayer (1993) reported that the irradiation dose required for inactivating 90 per cent of the CFU of common foods borne pathogens associated with meat and meat products were in the range of 1.0 to 4.0 kGy.

Naik *et al.* (1993) suggested a dose of 2.5 kGy would reduce the mesophilic count of buffalo meat samples immediately by 2 to 3 log cycles. After 3 weeks of storage at 0-3°C, the CFU of irradiated meat was equivalent to the initial CFU of control and had a shelf life of 4 weeks.

Mcateer *et al.* (1995) observed that low dose irradiation (2 and 3 kGy) reduced the number of microorganism in the meat to less than 100 per g and microbial growth did not occur during chill storage (2-3°C for 15 days) but changes in sensory characteristics limited the potential of irradiation to extend the shelf life and enhance the food safety of ready meal.

Patterson (1996) observed that irradiation followed by heat can have synergistic effect on the destruction of bacterial spores and vegetative cells in cook chill roast beef and gravy.

Zhao *et al.* (1996) studied packaging atmosphere had no apparent effect on total aerobic count in irradiated pork chops at 7 days, however air packed samples had a higher count than other treatment (vacuum or presence of carbon dioxide) at 14 days. Irradiation at dose of 1 kGy did not eliminate aerobic organism but reduced their numbers and subsequent growth during storage.

Gamage *et al.* (1997) found that microbial count on irradiated ground beef (2.2 to 2.4 kGy) stored at 4°C did not exceed 7.5 log CFU per g during 34 days of storage, while this level was attained in nonirradiated by day 13.

Alur *et al.* (1998) subjected the frozen processed pork meat products to gamma radiation at 2.5 kGy and observed 3 to 4 log reduction in mesophilic count.

Murano *et al.* (1998) observed that the microbial quality of irradiated ground beef patties were better than that of nonirradiated, with 2 to 3 log reduction in total viable count immediately after irradiation. Unirradiated patties reach a load of 10^7 cells / g after 8 days, whereas irradiated patties reached 10^7 cells / g after 55 days of storage at 4°C.

Giroux *et al.* (2001) found that irradiation at a level of 1.0 kGy after one day of storage produced a 1.78 log unit reduction of aerobic plate count in beef patties samples without ascorbic acid and 3.77 log reduction in samples containing ascorbic acid. Bacterial growth was below the detectable level when the samples were irradiated at 2.0 kGy.

Lewis *et al.* (2002) showed that irradiation dose of 1.0 and 1.8 kGy reduced the mean count of 4.6 log CFU per 200 ml of rinsate in boneless skinless chicken breast to 2.23 and 1.62 log CFU per 200 ml of rinsate, respectively.

In a refrigerated storage (0-3°C) of irradiated (3 kGy) ethnic Indian meat products nonirradiated chicken chilly had counts greater than 6 log CFU per g in less than 14 days, while in irradiated it did not reach the number even after 28 days of storage. Mutton shammi kababs control samples spoiled in less than a week, while irradiated samples spoiled after 28 days of storage. Nonirradiated pork salami had the count greater than 6 log CFU per g in less than seven days, while irradiated attained a similar count only after 18 days (Kanatt *et al.*, (2005).

Chouliara *et al.* (2006) noted the TVC of 6 log CFU per g in meat or fat trimmings used for greek dry salami was reduced by irradiation at a dose of 2 kGy (4.8 log CFU per g) and 4 kGy (3.9 CFU per g) with *Pseudomonas* showing highest sensitivity while yeast were most resistant followed by lactic acid bacteria. Both of these doses reduced population of *Enterobacteria*, *Enterococci* and pathogenic *Staphylococci* to 1, 2 and 2 log CFU per g, respectively while *Listeria* were undectable.

Kudra *et al.* (2007) reported that irradiation dose of 1.5 kGy eliminated 3 log CFU per g of inoculated 5 log CFU per g of *E. Coli* 0157: H7 on beef patties

and 2.5 kGy inactivated 3 log CFU per g of inoculated 5 log CFU per g of *Listeria monocytogens* on pork chops and frankfurters, packaged in either vacuum or modified atmosphere packaging. *E. Coli* 0157: H7 survived after irradiation but did not grow in beef patties during 6 weeks of refrigeration storage.

2.5.2. Psychrotrophic Count

Niemand *et al.* (1983) reported that radurization of minced beef at dose of 2.5 kGy completely eliminated *Pseudomonas* spp., and *Enterobacteriaceae* and could not be detected throughout the entire storage period.

According to Lee *et al.* (1983) there was no difference in the number of lactobacilli, psychrotrophs, aerobes and anaerobes between vacuum and nitrogen packed veal during 49 days of storage at 3 and 7°C. The initial psychrotrophs count consisted primarily of *Pseudomonas putida* (>72 per cent) but by day 49 *Lactobacillus* spp., compromised at least 64 per cent of the total count in both atmospheres. Psychotropic counts tend to be range between log 4.6 to 6.1 CFU per g of 70 days storage.

Irradiated (100 krad) vacuum packaged pork loins showed less psychrotrophic count of 0.7 to 1.9 log CFU per g than nonirradiated samples 0.7 to 3.6 CFU per g from 0 to 21 days of storage, as storage time increased difference become greater at 4°C storage (Mattison *et al.*, 1986).

A study on the influence of gas atmosphere packaging on the microbial growth and succession on steaks showed that atmosphere containing 10% CO_2, 5% O_2 and 85% N_2 was most effective in reducing psychrotrophic growth on steaks. *Pseudomonas* spp., were the dominated microflora for all packaging treatment combination during early storage, *Serratia liquefaciens* increased with storage time and *Enterobacter aerogenes* appeared at late storage period during 12 day of storage (Ahmad and Marchello, 1989).

Irradiation of fresh pork at 1.0 kGy reduced psychrotrophic and mesophilic bacterial populations by two log cycles and inactivated

Enterobacteriaceae, whereas lactic acid bacteria were largely unaffected regardless of packaging atmosphere (Lambert *et al.*, 1992).

Lacorix *et al.* (2000) reported that psychotropic microorganism was more resistant when irradiation treatment was done under aerobic than under vacuum packaging and started to increase after 10 days in pork loins.

Lewis *et al.* (2002) indicated that in boneless skinless chicken breast mean psychrotrophs count was 1.92 log CFU per 200 ml of rinsate in control and were not detected when the samples subjected to an irradiation at 1.0 or 1.8 kGy.

Gomes *et al.* (2003) reported that psychotropic bacterial counts were higher for nonirradiated samples in mechanically deboned chicken meat upto day 8 in refrigeration than irradiated samples. However, psychrotrophic bacterial count exceeded the recommended limit of 6.48 log CFU per g after 6 days in nonirradiated, while in irradiated (3.0 and 4.0 kGy) it was only after 12 days of storage.

Irradiation doses of 1.5 and 3.0 kGy reduced the counts of aerobic mesophilic bacteria, psychrophilic bacteria, yeast and mould and prolonged the shelf life of refrigerated rabbit meat samples from 12 to 21 days at chiller storage (Badr, 2004).

Chouliara *et al.* (2006) found that the count of *Pseudomonas*, *Enterococci* and pathogenic *Staphylococci* and *Enterobacteria* in meat and fat trimmings used for sausage production was reduced to less than 2 and 1 log CFU per g by irradiation at 2.0 and 4.0 kGy, respectively. Natural contamination of *Listeria* spp., was eliminated and *Pseudomonas* showed the highest sensitivity with reduction of more than 3.4 log CFU per g to either doses.

2.5.3. Yeast and Mould Count

Niemand *et al.* (1983) reported that vacuum packaging contributes to shelf life extension of ground beef and simultaneously it suppressed the fungal growth so vacuum packaging can be combined with irradiation to extend the shelf life of ground beef.

Monk *et al.* (1995) reported that yeast population on the chicken breast were reduced from 5×10^2 CFU per g to 3.2×10 CFU per g upon treatment with 2.5 kGy of irradiation. They also stated that *Sporobolmyces roseus* exhibited least resistance whereas *Trichosporon* and *Candida* show maximum resistance towards gamma irradiation.

Abu-Tarboush *et al.* (1997) showed that yeasts of genera *Candida*, *Saccharomyces* and *Alternaria* started to grow on day 12 in chicken treated with less than 5.0 kGy, but not in samples treated with more than 5 kGy and stored at 4°C for 21 days of storage.

Narvaiz *et al.* (1998) compared the effects of radiation on *Aspergillus parasiticus* and showed that heated or irradiated samples had a decreased level of aflatoxin as compared to untreated samples, and the combined treatment reduced the aflatoxin level below the detection limit of less than 30 ppb.

Doyle (1999) reported bacteria and parasites were more sensitive to irradiation dose of less than 1 kGy. However, enteric viruses, spores of *Clostridium* spp., *Bacillus* spp., moulds and microbial toxins from moulds, *Staphylococcus aureaus* and *Clostridium botulinum* were extremely resistant to irradiation and could not be effectively eliminated at approved dose of irradiation (10 kGy).

Nieto-Sandoval *et al.* (2000) observed moulds, yeasts and sulfite reducing *Clostridia* were the most resistant species, although irradiation at 10.0 kGy led to optimum sanitization of red paprika.

A study about gamma irradiation on aflatoxin B1 levels and fugal infection in peanut samples conducted by Prado *et al.* (2003) revealed that irradiation dose of 10 kGy completely inhibited the growth of moulds. They also suggested that decontamination of mould by irradiation, before production of aflatoxin B1 was the most acceptable method.

Balamatsia *et al.* (2006) studied the effect of low dose radiation on the microbiological characters of chicken meat stored aerobically at 4°C and they

found that *Pseudomonas* spp., *Enterobacteriaceae*, yeast and moulds were highly sensitive to gamma radiation and were completely eliminated at 2 kGy.

Chouliara *et al.* (2006) reported that yeast were most resistant followed by lactic acid bacteria and their reduction is dose dependent. Yeast did not show any major growth due to injury caused by irradiation (2 and 4 kGy) but survival without death. Hence, irradiation did not affect the yeast population during 28 days of ripening of fermented sausage.

Kuttinarayanan *et al.* (2006c) observed a 97 per cent reduction with respect to yeast and mould count in minced beef by irradiation at 2.0 kGy.

Kuttinarayanan (2007) reported 95 to 98 per cent reduction with respect to yeast and mould count in meat and meat products by irradiation at 2.0 kGy.

2.6. ORGANOLEPTIC QUALITIES

2.6.1. Colour

Kropf (1980) reported that colour is probably the single greatest appearance that determines whether the meat cut would be purchased.

Lefebvre *et al.* (1994) conducted the sensory evaluation of irradiated ground beef (1.0, 2.5 and 5.0 kGy) and found that odour and flavour of the irradiated cooked ground beef was slightly disliked while no difference was perceived in the colour and texture. The lower the dose of irradiation, the better the taste appreciated.

Sensory evaluation was conducted by Fu *et al.* (1995) in raw beef steaks and ground beef irradiated at 2.0 kGy and reported no significant difference in colour, but detected off odours that quickly dissipated after opening vacuum pouches.

Zhao *et al.* (1996) observed colour of irradiated pork was significantly less desirable than unirradiated samples throughout the storage. Colour of irradiated pork sample in aerobic packaging samples was less desirable immediately after

irradiation. Carbon dioxide packaging was less desirable after 2 weeks of storage whereas vacuum packaging retained the colour throughout 4 weeks of storage.

Alur *et al.* (1998) showed that radicidation dose of 2.5 kGy in pork meat products did not cause any adverse effect on texture, odour, flavour and pigments of products.

Murano *et al.* (1998) showed that irradiation did not affect colour of ground beef patties, with differences being due to packaging atmosphere. Samples stored under vacuum were darker and redder than aerobically packed samples.

Jo *et al.* (2000) concluded that extent of colour change by irradiation in vacuum packaged cooked pork sausage was lesser than that of raw pork. Irradiation significantly increased the redness of cooked vacuum packaged sausages regardless of storage time.

Zhu *et al.* (2003) reported that irradiation upto 2 kGy has limited effects on colour and oxidation of vacuum packaged commercial turkey ham.

Smith and Pillai (2004) reviewed that irradiation at a dose less than 3 kGy causes no difference in flavour, texture or colour of ground beef.

Arthur *et al.* (2005) noted that low dose irradiation of ground beef patties did not affect colour measurement of raw ground beef patties.

2.6.2. Flavour

Niemand *et al.* (1981) observed a higher ranking throughout storage period for both appearance and odour evaluation in radurized samples. On the day of irradiation, experienced person could detect a faint but typical irradiation odour in radurized samples although it was not found to be objectionable. Radurized samples had a low score in fourth week and higher score at eight week than control when evaluated for aroma and taste.

Irradiation produced a detectable odour in raw thigh after exposure to 100, 200 and 300 krads and in cooked thigh after exposure to 200 and 300 krads. No

odour was found in cooked thighs after irradiation at 100 krads and was dependent on fat content of sample (Heath *et al.*, 1990).

Hashim *et al.* (1995) reported that irradiating uncooked chicken meat produced a characteristic bloody and sweet aroma that remained even after cooking the meat.

Zhao *et al.* (1996) showed that odour of irradiated products was as less desirable than nonirradiated but score did not change during 4 weeks of storage. For nonirradiated pork in air permeable packages, odour score were high initially, then decreased after 2 weeks of storage. Score between irradiated and nonirradiated remained the same after two weeks of storage.

Ahn *et al.* (1998) suggested that irradiation produced many unidentified volatiles products that could be responsible for the off odour in irradiated raw meat.

Ahn and Jo (2000) found that sensory evaluation of pork patties the panelist could detect differences in irradiation odour in refrigerated samples at day 0, but could not separate among irradiation doses (1.5, 3.0, or 4.5 kGy) and patties stored for 1 or 2 weeks showed lower odor preferences than those of day 0.

Ahn *et al.* (2000) did not observe irradiation dose effect on odour preferences of pork patties with vacuum packaging but panelist preferred odour of aerobic-packaged nonirradiate samples to that of irradiated ones at day 0. Nonirradiated patties stored for 1or 2 weeks in vacuum and aerobic packaging showed lower odour preferences than those of the day 0.

Dietary conjugated linoleic acid treatment had no effect on the odour of irradiated cooked chicken meat but irradiation produced relatively small significant odour difference in cooked chicken meat patties (Du *et al.*, 2001a).

For short term storage, irradiation of turkey breast meat in which lipid oxidation is not a great problem, aerobic packaging would be more beneficial than vacuum packaging, because sulphur volatile compounds responsible for the

irradiation off odour could be reduced under aerobic conditions (Nam and Ahn, 2002a).

Zhu *et al.* (2003) reported that irradiation had a significant influence on odour and flavour of vacuum packaged turkey ham, but overall quality changes in irradiated turkey ham at 2.0 kGy were less.

Irradiation at 1.5 and 2.5 kGy resulted slightly difference in aroma, taste and aftertaste attributes of ground beef patties. Cooked aroma, cooked flavour and cardboard aroma increased slightly 0.2 to 0.4 units with increase in irradiation dose (Movileanu *et al.*, 2004).

Zhu *et al.* (2004) reported that sulfury odour and flavour of ready-to-eat turkey breast rolls under vacuum packaging conditions irradiated at 2.0 kGy were stronger than those of nonirradiated. But no difference was detected between irradiated (1.0 kGy) and nonirradiated samples. The intensity of metallic oxidation and sweet odour increased with irradiation dose but the increase was not significant.

Ahn and Lee (2005) observed that irradiation of ready-to-eat turkey breast rolls at 3 kGy showed irradiation odour in treated samples two times higher than those of nonirradiated samples and irradiation had no effect on colour and texture of ready-to-eat turkey breast rolls.

Arthur *et al.* (2005) reported there was no difference in flavour of irradiated (1 kGy) and nonirradiated ground beef patties samples when chilled carcasses were subjected to low dose irradiation.

Kanatt *et al.* (2005) reported that irradiation of Indian ethnic meat product like chilly chicken, mutton shammi kabab and pork salami either at 1, 2 or 3 kGy did not impart any detectable odour.

Nortje *et al.* (2005) reported that beef biltong irradiated at 2.0 and 4.0 kGy was liked more than nonirradiated samples, indicating non-oxidative irradiation induced flavour changes. They also opinioned that irradiation had flavour development in the bland moist biltong.

2.6.3. Juiciness

Berry *et al.* (1981) stated that hot boned roast from *semimembranosus* and *semitendinosus* muscles had higher shear force values, higher amount of connective tissue, lower tenderness and higher juiciness score than cold deboned cooked roast when served as cubes.

Smith *et al.* (1983) reported that after 7 days of storage cooked chops from loins that had been vacuum packaged were less juicy than cooked lamb chops from loins that had been packaged in either of the modified atmospheres (20% CO_2 80% N_2 or 40% CO_2 60% N_2). There was no difference in juiciness, flavour desirability or overall palatability among cooked chops that were related to the method of packaging.

Luchsinger *et al.* (1996) evaluated acceptance of fresh or frozen irradiated boneless pork chops (1.5, 2.5 and 3.85 kGy) using a trained panelist and consumers. They did not observe any differences in acceptance, meatiness, freshness or juiciness of products irradiated at 2.5 kGy or below.

Abu-Tarboush *et al.* (1997) reported that irradiation doses (2.5 to 10.0 kGy) had little effect on the sensory acceptability (appearance, odor, texture and taste) of both raw and cooked chicken. Moreover juiciness and tenderness of cooked chicken were only slightly affected by irradiation.

Ground beef patties irradiated under vacuum and tasted one day later demonstrated increased juiciness, while those irradiated under vacuum but stored under air showed increased tenderness. Samples evaluated after seven days of storage showed no difference in any sensory attributes (Murano *et al.*, 1998).

In an experiment by Ohene-Adjei *et al.* (2004) reported that irradiation neither affected juiciness of ground pork and the loin chops, nor the texture or mouth feel of the ground pork but decreased the tenderness of loin chops. An increased juiciness was noted in irradiated ground pork when supplemented with vitamin E.

Johnson *et al.* (2004) showed that overall acceptance, juiciness and tenderness of nonirradiated diced chicken and frankfurters were significantly lower than irradiated (1, 2, and 3 kGy) at day 18 and day 32, respectively at 4°C.

2.6.4. Tenderness

Collagen shrinks when irradiated wet (Perron and Wright, 1950) and caused softness and tenderness of texture as an immediate effect (Coleby *et al.*, 1961).

Perception of tenderness has been described in terms of following conditions of meat during mastication such as softness to tongue and cheek, persistence to tooth pressure, ease of fragmentation, meatiness, adhesion and residue after chewing (Forrrest *et al.*, 1975).

The effect of irradiation on refrigerated and frozen chicken on sensory properties was investigated on skinless boneless breast (white) and leg (dark). It was found that cooked irradiated frozen dark meat had more chicken flavour and cooked irradiated refrigerated dark meat was tender than control (Hashim *et al.*, 1995).

Murano *et al.* (1998) investigated the changes in flavour, texture and juiciness of ground beef patties after either 2 or 7 days storage at 25°C prior to cooking. It was noted that, irradiated air or vacuum packed samples were more tender, irradiated vacuum packed samples were more moist and irradiated air samples had least after taste.

Ohene-Adjei *et al.* (2004) reported that irradiation (1.5 kGy) of loin chops decreases the tenderness, which might be due to weakened texture of meat system due to irradiation that caused loss of moisture through drip or purge loss.

Arthur *et al.* (2005) reported that low dose irradiation (1 kGy) of ground beef patties the tenderness and juiciness were not dose related and ratings decreased with increased frozen storage.

2.6.5. Overall acceptability

When beef was irradiated by 1.0 kGy prior to the addition of mayonnaise sauce showed no significant taste difference when compared to nonirradiated samples (Tarowski *et al.*, 1984).

Dempster *et al.* (1985) showed no sensory differences between irradiated and nonirradiated raw beef burgers up to 11 days after irradiation (1.5 kGy) under vacuum.

Naik *et al.* (1994) showed that after 2 weeks of storage the control samples had an acceptability score of less than 5 with off odour and signs of spoilage in buffalo meat. In contrast, irradiated meat (2.5 kGy) showed high sensory scores of above 7.5 and had an overall acceptability score higher at 6.5 even at the end of five weeks.

Hashim *et al.* (1995) studied the consumer acceptance of irradiated poultry cooked products based on colour, appearance, flavour, mouth feel and overall acceptability using a nine point hedonic scale, 73 per cent participants gave the product a minimum rating of 7.0. Consumers were willing to purchase irradiated products if provided more information of such products.

Sawant (1998) observed the spoilage changes of unirradiated and irradiated beef burger and beef kabab samples in the form of souring, stickiness and disintegration. Colour and appearance were good but decrease in odour, texture and overall acceptability were noticed in irradiated and nonirradiated kababs on storage.

The results of study by Wheeler *et al.* (1999) indicated that hamburgers made from ground beef patties irradiated under usual conditions would encounter little consumer acceptance problems at the 3.0 kGy dose and only slightly greater problems at 4.5 kGy dose.

Badr *et al.* (2004) reported that samples of fried burgers prepared from both irradiated and nonirradiated fresh rabbit meat had similar high score for odour, taste, texture and juiciness. This indicated that irradiation of rabbit meat at

1.5 and 3.5 kGy doses did not significantly affect the sensory quality of cooked meat.

Johnson *et al.* (2004) reported that overall acceptance of flavour, juiciness, tenderness and mouthfeel of nonirradiated diced chicken and frankfurter were significantly lower than irradiated (1, 2 and 3 kGy) at day 18 and 32, respectively. Although quality of the irradiated samples decreased with increasing storage time.

Kanatt *et al.* (2005) reported that overall sensory scores for appearance, flavour and texture of irradiated samples (1, 2 and 3 kGy) of three meat products (chicken chilly, mutton shammi kababs and pork salami) were different from its nonirradiated controls and were acceptable immediately after irradiation.

Consumer acceptance study of irradiated cutlet, beef and minced beef by Kuttinarayanan (2005) revealed that 20 to 22 per cent consumer responded, 72.5 per cent like to purchase irradiated cutlet and 37 per cent were ready to pay more to irradiated product since it can be kept at chiller conditions. Majority of them did not observe any peculiar smell or taste difference in the products due to irradiation.

Materials and Methods

MATERIALS AND METHODS

A study on the effect of low dose gamma irradiation on the keeping quality of beef cutlet under different packaging systems was conducted from October 2006 to March 2007 in the Department of Livestock Products Technology, Mannuthy.

Six batches of samples were prepared, packaged, irradiated at 2.5 kGy and stored at room temperature (25-30°C) and chiller conditions (3-4°C). Samples were analysed for physical, physicochemical, microbiological and organoleptic qualities on day of preparation and on day 5, 10, 15, 20, 30, 45, 60 and 70 of chiller storage or untill spoilage, whichever was earlier. The samples were analysed for proximate composition on the day of preparation.

3.1. PREPARATION OF BEEF CUTLET

Frozen beef was cut into steaks of size 15×6×4 cm (Sirman Band Saw, Italy). After refrigerated thawing the steaks were pressure cooked at 115°C to an internal temperature of 80°C and the steaks were minced in a meat mincer (Mado Junior, Germany) by passing through a 9 mm plate.

Clean potatoes were cooked in hot water, peeled and mashed uniformly taking hygienic precautions.

Chopped onion was sautéed in tallow till it was golden brown. The paste of finely chopped ginger, green chilies and curry leaves along with clean ground spices and salt were added to onion and sautéed for some more time. They were finally mixed thoroughly with meat and potato. The mix was formed into oval shape cutlets using a mold of size 65 × 45 × 10 mm. The formed cutlets were dipped in whipped egg and breaded with bread crumbs. Approximate weight of each beef cutlet was 25 ± 1 g.

3.2 PACKAGING

3.2.1. Aerobic Packaging

Five cutlets each were aerobically packaged in oxygen permeable high-density polyethylene pouches (HDPE, 200 μ) and sealed by pulsed sealing machine (Sevana, Kochi).

3.2.2. Vacuum Packaging

Similarly, five cutlets were vacuum packaged (740 mm of Hg) in oxygen impermeable polyamide-polyethylene pouches (PA-PE, 80 μ, OTR: < 52 cc / m^2 / 24 h, CO_2 TR: 208 cc / m^2 24 h, WTR: 5g / cc / m^2 / 24 h at 38°C, 90 % RH) using a single chamber vacuum packaging machine (Sevana, Kochi).

Table 1. Ingredients of beef cutlet

Ingredients	Quantity (g)
Beef	1000.0
Potato	580.0
Tallow	140.0
Onion	182.0
Ginger	20.0
Green Chilly	25.0
Curry Leaves	3.5
Pepper	15.0
Anise	8.0
Cinnamon	4.0
Clove	2.5
Salt	20.0
Bread Crumbs	166.0
Egg (numbers)	3.0

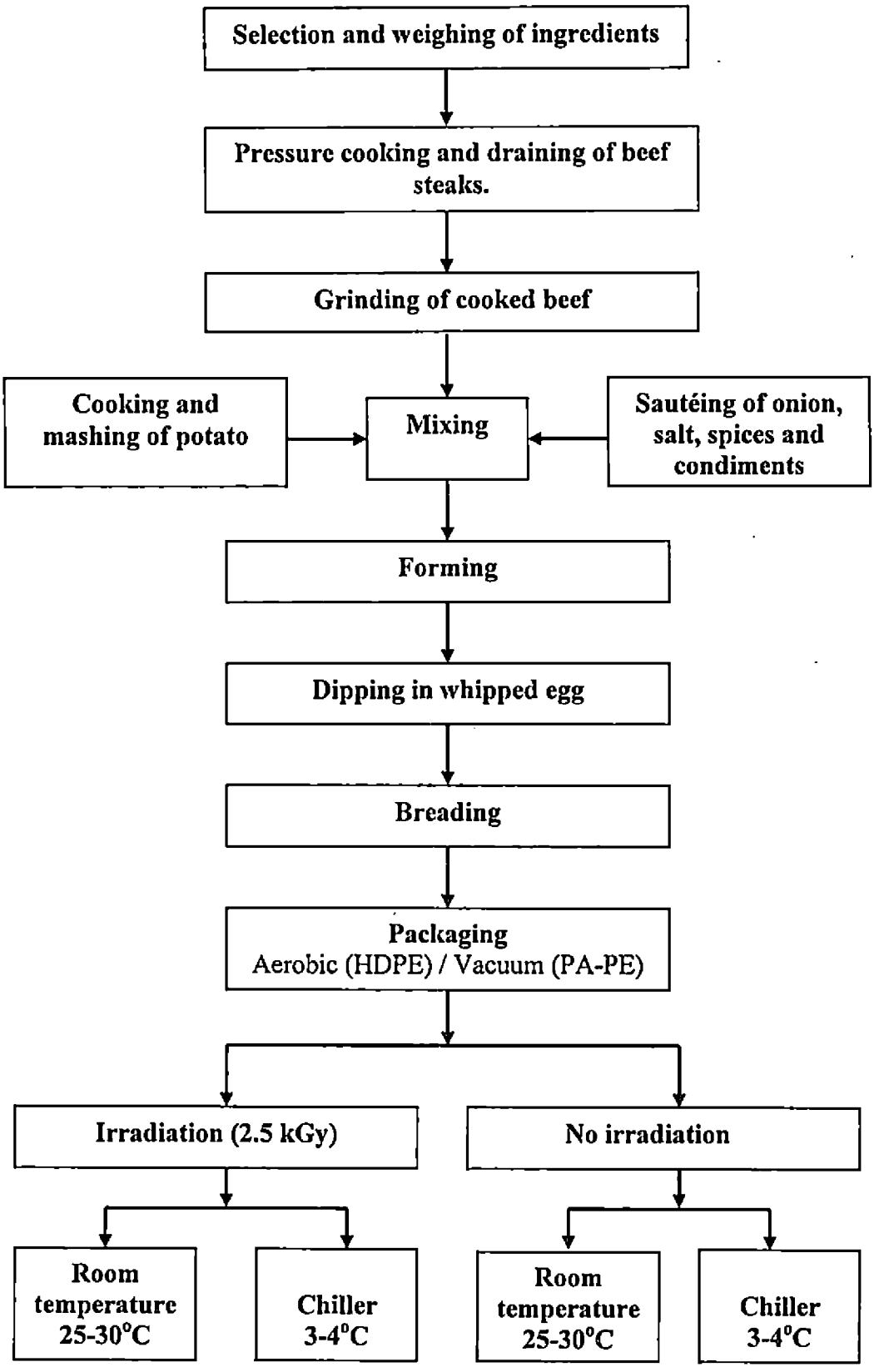

Figure 1. Flow chart for beef cutlet preparation

3.3. GAMMA IRRADIATION

The aerobically and vacuum packaged samples were maintained at a temperature of 2°C before irradiation so that there is no temperature fluctuations of 4°C between irradiation and storage. Samples were irradiated (IR) at a dose level 2.5 kGy and dose rate of 0.13 kGy / min at ambient temperature in a Gamma Chamber 5000, (BRIT-DAE, Mumbai) with ^{60}Co as source of radiation. The aerobically packaged irradiated beef cutlets were designated as IRAP that nonirradiated were designated as NRAP. Vacuum packaged irradiated beef cutlet were designated as IRVP and nonirradiated samples as NRVP.

Sufficient numbers of packets were kept at room temperature (25-30°C) and assessed physically for colour and odour as the signs of spoilage. Samples stored in chiller at 3-4°C were periodically analysed on day 0, 5, 10, 15, 20, 30, 45, 60 and 70 or untill spoilage for the following parameters.

3.4. PHYSICAL PARAMETERS

Beef cutlet packets stored at room temperature were opened at 0, 8, 16, 24, 32, 40 and 48 hours of preparation and examined for signs of spoilage like change in colour, odour, consistency, slime formation and mould growth. The cutlet kept at the chiller storage were examined on day 5, 10, 15, 20, 30, 45, 60 and 70 of preparation and recorded as spoiled or non spoiled with the help of same physical parameters.

3.5. PHYSICOCHEMICAL PARAMETERS

3.5.1. Proximate Analysis

The beef cutlets were analysed for their proximate and mineral compositions viz., moisture, fat, protein, ash, calcium and phosphorous content on day of preparation. The composition was expressed as percentage of the beef cutlet.

3.5.1.1. Moisture

The moisture content of the beef cutlet was analysed as per (AOAC, 1990). A 30 g sample in an evaporating dish was kept in a hot air oven at 100°C to 102°C for 16 to 18 h. The weight of the dry samples was taken after cooling in a desiccator. The difference in the weight is the moisture content of the sample and expressed as percentage.

3.5.1.2. Fat

Fat was estimated as per AOAC (1990). Fat content of three gram of moisture free sample was extracted in Hexane using Socs Plus Solvent Extraction System (Pelican Equipments, India). Ether extract obtained is dried to a constant weight at 100°C, cooled and weighed. The difference in weight is the total fat content of sample and expressed as percentage of the beef cutlet.

3.5.1.3. Protein

The Copper Catalyst Kjeldal method was used to determine the protein content of the samples (AOAC, 1990). The analysis was conducted in Kel Plus Nitrogen Estimation System (Pelican Equipments, India). The total nitrogen estimated was converted to percentage of protein by multiplying with the constant.

Protein % = 6.25 X % Nitrogen.

3.5.1.4. Ash

Ash is the total mineral content of a sample. Five gram of the moisture free-fat free sample was placed in a silica crucible and kept in a muffle furnace at 600°C for 2.5 hours. Then the sample was transferred to a desiccator, allowed to cool and weighed immediately. The resultant weight is the total mineral content of the sample and ash content was converted to wet matter basis (AOAC, 1990).

3.5.1.5. Calcium content

Total calcium content was estimated as per AOAC (1990) using Atomic Absorption Spectrophotometer (PERKIN ELMER 3110, US instrument division, Norwalk, USA). The reading obtained was converted to gram percentage using the formula given below.

$$\text{Calcium \%} = \frac{\text{AAS reading X dilution of the sample}}{\text{Weight of the sample X 10000}}$$

3.5.1.6. Phosphorus content

The phosphorus content was estimated as per AOAC (1990) using spectrophotometer in Spectronic 1001 Plus (Miton Roy Company, USA). The phosphorus content was calculated from the optical density (OD) values at 490 nm using the formula given below. (AOAC, 1990)

$$\text{Phosphorus \%} = \frac{\text{OD of the sample X concentration of standard X dilution factor X 100}}{\text{OD of the standard X weight of the sample X 1000}}$$

3.5.2. pH

The pH of irradiated and nonirradiated, aerobically and vaccum packaged samples stored at room temperature and chiller conditions was recorded by using a digital pH meter (μ pH system-Systronics, India) as described by O'Halloran *et al.* (1997). About 50 g of cutlet was taken in a glass beaker and the electrode was inserted into the sample without entrapping any air space around the bulb of the electrode. The pH was recorded and the probe was thoroughly rinsed with deionised distilled water before each measurement. The pH meter was standardized using pH 4 and pH 7 buffer solutions at weekly intervals.

3.5.3. Thiobarbituric Acid Reacting Substances (TBARS)

The TBARS were determined as per Witte *et al.* (1970) with modifications. 20 g sample was blended with 50 ml chilled extracting solution containing 20 per cent trichloroacetic acid in 2 M ortho-phosphoric acid for 1.5 to

2 min. The resultant solution was transferred to a 100 ml volumetric flask. Then the sample was made up to 100 ml using deionised distilled water. This solution was filtered through Whatman No.1 filter paper. Five ml filtrate was transferred to a screw capped vial followed by the equal quantity of 2-thiobarbituric acid solution (Merck, Germany) (0.005M in distilled water). The solution was mixed by inverting the vial and kept for 15 h in darkness at room temperature. The absorbance was determined at 530 nm against blank containing 5 ml distilled water and 5 ml 2-thiobarbituric acid solution (0.005M in distilled water) in UV Vis Spectrophotometer 119 (Systronics, India). The absorbance was converted to TBARS values and was expressed as mg of malonaldehyde per kg (mg mal / kg) of beef cutlet.

3.5.4. Tyrosine Value (TV)

The tyrosine values of cutlet samples were estimated as per the method described by Strange *et al.* (1977) with modifications.

3.5.4.1. Preparation of trichloroacetic acid extract (TCA)

Twenty grams of sample was blended in 50 ml of cold 20 per cent tricholoroacetic acid for 2 min. The blended contents were rinsed with 50 ml of distilled water, mixed together and filtered through the Whatman No.1 filter paper and the filtrate was collected. The filtrate, termed TCA extract was used in the estimation of tyrosine value.

3.5.4.2. Estimation of tyrosine value

To 2.5 ml of TCA extract, equal quantity of distilled water was added in a test tube. To this 10 ml of 0.5 N NaOH was added followed by 3 ml of diluted Folin and Ciocalteu's phenol (FC) reagent (1 ml of concentrated FC reagent and 2 ml of distilled water). After mixing, the contents were allowed to stand for 15 min at room temperature. The developed colour was measured as absorbance at 660 nm in UV-Vis Spectrophotometer 119 (Systronics, India) using a blank for comparison. With reference to a standard graph (Fig. 1.) the TV was calculated and expressed as mg per cent of beef cutlet.

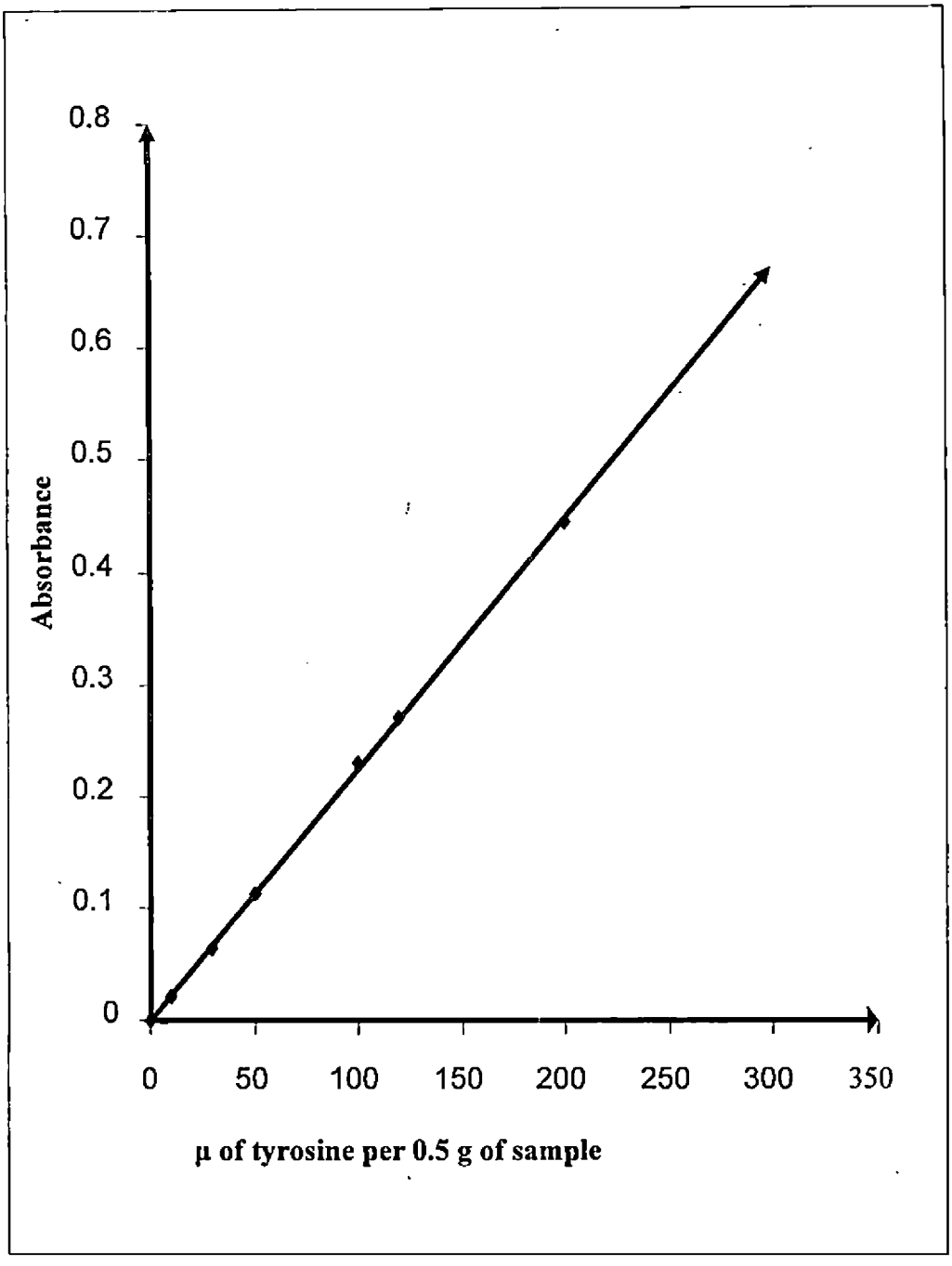

Fig. 1 Standard graph for Tyrosine value

3.5.4.3. Standard graph for tyrosine value

100 mg of L-tyrosine was dissolved in 500 ml of 5 per cent TCA in a volumetric flask. The following volumes of the above solution were then transferred to a series of 100 ml volumetric flasks: 0, 1, 3, 5, 7, 10, 12 and 15 ml and were made up to the mark with distilled water and mixed thoroughly. To 5 ml of each of the resultant solutions, 10 ml of 0.5 NaOH and 3 ml of diluted FC reagent were added and then treated as described for tyrosine value. The standard graph was prepared with the known concentration of L-tyrosine in the solutions and their corresponding absorbance values (Fig. 1).

3.6. MICROBIOLOGICAL ANALYSIS

3.6.1. Processing of Samples

Aerobic plate count, psychrotrophic count and yeast and mould count in the beef cutlet samples were evaluated as follows:

The sealed pouches were opened taking all aseptic precautions. 25 g of sample was weighed and transferred to the stomacher bag containing 225 ml of 0.1 per cent peptone water and blended in the stomacher (Seward Stomacher® 400 circulator) for 30 sec so that it forms 10^{-1} dilution. Further serial dilutions were prepared and selected dilutions were used for assessing various microbial counts.

3.6.2. Aerobic Plate Count

Aerobic plate count (APC)) of each sample was estimated by pour plate technique, as described by Mortan (2001). From the selected dilution of each sample, 1 ml of inoculum was transferred in labeled duplicate petri dishes. To each of these inoculated plates, about 15-20 ml sterile molten Standard Plate Count Agar (HiMedia, Mumbai) maintained at 45°C was poured and mixed with the inoculum by gentle rotatory, forward and backward movements. The inoculated plates were allowed to solidify at room temperature and incubated at 37°C for 24 h in inverted position. At the end of the incubation period, petri dishes with a bacterial count between 20 and 200 colonies were selected and the

colony counts were taken with the help of a digital colony counter (Royal, India). The number of colony forming units (CFU) per gram of the sample was calculated by taking the average of duplicate plates and multiplied by the dilution factor and converted to $\log_{10}$ CFU / g of sample.

3.6.3. Psychrotrophic Count

Psychrotrophic count was assessed as per Cousin *et al.* (2001). Inoculated agar plates by pour plate method prepared as in the case of aerobic plate count was incubated at 4 ± 1°C for 10 days in BOD incubator (Rotec, India). At the end of the incubation period, petri dishes with a bacterial count between 20 and 200 colonies were selected and the colony counts were taken with the help of a digital colony counter (Royal, India). The number of colony forming units (CFU) per g of the sample was calculated by taking the average of duplicate plates and multiplied by the dilution factor and converted to $\log_{10}$ CFU / g of sample.

3.6.4. Yeast and Mould Count

Method described by Beuchat and Cousin (2001) was followed for estimation of yeast and mould count per gram of the sample. Potato Dextrose Agar (HiMedia, Mumbai) was used for the estimation of yeast and mould count by pour plate technique. From the selected dilutions of each sample 1 ml of inoculums was transferred on to duplicate plates. To each plate 15 to 20 ml of molten media at 45°C was added mixed well and allowed to solidify. The plates were incubated at 25-27°C for 3 days. After incubation colonies were counted with the help of a colony counter and mean count was multiplied with the dilution factor and expressed as $\log_{10}$ CFU / g.

3.7. SENSORY EVALUATION

Taste panel assessment of the non spoiled cutlet was done with the help of trained taste panelists drawn from Department of Livestock Products Technology, Mannuthy. Uniform amount of cutlets from each group were selected and pan-fried separately in double refined deodourised sunflower oil. The fried cutlet samples were served to the panelist with code number and score card (Table 2.)

and asked to rate in the nine point Hedonic scale (Badr, 2004). The individual score were recorded and the average was arrived at and taken as the score for particular attributes.

3.8. STATISTICAL ANALYSIS

The data obtained on physicochemical, microbiological and sensory evaluation of samples were statistically analysed by one-way analysis of variance upto 15 days of storage period and thereafter by *t*-Test (Two samples assuming equal variances) as per Snedecor and Cochran (1994).

Table 2. SCORE CARD FOR TASTE PANEL EVALUATION

Name of the Product: **Beef Cutlet** Date: Sample No:

	Colour	Flavour	Juiciness	Tenderness	Overall acceptability	
	Extremely Appealing	Delicious	More Juicy	Very Tender	More Acceptable	9
						8
						7
	Appealing	Desirable	Juicy	Tender	Acceptable	6
						5
						4
	Less appealing	Not so desirable	Less Juicy	Tough	Less Acceptable	3
						2
						1

Guide lines for giving judgement: If you feel that the colour of the product given to you for taste panel evaluation is extremely appealing, put a tick mark in any one of the three boxes against colour. Lower box signifies that it is less appealing and a tick in the central box signifies that it is for appealing. Similarly mark for the other characters viz., flavour, juiciness, tenderness and overall acceptability.

Specify comments if any:

Name and designation: Signature:

RESULTS

The Beef cutlets were prepared, packaged aerobically in HDPE or under vacuum in PA-PE packets. Half of the samples were subjected to irradiation at dose of 2.5 kGy. The samples were stored at room temperature (25-30°C) or at chiller storage (3-4°C). The irradiated and nonirradiated samples in different packaging were analysed for physical, physicochemical, microbiological and organoleptic qualities on various days of storage.

4.1. PHYSICAL QUALITIES

The physical appearance of the meat product presented to the consumer should be acceptable. The appearance of the meat product is the principle characteristic upon which consumer base their initial purchase. The shelf life of beef cutlet based on physical signs of spoilage is shown in Table 3. 1

The maximum shelf life at room temperature was observed in IRVP sample i.e. 39 to 42 h and the least was 15 to 17 h in NRAP samples. The picture was similar in case of chiller condition, where IRVP samples had the keeping quality of 66 to 71 days. The most commonly available system of packaging using HDPE aerobic packaging had a shelf life of 12 to 15 days under chiller conditions, whereas an irradiated sample (IRAP) at 2.5 kGy had the enhanced shelf life of 50 to 55 days. Since, all samples kept at room temperature were spoiled within 48 h these were discarded without further analysis. Samples kept at chiller temperature were assessed for signs of spoilage like change in colour, consistency, odour, slime formation and mould growth. The non spoiled samples were analysed for its physicochemical, microbiological and sensory qualities on day 5, 10, 15, 20, 30, 45, 60 and 70 of chiller storage.

Table 3. Shelf life of beef cutlet based on physical signs of spoilage

Treatment groups	Room Temperature (h)	Chiller Conditions (days)
NRAP	15-17	12-15
IRAP	30-34	50-55
NRVP	19-21	19-22
IRVP	39-42	66-71

4.2. PHYSICOCHEMICAL PROPERTIES

4.2.1. Proximate Composition

The results of irradiated and nonirradiated beef cutlet samples were analysed for proximate composition on the day of preparation and their data are presented in Table 4.

It was observed that due to irradiation there was no significant difference in the proximate composition like moisture, protein, fat, ash, calcium and phosphorous content. The ready-to-fry cutlet had 54.07 ± 0.12 per cent moisture and 10.79 ± 0.41 per cent protein (nonirradiated sample). From the data it can be inferred that irradiation had no significant difference in major constituents.

Table 4. Proximate composition of beef cutlet (Percentage)

Constituents	Nonirradiated	Irradiated
Moisture	54.07 ± 0.12	53.90 ± 0.09
Fat	10.01 ± 0.11	10.06 ± 0.09
Protein	10.79 ± 0.41	10.85 ± 0.36
Ash	1.602 ± 0.03	1.610 ± 0.01
Calcium	1.096 ± 0.04	1.098 ± 0.03
Phosphorus	0.140 ± 0.01	0.140 ± 0.01

4.2.2. pH

The pH values of irradiated and nonirradiated beef cutlets under different packaging conditions during refrigerated storage are shown in Table 5. Neither packaging nor irradiation had any effect on pH values of beef cutlet on the day of preparation. IRVP samples had a pH of 5.96 ± 0.07 on the day of preparation, by 5th day of storage the value were non significantly increased to 6.06 ± 0.05. The chiller stored samples had a storage life more than 5 days. The stastical analysis of the data upto 15 days of storage revealed that the pH values were non significant for all treatment combination. IRAP and IRVP samples had a keeping quality of 45 and 60 days, respectively during these periods also the pH value were non significant and maintained to that of control sample (NRAP) without much change. By 60th day pH values were 5.93 as against 5.96 on the day of preparation and irradiation. The data are presented in Fig. 3. The lowest pH of 5.90 ± 0.10 was noticed in NRAP samples on 15th day of storage and highest values were recorded on 5th day of storage in IRAP and NRVP samples.

Table 5. pH values of irradiated and nonirradiated beef cutlet

Treatment	Days of storage							
	0	5	10	15	20	30	45	60
NRAP	5.98 ± 0.05	6.01 ± 0.06	5.98 ± 0.07	5.90 ± 0.10	S	S	S	S
IRAP	5.96 ± 0.07	6.06 ± 0.05	6.05 ± 0.05	6.00 ± 0.05	5.99 ± 0.06	5.95 ± 0.05	5.92 ± 0.07	S
NRVP	5.98 ± 0.05	6.07 ± 0.06	6.06 ± 0.06	6.05 ± 0.04	5.95 ± 0.04	S	S	S
IRVP	5.96 ± 0.07	6.03 ± 0.05	6.05 ± 0.05	6.00 ± 0.06	5.99 ± 0.06	5.96 ± 0.05	5.94 ± 0.04	5.93 ± 0.04

S: Spoiled

4.2.3. Thiobarbituric Acid Reacting Substances

The TBARS values of aerobically and vacuum packaged, irradiated and nonirradiated beef cutlets at different days of storage are shown in Table 6. It is expressed as mg of malonaldehyde per kg of cutlet.

On the day of preparation, the nonirradiated samples under both packaging treatments (NRAP and NRVP) had TBARS value of 0.22 ± 0.01 mg mal / kg of cutlet and after irradiation the value had non significantly ($P>0.05$) increased to 0.26 ± 0.02 mg mal / kg of beef cutlet (IRAP and IRVP). TBARS values on the day of preparation were nonsignificant irrespective of packaging and irradiation. The data upto 15th day of storage were analysed by ANOVA. It was found that on 10th day the IRAP samples had significantly ($P<0.05$) higher TBARS values compared to vacuum packaged and nonirradiated samples. The method of packaging had no significant effect on TBARS values due to irradiation. During rest of the days there were no significant differences among various groups of treatments.

As storage period enhanced from zero to till spoilage in NRAP and NRVP samples a steady increase in TBARS values were noticed Fig. 4. Similarly, in irradiated samples steady increase was observed upto day 15th of storage from there the increase was not steady and maintain a plateau. Even after 60 days of storage, IRVP samples had a TBARS value of 0.42 ± 0.02 mg mal / kg as compared to 0.39 ± 0.04 mg mal / kg on 15th day of chiller storage in NRAP samples. The treatment groups NRAP and NRVP also did not show any significant ($P>0.05$) difference in TBARS values on chiller storage as revealed by their final values of 0.39 ± 0.04 and 0.40 ± 0.01 mg mal / kg of beef cutlet, respectively.

Table 6. TBARS values of irradiated and nonirradiated beef cutlet, mg of malonaldehyde / kg of beef cutlet

Treatment	Days of storage							
	0	5	10	15	20	30	45	60
NRAP	0.22 ± 0.01[a]	0.32 ± 0.02[a]	0.37 ± 0.01[ab]	0.39 ± 0.04[a]	S	S	S	S
IRAP	0.26 ± 0.02[a]	0.35 ± 0.03[a]	0.40 ± 0.02[b]	0.42 ± 0.02[a]	0.44 ± 0.02[a]	0.44 ± 0.02[a]	0.46 ± 0.03[a]	S
NRVP	0.22 ± 0.01[a]	0.31 ± 0.02[a]	0.35 ± 0.02[a]	0.37 ± 0.03[a]	0.40 ± 0.01	S	S	S
IRVP	0.261 ± 0.02[a]	0.32 ± 0.02[a]	0.37 ± 0.02[ab]	0.39 ± 0.02[a]	0.40 ± 0.02[a]	0.40 ± 0.02[a]	0.41 ± 0.02[a]	0.42 ± 0.02

Identical superscripts in same column do not differ significantly (P>0.05)
S: Spoiled

4.2.4. Tyrosine Value

The tyrosine values of beef cutlet affected by packaging and irradiation on different days of storage are shown in Table 7. The trend of increase in tyrosine value of the same is shown in Figure 5. Initially the nonirradiated samples in different packets had higher values than that of irradiated samples. The analysis of the data upto 15th day of storage revealed that treatments had no significant (P>0.05) effect on tyrosine value of beef cutlet. From the graph (Fig. 5) it was noted a uniform increase in tyrosine value due to storage. The values had maintained the initial differences, i.e. NRAP and NRVP samples had higher TV values than that of IRAP and IRVP samples on the similar days of storage. The maximum value of 8.92 ± 0.32 mg / 100g was observed in NRVP on 20th day of storage. Whereas the irradiated sample in aerobic packaging (IRAP) on 45th day

of storage had the value of 8.29 ± 0.32 and 8.87 ± 0.33 in case of vacuum packaging (IRVP) on 60th day of storage.

Table 7. Tyrosine values of irradiated and nonirradiated beef cutlet, mg / 100 g

Treatment	Days of storage							
	0	5	10	15	20	30	45	60
NRAP	7.34 ± 0.48	7.65 ± 0.49	8.08 ± 0.57	8.42 ± 0.43	S	S	S	S
IRAP	6.97 ± 0.39	7.06 ± 0.37	7.19 ± 0.36	7.33 ± 0.35	7.77 ± 0.30	8.07 ± 0.33	8.29 ± 0.32	S
NRVP	7.34 ± 0.48	7.47 ± 0.49	7.94 ± 0.48	8.35 ± 0.46	8.92 ± 0.32	S	S	S
IRVP	6.97 ± 0.39	7.14 ± 0.36	7.37 ± 0.32	7.58 ± 0.32	7.92 ± 0.25	8.00 ± 0.24	8.47 ± 0.28	8.87 ± 0.33

S: Spoiled

4.3. MICROBIOLOGICAL ANALYSIS

4.3.1. Aerobic Plate Count

The total aerobic plate count of various treatment groups at different days of storage are shown in Table 8. Initially the ready-to-fry packaged cutlet had a count of 4.42 log CFU / g of beef cutlet that has been reduced to more than 3 log (1.06 $\log_{10}$ CFU / g) by irradiation at a dose of 2.5 kGy. The reduction was significant ($P<0.05$) and as storage period enhanced to 15th day of storage both IRAP and IRVP sample had a significant lower count than that of nonirradiated samples. As storage period increased the count gradually enhanced in all the four treatment groups (Fig. 6). The maximum microbial load observed in IRVP

samples on 60th days of storage was only 4.5 ± 0.45 log CFU / g and similarly, in IRAP sample it was only 4.69 ± 0.34 log CFU / g on 45th day of storage. These were almost similar to count obtained on 5th day of storage in case of nonirradiated samples.

Table 8. Total aerobic plate count of irradiated and nonirradiated beef cutlet, log_{10} CFU per g

Treatment	Days of storage							
	0	5	10	15	20	30	45	60
NRAP	4.42 ± 0.12[b]	4.41 ± 0.23[b]	6.00 ± 0.56[b]	6.38 ± 0.53[b]	S	S	S	S
IRAP	1.06 ± 0.34[a]	1.87 ± 0.07[a]	2.49 ± 0.18[a]	3.16 ± 0.31[a]	3.50 ± 0.35[a]	3.93 ± 0.34[a]	4.69 ± 0.34[b]	S
NRVP	4.42 ± 0.11[b]	4.30 ± 0.16[b]	5.22 ± 0.42[b]	5.90 ± 0.39[b]	6.40 ± 0.27	S	S	S
IRVP	1.06 ± 0.34[a]	1.71 ± 0.07[a]	1.98 ± 0.12[a]	2.64 ± 0.22[a]	2.88 ± 0.21[a]	3.29 ± 0.31[a]	3.49 ± 0.32[a]	4.50 ± 0.45

S: Spoiled
Identical superscripts in same column do not differ significantly (P>0.05)

4.3.2 Psychrotrophic Count

The psychrotrohic organisms are important in any cold-chain maintained food items. The mean log count of pschrotrophic organism of irradiated and nonirradiated beef cutlet packaged in HDPE and PA-PE pouches stored at chiller conditions are shown in Table 9.

It was observed a significant reduction (P<0.05) in psychrotrophic count due to irradiation method of preservation in both types of packaging. The values

were significantly different upto 15th day of storage as evidenced by the ANOVA. As storage period enhance it was observed a significant increase in all treatments (Fig. 7). The values of IRAP and IRVP samples on day 20th, 30th and 45th day of storage were non significant. The maximum count of 5.75 ± 0.71 log CFU / g was noticed in NRVP samples on 20th day of storage, whereas IRVP samples on 60th day had only a low count of 4.39 ± 0.35 log CFU / g. About 74 per cent reduction was noticed in psychrotrophic count on the day of preparation due to irradiation at 2.5 kGy. Since, the initial count was very low the cutlet stored under chiller condition on 60th day also had a comparatively lower count than that of NRAP packaged sample on 15th day.

Table 9. Psychrotrophic count of irradiated and nonirradiated beef cutlet, log_{10} CFU per g

Treatment	Days of storage							
	0	5	10	15	20	30	45	60
NRAP	3.24 ± 0.31[b]	3.59 ± 0.37[b]	4.67 ± 0.17[b]	5.70 ± 0.20[b]	S	S	S	S
IRAP	0.84 ± 0.38[a]	1.80 ± 0.21[a]	2.37 ± 0.17[a]	2.53 ± 0.10[a]	2.81 ± 0.16[a]	3.33 ± 0.29[a]	4.10 ± 0.32[a]	S
NRVP	3.24 ± 0.31[b]	3.60 ± 0.34[b]	4.29 ± 0.25[b]	4.90 ± 0.30[b]	5.75 ± 0.71	S	S	S
IRVP	0.84 ± 0.38[a]	1.76 ± 0.25[a]	2.25 ± 0.22[a]	2.33 ± 0.21[a]	2.54 ± 0.20[a]	3.14 ± 0.26[a]	3.88 ± 0.32a	4.39 ± 0.35

S: Spoiled
Identical superscripts in same column do not differ significantly (P>0.05)

4.3.3. Yeast and Mould Count

The yeast and mould count of irradiated and nonirradiated beef cutlet samples packaged under aerobic or vacuum packaging on different days of chiller storage are shown in Table 10.

Table 10. Yeast and mould count of irradiated and nonirradiated beef cutlet, log_{10} CFU per g

Treatment	Days of storage							
	0	5	10	15	20	30	45	60
NRAP	3.41 ± 0.43[b]	4.01 ± 0.47[b]	5.24 ± 56[b]	5.89 ± 0.44[d]	S	S	S	S
IRAP	1.02 ± 0.33[a]	1.82 ± 0.22[a]	2.26 ± 0.14[a]	2.85 ± 0.13[b]	3.37 ± 0.15[b]	3.60 ± 0.18[a]	4.14 ± 0.35[a]	S
NRVP	3.41 ± 0.43[b]	3.69 ± 0.48[b]	4.88 ± 0.59[b]	5.38 ± 0.60[c]	5.47 ± 0.55	S	S	S
IRVP	1.02 ± 0.33[a]	1.48 ± 0.12[a]	1.76 ± 0.16[a]	2.17 ± 0.23[a]	2.58 ± 0.25[a]	2.90 ± 0.29[a]	3.23 ± 0.36[a]	3.65 ± 0.44

S: Spoiled
Identical superscripts in same column do not differ significantly (P>0.05)

The maximum count obtained on the day of preparation was 3.41 ± 0.43 log CFU / g in nonirradiated sample, which was significantly (P<0.05) reduced to 1.02 ± 0.33 log CFU / g in irradiated samples under both packaging systems. Irradiation of beef cutlet at a dose of 2.5 kGy showed a reduction of 70 per cent in yeast and mould count on the day of preparation. As storage period enhanced count has gone up and reached 4.14 ± 0.35 log CFU / g in IRAP samples by 45th day of storage and 3.65 ± 0.44 log CFU / g on 60th day of storage in case of IRVP

sample. Irradiation had significantly reduced the count upto 15th day of storage as revealed by the analysis of data. Among the packages combined with irradiation, IRVP samples had a lower count than that of IRAP and it was significantly ($P<0.05$) lower on 20th day of storage. Irrespective of packaging and treatment, storage had a significant effect and the count attained more than that of control sample (day 0) by 45th day in IRAP and 60th day in case of IRVP samples (Fig. 8). The maximum count obtained was 5.89 ± 0.44 log CFU / g in NRAP sample on 15th day of storage followed by 5.47 ± 0.55 log CFU / g in NRVP sample on 20th day of storage.

4.4. ORGANOLEPTIC EVALUATION

4.4.1. Colour

The colour of meat and meat product is of the utmost importance in marketing since it is the first quality attributes seen by the consumer who uses the product. The colour score of beef cutlet affected by packaging, irradiation and storage conducted with help of nine point Hedonic scale is shown in Table 11.

Analysis of the data on the day of preparation and on 5th day of storage showed non significant values either due to packaging or irradiation. The maximum score obtained in irradiated and nonirradiated samples on the day of preparation was 8.39 ± 0.11 and 8.34 ± 0.11, respectively. As storage period enhanced the colour score had reduced and lowest score was noticed in NRAP sample on 15th day of storage. Vacuum packaged and irradiated cutlet even after 60 days of storage maintained a very good colour score of 7.30 ± 0.13. At the same time vacuum packaged nonirradiated samples on 20th day of preparation had obtained a score of only 7.00 ± 0.19. There was no significant effect on colour score due to packaging during entire course of study.

Table 11. Colour score of irradiated and nonirradiated beef cutlet

Treatment	Days of storage							
	0	5	10	15	20	30	45	60
NRAP	8.34 ± 0.11^{a}	8.06 ± 0.12^{a}	7.61 ± 0.12^{a}	6.98 ± 0.21^{c}	S	S	S	S
IRAP	8.39 ± 0.11^{a}	8.04 ± 0.009^{a}	7.88 ± 0.10^{ab}	7.84 ± 0.11^{b}	7.70 ± 0.18^{b}	7.43 ± 0.11^{b}	7.07 ± 0.17^{b}	S
NRVP	8.34 ± 0.11^{a}	8.13 ± 0.13^{a}	8.06 ± 0.08^{b}	7.57 ± 0.15^{c}	7.00 ± 0.19	S	S	S
IRVP	8.39 ± 0.11^{a}	8.11 ± 0.11^{a}	8.01 ± 0.06^{b}	8.00 ± 0.10^{b}	7.87 ± 0.14^{b}	7.63 ± 0.12^{b}	7.40 ± 0.19^{b}	7.30 ± 0.13

S: Spoiled
Identical superscripts in same column do not differ significantly (P>0.05)

4.4.2 Flavour

The flavour score of irradiated and nonirradiated beef cutlet under different packaging systems in chiller storage is presented in Table 12. On the day of preparation the flavour score was not significantly different either due to irradiation or packaging. As days of storage increased the scoring rate reduced and non significant level maintained upto 5th day of storage. On 10th day NRAP sample recorded the significantly (P<0.05) lower score of 7.60 ± 0.16 compared to higher score in all other samples. On 15th day also nonirradiated samples had a significant (P<0.05) lower score than that of irradiated samples packaged either in HDPE or PA-PE pouches. As revealed by *t*-Test, there was no significant difference between IRAP and IRVP sample score on day 20th, 30th and 45th of storage. Even after 60 days of chiller storage, IRVP sample had a very good flavour score of 7.27 ± 0.22.

Table 12. Flavour score of irradiated and nonirradiated beef cutlet

Treatment	Days of storage							
	0	5	10	15	20	30	45	60
NRAP	8.40 ± 0.08^{a}	8.26 ± 0.13^{a}	7.60 ± 0.16^{a}	7.34 ± 0.28^{c}	S	S	S	S
IRAP	8.30 ± 0.10^{a}	8.24 ± 0.13^{a}	8.20 ± 0.10^{b}	8.17 ± 0.09^{b}	8.00 ± 0.09^{b}	7.73 ± 0.16^{b}	7.36 ± 0.17^{b}	S
NRVP	8.33 ± 0.07^{a}	8.21 ± 0.13^{a}	8.00 ± 0.06^{b}	7.76 ± 0.08^{c}	7.45 ± 0.22	S	S	S
IRVP	8.24 ± 0.20^{a}	8.21 ± 0.14^{a}	8.20 ± 0.07^{b}	8.18 ± 0.06^{b}	8.05 ± 0.13^{b}	7.85 ± 0.13^{b}	7.56 ± 0.26^{b}	7.27 ± 0.22

S: Spoiled
Identical superscripts in same column do not differ significantly (P>0.05)

4.4.3. Juiciness

The juiciness score of beef cutlet affected by irradiation and packaging during refrigerated storage is shown in Table 13. It was observed that a significant (P<0.05) increase in juiciness due to irradiation (both in aerobically and vacuum packaged samples) with the highest score of 8.54 ± 0.07 in IRVP samples. Upto 10th day there was no significant difference between juiciness score of IRAP and IRVP samples with always a better score for irradiated samples than nonirradiated counterparts. As far as juiciness is concerned from 20th day onwards the IRVP samples had a better score (P<0.05) than that of IRAP sample. By 45th day of storage IRAP sample had a juiciness score of 7.25 ± 0.07 and IRVP had a score of 7.15 ± 0.11 by 60th day of storage. During the storage period a gradual reduction in the score was noticed irrespective of treatment.

Table 13. Juiciness score of irradiated and nonirradiated beef cutlet

Treatment	Days of storage							
	0	5	10	15	20	30	45	60
NRAP	8.10 ± 0.09^{a}	8.28 ± 0.07^{a}	7.98 ± 0.13^{a}	7.66 ± 0.09^{a}	S	S	S	S
IRAP	8.34 ± 0.08^{ab}	8.34 ± 0.08^{a}	8.26 ± 0.08^{ab}	8.06 ± 0.06^{c}	7.90 ± 0.07^{c}	7.65 ± 0.06^{c}	7.25 ± 0.07^{c}	S
NRVP	8.10 ± 0.09^{a}	8.29 ± 0.07^{a}	8.10 ± 0.09^{ab}	7.83 ± 0.10^{d}	7.43 ± 0.15	S	S	S
IRVP	8.54 ± 0.07^{b}	8.45 ± 0.07^{a}	8.36 ± 0.05^{b}	8.25 ± 0.05^{b}	8.10 ± 0.04^{b}	7.97 ± 0.06^{b}	7.54 ± 0.11^{b}	7.15 ± 0.11

S: Spoiled
Identical superscripts in same column do not differ significantly (P>0.05)

4.4.4. Tenderness

The tenderness of meat and meat products is directly related to the juiciness of the product and in the present study also a similar trend was noticed. The data is shown in Table 14.

The NRAP samples on the day of preparation had a significantly lower score of 8.25 ± 0.06 compared to highest score of 8.43 ± 0.06 in IRVP sample on the day of preparation. As storage period increased upto 10th day it maintained a plateau (Fig. 9). On 15th day of preparation the irradiated samples significantly (P<0.05) scored higher than of nonirradiated counterparts with the maximum score in IRVP samples. A satisfactory tenderness score of 7.81 ± 0.05 was maintained upto 60th day of preparation in case of IRVP sample and 7.76 ± 0.04 on 45th day of preparation in case of IRAP samples. It can be inferred that

irradiation irrespective of packaging had a significant ($P<0.05$) effect on increasing the tenderness of beef cutlet.

Table 14. Tenderness score of irradiated and nonirradiated beef cutlet

Treatment	Days of storage							
	0	5	10	15	20	30	45	60
NRAP	8.25 ± 0.06^{a}	8.31 ± 0.04^{a}	8.19 ± 0.07^{a}	7.96 ± 0.07^{c}	S	S	S	S
IRAP	8.32 ± 0.05^{ab}	8.34 ± 0.04^{a}	8.34 ± 0.04^{ab}	8.25 ± 0.06^{b}	8.14 ± 0.06^{c}	7.96 ± 0.05^{c}	7.76 ± 0.04^{c}	S
NRVP	8.27 ± 0.05^{ab}	8.32 ± 0.04^{a}	8.24 ± 0.04^{a}	8.13 ± 0.04^{c}	7.87 ± 0.06	S	S	S
IRVP	8.43 ± 0.06^{b}	8.45 ± 0.06^{a}	8.46 ± 0.05^{b}	8.39 ± 0.07^{b}	8.37 ± 0.06^{b}	8.27 ± 0.01^{b}	8.11 ± 0.04^{b}	7.81 ± 0.05

S: Spoiled
Identical superscripts in same column do not differ significantly ($P>0.05$)

4.4.5 Overall acceptability

The overall acceptability scores of beef cutlet, packaged in different packaging systems and subjected to irradiation dose of 2.5 kGy are shown in Table 15.

It was observed a non significant overall acceptability score on the day of preparation among various treatments groups and a similar trend was noticed on 5th day of storage (Fig. 10). As storage period enhanced from 10th and 15th day of storage nonirradiated sample had a significant ($P<0.05$) lower score than that of irradiated samples in both packaging. This indicated that packaging had no significant effect on overall acceptability upto 15th day of storage under chiller

conditions. As revealed by *t*-Test from 20th day onwards the score of IRAP was significantly ($P<0.05$) lower than that of IRVP on 20th, 30th and 45th day of preparation. Even though both samples maintained a very good overall acceptability, the IRVP samples on 60th day of preparation recorded a good score of 7.26 ± 0.18 indicating that beef cutlets were acceptable upto 60 days under chiller condition if it is subjected to low dose irradiation.

Table 15. Overall acceptability score of irradiated and nonirradiated beef cutlet

Treatment	Days of storage							
	0	5	10	15	20	30	45	60
NRAP	8.64 ± 0.04^{a}	8.34 ± 0.09^{a}	7.87 ± 0.19^{a}	7.49 ± 0.22^{c}	S	S	S	S
IRAP	8.69 ± 0.03^{a}	8.45 ± 0.03^{a}	8.38 ± 0.03^{b}	8.20 ± 0.06^{b}	8.05 ± 0.06^{c}	7.78 ± 0.04^{c}	7.42 ± 0.09^{c}	S
NRVP	8.61 ± 0.04^{a}	8.34 ± 0.05^{a}	8.10 ± 0.08^{ab}	7.75 ± 0.09^{c}	7.23 ± 0.21	S	S	S
IRVP	8.66 ± 0.04^{a}	8.42 ± 0.04^{a}	8.36 ± 0.04^{b}	8.30 ± 0.04^{b}	8.22 ± 0.04^{b}	8.12 ± 0.037^{b}	7.81 ± 0.07^{b}	7.26 ± 0.18

S: Spoiled
Identical superscripts in same column do not differ significantly ($P>0.05$)

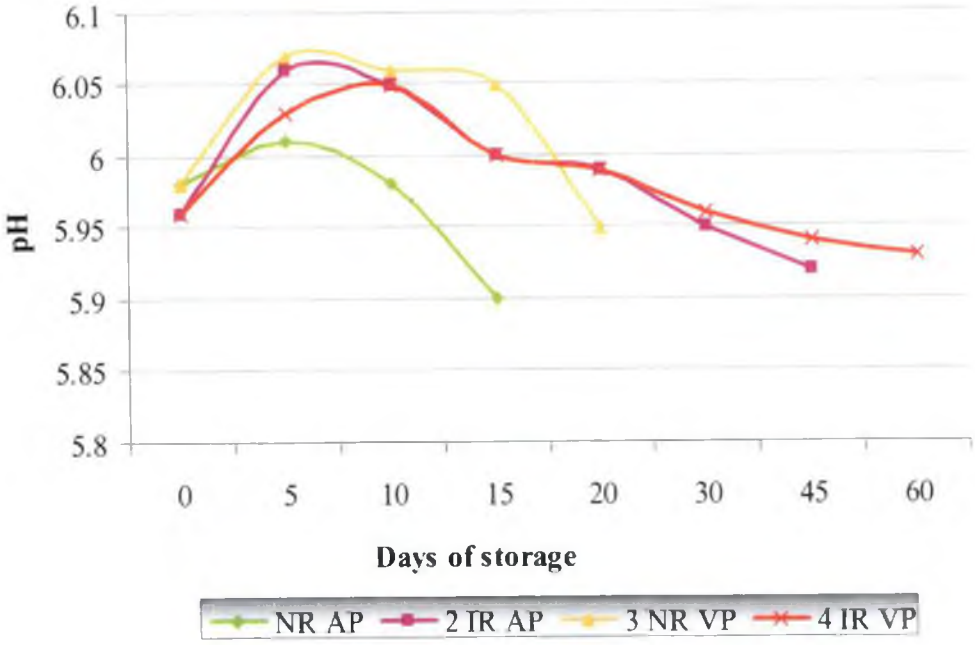

Fig. 3. pH values of beef cutlet on storage

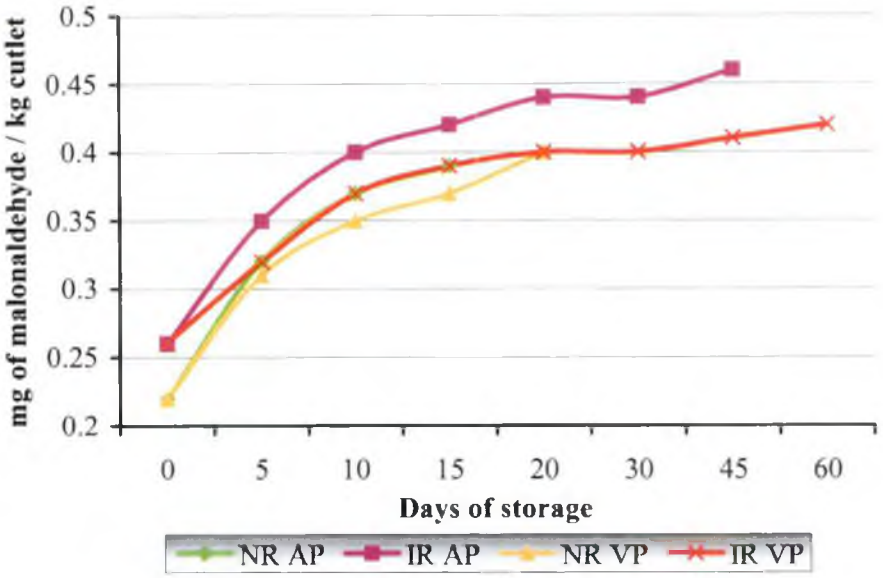

Fig. 4. TBARS value of beef cutlet on storage

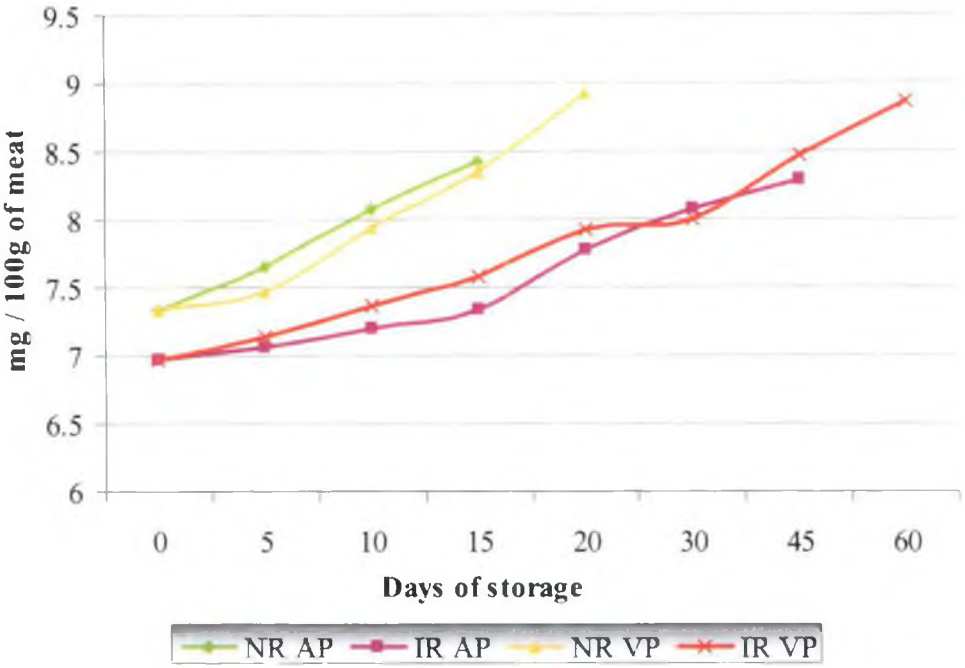

Fig. 5. Tyrosine value of beef cutlet on storage

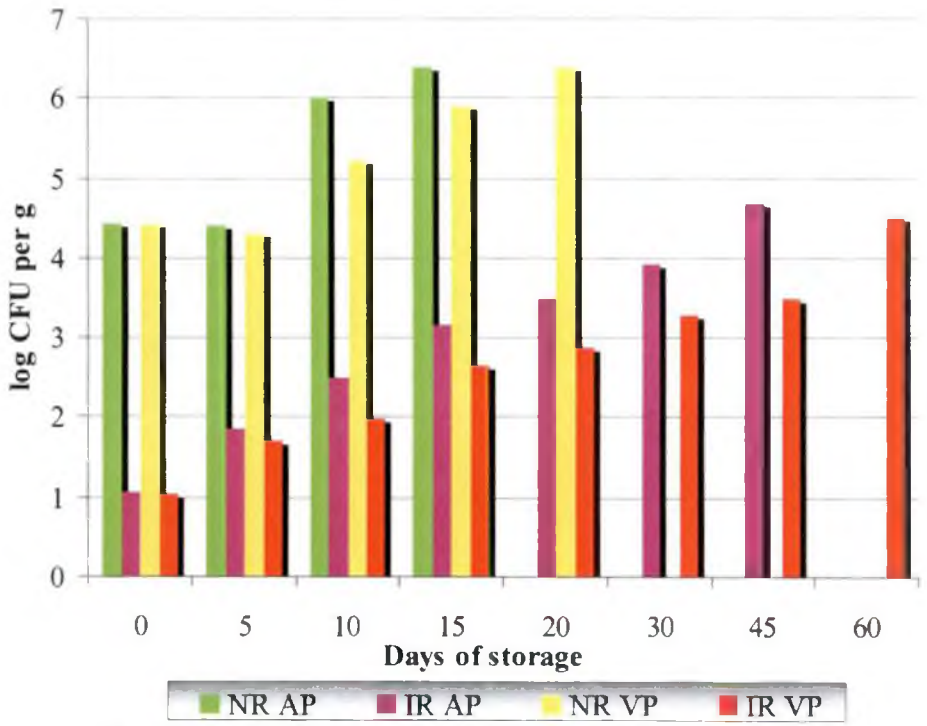

Fig. 6. Aerobic plate count of beef cutlet on storage

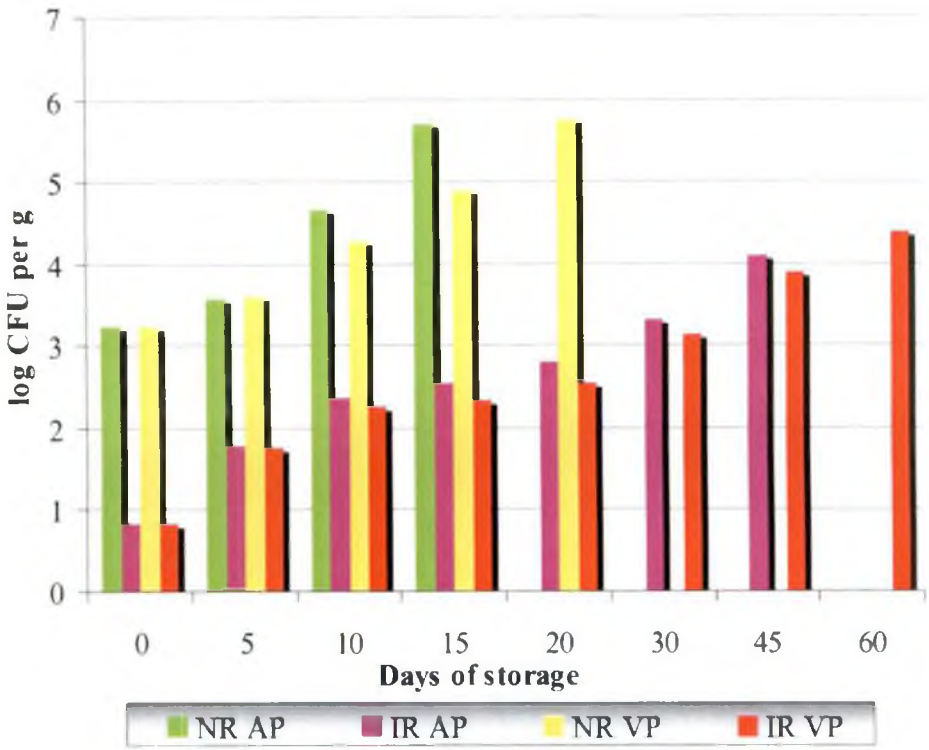

Fig.7. Psychrotrophic count of beef cutlet on storage

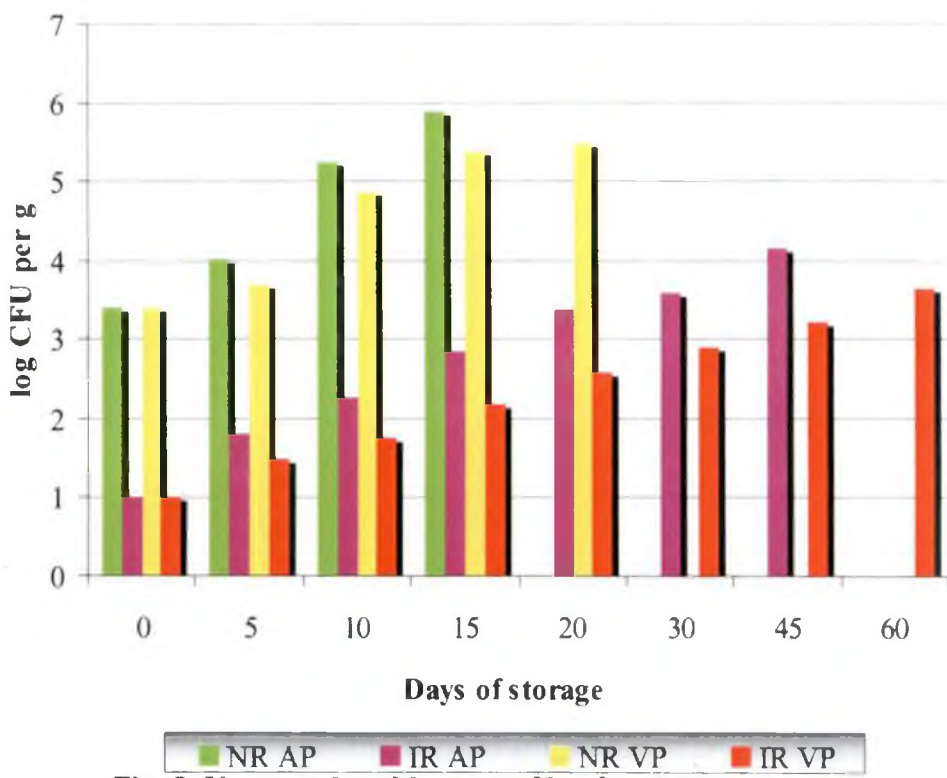

Fig. 8. Yeast and mold count of beef cutlet on storage

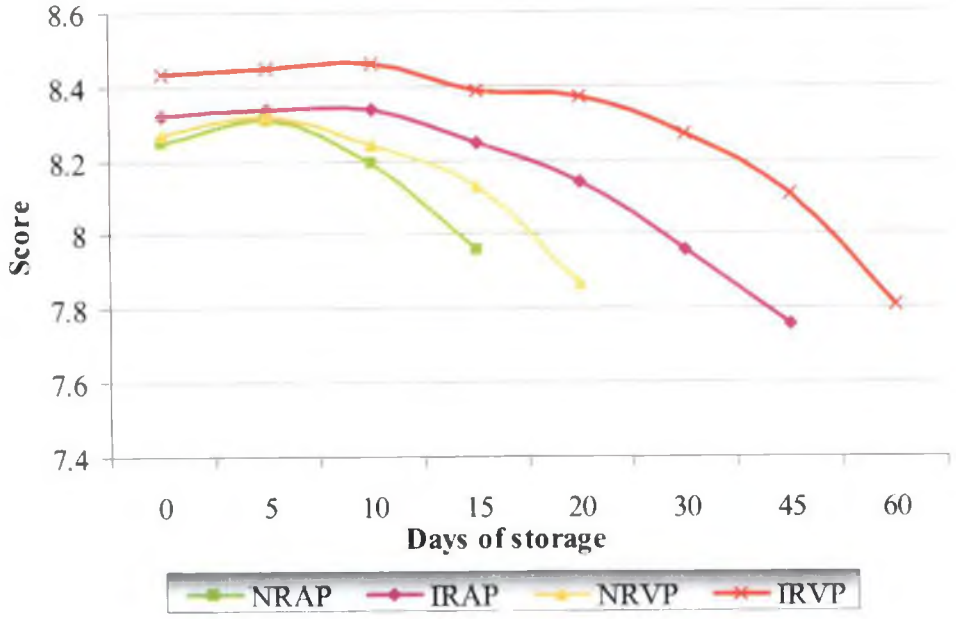

Fig. 9. Tenderness score of beef cutlet on storage

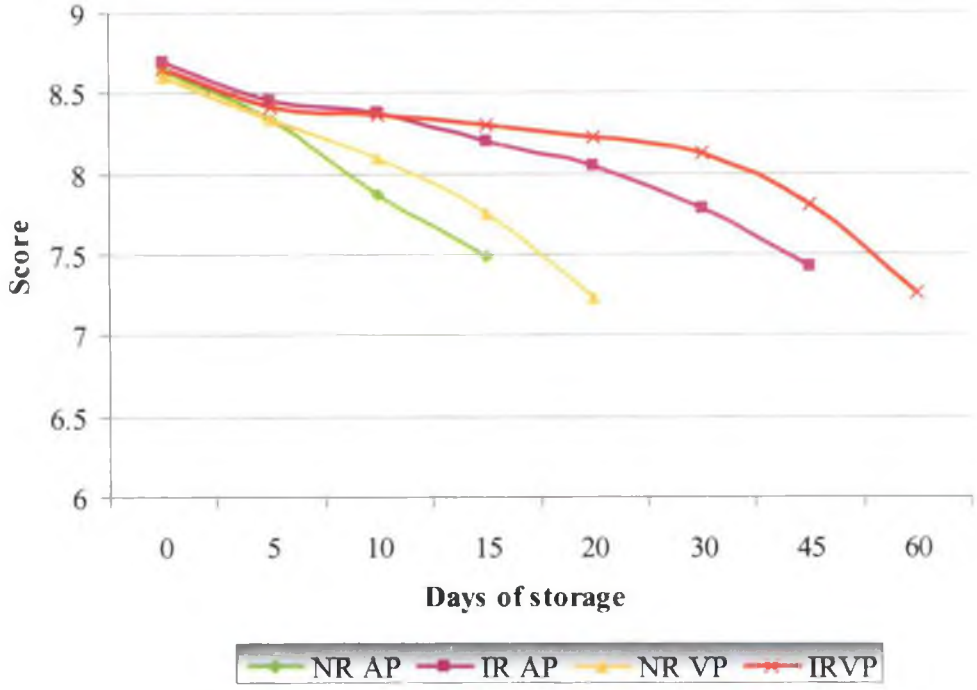

Fig. 10. Overall acceptability score of beef cutlet on storage

DISCUSSION

Six batches of cutlet were prepared and aerobically packaged in HDPE or vacuum packaged in PA-PE pouches. Half numbers in each group were subjected to irradiation employing gamma irradiation at dose of 2.5 kGy at melting ice temperature. Samples were analysed for proximate composition on the day of preparation and for pH, TBARS, TV, aerobic plate count, psychrotophic plate count, yeast and mould count and organoleptic qualities. Shelf life of the samples kept at room temperature as well as chiller storage was assessed by physical qualities.

5.1. PHYSICAL QUALITIES

Cutlets are ready-to-fry snack available in many parts of India. Whether it is a vegetable cutlet, meat cutlet or fish cutlet basically the binder used is potato, hence spoilage of cutlet are at rapid rate due to changes that occur in starch and meat on storage. The nonirradiated sample kept at room temperature had a shelf life of 15 to 21 h in either packaging system, whereas irradiated sample had a shelf life of 30 to 42 h indicating a significant effect of irradiation on shelf life of product (Table 3.). This clearly indicates that vacuum packaging combined with low dose irradiation definitely plays an important role in extending the shelf life under room temperature. Normally available cutlets in any Indian supermarket are deep frozen; hence it is not a convenient food. Such products on chiller storage are having a shelf life of 12 to 15 days, by irradiating the same at 2.5 kGy shelf life can be extended to 50 to 55 days and by combining with vacuum packaging it can be further extended upto 66 to 71 days. Murano *et al.* (1998) reported that ground beef patties irradiated at 2 kGy had a shelf life of 55 days at 4°C and similarly, Robert and Weese (1998) also reported a shelf life of 42 days at a dose of 5 kGy irradiation. The results of the present study were in agreement with Ahn *et al.* (2000) who reported extended shelf life with minimum off odour during storage in case of vacuum packaged irradiated meat. Kanatt *et al.* (2005) observed

two weeks extension of shelf life in ethnic Indian meat product at 3 kGy. In the present study storage period was better than earlier reports. Jenifer (2006) reported a shelf life of 32 to 33 days at 3 kGy in irradiated minced beef and 2 to 3 days in nonirradiated minced beef. Since cutlets are ready-to-fry snack containing spices and low moisture, irradiation had an added advantage for extending shelf life. Irradiation at dose of 2.5 kGy enhanced the shelf life of beef cutlet by 3-4 times in IRAP samples and 4-5 times in IRVP samples as compare to nonirradiated samples (NRAP).

5.2. PHYSICOCHEMICAL PROPERTIES

5.2.1. Proximate Composition

Proximate composition of irradiated and nonirradiated cutlets were analysed on the day of preparation. It was observed the values were non significant between treatment and control sample with respect to moisture, fat, protein, ash, calcium and phosphorous content. The results of the present study are in agreement with Heath *et al.* (1990) who reported no significant difference due to irradiation with respect to moisture content of chicken meat. Wheeler *et al.* (1999) also reported non significant effect of irradiation with respect to fat and moisture content of beef patties. Similarly, Al-Bachir *et al.* (2005) in luncheon meat and Rana Raj (2006) in pet food also reported non significant effect in proximate composition. The results of study for Ca and P content of beef cutlet were in agreement with Smith and Pillai (2004), who reported a non significant effect of irradiation on mineral content of meat.

5.2.2. pH

The pH values of the beef cutlet, with the increase in storage period showed a non significant increase from 0 to 10 days of storage and thereafter it was gradually reduced. The plateau was maintained upto 20^{th} day in NRVP, upto 45^{th} day in IRAP and upto 60^{th} day in IRVP samples. Nam *et al.* (2001) in pork meat and Nam and Ahn (2002a) in turkey breast meat reported a non significant effect due to packaging and irradiation. Al-Bachir (2005) in irradiated luncheon

meat (2 kGy), Kudra *et al.* (2007) in beef patties, pork chops and frankfurters (vacuum packed, modified atmosphere packed and irradiated) reported similar non significant effect of pH. Vivek (2006) reported non significant effect due to irradiation on the pH of meat upto 24 h of storage. Jenifer (2006) also reported non significant effect due to irradiation in case of minced beef. In the present study also neither irradiation and packaging nor storage period had any significant effect on pH, since the initial control sample pH 5.98 ± 0.05 (NRAP on the day of preparation) had attained a pH of 5.93 ± 0.04 by 60th day of storage (IRVP samples).

5.2.3. Thiobarbituric Acid Reacting Substances (TBARS)

Estimation of thiobarbituric acid substance in meat and meat product will enlighten the extent of oxidative rancidity changes. Fat is one of the most important components in meat and meat products, which is affected by gamma irradiation and led to increased value with respect to TBARS (Dempster *et al.*, 1985; Houser *et al.*, 2003). Similarly, storage of meat and meat product also enhances the TBARS values. From the data of present study it can be inferred that on the day of preparation, packaging and irradiation the values were non significantly different and this was maintained upto 5th day of storage. On 10th day of preparation there was no significant difference between NRAP and IRAP samples, similarly with NRVP and IRVP samples. Whereas, IRAP and NRVP samples were significantly different having a higher TBARS values in aerobically packed irradiated sample, this trend was continued upto 45 days of storage. Ahn *et al.* (1998) reported that irradiation caused accelerated lipid oxidation and oxygen exposure was an important factor than irradiation. In the present study samples packaged in oxygen permeable film (aerobic packaging) and irradiated had increased value of TBARS 0.42 ± 0.02 by 15th day of storage whereas vacuum packaging followed by irradiation has marked the same value by 60th day of storage. Du *et al.* (2001a) obtained a higher TBARS value on storage in chicken meat patties and reported that irradiation had a minor impact on lipid oxidation. Nam and Ahn (2003) also stressed the importance of vacuum packaging to

prevent lipid oxidation. Zhu *et al.* (2003; 2004) reported that change in TBARS value due to irradiation were disappeared after 7 and 14 days at 1 and 2 kGy irradiation and values were non significant in vacuum packaged meat.

Kanatt *et al.* (2005) reported that spices added to ethnic Indian meat products are having antioxidant agent. Cutlets are prepared incorporating various spices and condiments that are considered as best antioxidant material. The initial control values were significantly lower than many other earlier reports and subsequent storage also did not reach the maximum level. It was found that the storage period had a significant role in elevating the level of TBARS than that of aerobic packaging or irradiation.

5.2.4. Tyrosine Value

The tyrosine value indicates the protein breakdown of meat and meat products, which is subjected to storage or any other treatment. In the present study the changes in tyrosine value was similar to TBARS with slight decrease in tyrosine value as far as irradiated samples are concerned. During the entire study period irradiated (both packages) had a lower value (non significant) than that of its nonirradiated counterparts. Lawrie (1998) stated irradiation as a method to reduce proteolysis in meat and to retain its quality and Balamatsia *et al.* (2006) reported a lower total volatile basic nitrogen value in irradiated sample stored at 4°C. As storage period enhanced tyrosine value content of beef cutlet had gradually increased and reached the highest value of 8.87 ± 0.33 on 60th day of storage in IRVP sample. In the present study the effect on different packaging system on tyrosine value were non significant and is in agreement with Jayanthi (2003). Kuttinarayanan *et al.* (2005) observed a non significant effect due to irradiation in turkey breast samples and with the increase in storage period there was a non significant increase in tyrosine value as normal biochemical change is expected in refrigerated meat. The results of present study are in agreement with observations by Jenifer (2006).

5.3. MICROBIOLOGICAL ANALYSIS

5.3.1. Aerobic Plate Count

Irradiation of packaged cutlet in either HDPE or PA-PE pouches had shown a significant reduction of about 76 per cent in aerobic plate count on the day of preparation. Throughout the entire storage period the nonirradiated sample had a significantly ($P<0.05$) higher count than irradiated sample in both packages. Storage had a significant effect and both packages attained a count of nearly 6.4 log units by the time of spoilage. It was also observed the nonirradiated sample packed in HDPE had a count of 4.69 ± 0.34 log CFU / g on 45th day and 4.50 ± 0.45 log CFU / g on 60th day of storage in IRVP samples.

Thayer (1993) reported 90 per cent reduction of aerobic plate count in meat and meat products by irradiation at dose of 1 to 4 kGy. Naik (1994) reported 2 to 3 log reduction in buffalo meat samples. Zhao *et al.* (1996) reported 1 kGy irradiation did not eliminated aerobic microorganism but reduced their number and its subsequent growth. The studies of Murano *et al.* (1998) are in agreement with present reduction rate in total viable count. Giroux *et al.* (2001) obtained a substantial low level of count than present study in beef patties. The present study values are lower than that of Kuttinarayanan *et al.* (2005), who reported 95 per cent reduction by 2.5 kGy irradiation. Jenifer (2006) reported that as storage period increased a proportionate increase in colony count was noticed in 3 kGy irradiated sample and control sample of minced beef. Storage had a significant role as evidenced by about 3 log increase in case of irradiated sample and 2 log increase in nonirradiated refrigerated sample at the end of their storage period.

5.3.2. Psychrotrophic Count

A similar trend to that of aerobic plate count was observed in psychrotrophic count of beef cutlet. In both type of packaging irradiation had significantly reduced the bacterial count and about 74 per cent reduction was noticed. As storage period enhanced the difference was retained with an increasing trend. The different packaging system had no significant ($P>0.05$)

effect with respect to psychrotrophic organism. By the time of spoilage of cutlet the count had reached 5 log unit in case of nonirradiated sample and 4 log unit in case of irradiated samples. Niemand *et al.* (1983) reported that 2.5 kGy irradiation completely destroyed *Pseudomonas*, whereas this reduction rate was not achieved in the current study. Lambert *et al.* (1992) reported a 2 log reduction whereas, Lacorix *et al.* (2000) reported psychrotrophic microorganism are more resistant to irradiation under aerobic than under vacuum conditions. Badr (2004) reported an enhanced storage life of 12 to 21 days in irradiated sample with reduction in psychrophilic bacteria. In the present study the storage life was extended by 45 days in IRAP and 60 days in IRVP samples.

Packaging of ready-to-fry cutlet under vacuum packaging condition had shown nearly 5 days enhancement of storage life, whereas irradiating the same sample had an added advantage of 40 days in extension of storage life. Since psychrotophic organism are important with respect to cold chain maintained product, reduction in their number is important for enhanced storage life. This clearly indicated vacuum packaging followed by low dose irradiation has an added advantage on extension of shelf life.

5.3.3. Yeast and Mould Count

Like that of psychrotrophs, spoilage of cold chain maintained foods are also due to yeast and mould growth. The initial yeast and mould count of 3.41 ± 0.43 log CFU / g has been reduced by 70 per cent at 2.5 kGy irradiation indicating a significant ($P<0.05$) reduction in count. There existed a significant difference between irradiated and nonirradiated samples throughout the storage period. Significant difference between irradiated and nonirradiated in both packages continue upto 10^{th} day of storage and on 15^{th} day of observation IRVP sample had the significantly lower count compared to IRAP, NRVP and NRAP samples, with maximum count in NRAP samples. At the time of maximum shelf life, the NRAP sample had a count of 5.89 ± 0.44 (15^{th} day) and 5.47 ± 0.55 log CFU / g (20^{th} day) in case of NRVP samples. On 30^{th} and 45^{th} day of storage the count were non significant among IRAP and IRVP samples. The study is in agreement with

Niemand *et al.* (1983) who reported an extension of shelf life due to vacuum packaging. Balamatsia *et al.* (2006) reported complete elimination of yeast and mould count at 2 kGy irradiation and Badr (2004) observed a reduction of 84 per cent at 1.5 kGy. The present reduction rate was less than that of Kuttinarayanan *et al.* (2006c) and Kuttinarayanan (2007) who reported 95 to 98 per cent reduction by 2 kGy irradiation. Similar to psychrotrophs chilled products as well as room temperature stored products that are having low percent of moisture are spoiled mainly due to fungal spoilage. Irradiation alone or with vacuum packaging can be recommended for enhancing the shelf life by controlling yeast and mould population in ready-to-fry food items.

5.4. ORGANOLEPTIC EVALUATION

The sensory evaluation of the cooked product was conducted with help of nine point Hedonic scale. Similar to other physicochemical and microbiological parameter there was no significance with respect to many other characters under investigation. The colour of irradiated and nonirradiated sample under different packaging system was not significantly different on the day of preparation and on 5^{th} day. On 10^{th} day of observation NRAP sample had a significantly lower value as compared to that of NRVP and IRVP samples and a numerical difference in IRAP sample clearly indicated that irradiation had not reduced the colour score. Lefebvre *et al.* (1994) reported a lower score in irradiated ground beef patties, whereas the present study is in agreement with Fu *et al.* (1995) who did not observed any significant difference in colour due to irradiation. Similar reports were already observed by Alur *et al.* (1998) in pork, Murano *et al.* (1998) and Arthur *et al.* (2005) in ground beef patties, Smith and Pillai (2004) in ground beef. Jo *et al.* (2000) reported a colour change due to irradiation and vacuum packaging in pork sausage. In the present study there was no significant difference between IRAP and IRVP sample even though vacuum packaging had a better score than that of aerobic packaging. It can be inferred that vacuum packaging of cutlet with irradiation will not affect the quality of cutlet stored under chiller condition.

A similar trend was observed in case of flavour score to that of colour score. Ahn *et al.* (2000) in pork patties, Du *et al.* (2001a) in chicken meat patties, Zhu *et al.* (2004) and Ahn and Lee (2005) in turkey breast rolls and Kanatt *et al.* (2005) in few Indian meat products has not reported any significant effect due to irradiation. Nortje *et al.* (2005) reported a higher score in irradiated samples (beef biltong) at the same time lower score, off flavour were detected by various authors, Heath *et al.* (1990) in chicken meat, Hashim *et al.* (1995) in cooked chicken meat, Ahn *et al.* (1998) in raw meat. Zhu *et al.* (2003) reported difference in flavour due to irradiation in turkey ham. Storage had a significant effect on reducing the flavour score especially after 20 days of storage as revealed by lower score obtained. Even then, IRAP sample showed a comparative better score of 7.36 ± 0.17 on 45 day of storage and slightly reduced score of 7.27 ± 0.22 on 60th day of storage in case of IRVP samples.

Juiciness score was different than that of colour and flavour where irradiation had a significantly ($P<0.05$) higher score especially in case of IRVP sample. The original score of 8.10 ± 0.09 was increased to 8.34 ± 0.08 in aerobically packed irradiated sample and 8.54 ± 0.07 in vacuum packaged irradiated sample on the day of preparation. By 5th day of storage there was no much difference, whereas by 15th day similar to that of flavour NRAP sample showed a significantly lower score than that of other samples. From 20th day onward vacuum packaged irradiated sample had a significantly ($P<0.05$) higher score with respect to juiciness as compare to IRAP samples. Luchsinger *et al.* (1996) did not observe any difference in irradiated pork chops. Murano *et al.* (1998) observed increased juiciness in vacuum packed irradiated ground beef patties on the day of preparation. Ohene-Adjei *et al.* (2004) observed increased juiciness score in ground pork. Similar, reports were there for diced chicken and frankfurters, where an increased juiciness was noticed due to irradiation (Johnson *et al.*, 2004). In the present study also juiciness was increased due to irradiation so also vacuum packaging had an added advantage in enhancing the juiciness of meat product.

Tenderness and juiciness are highly related organoleptic qualities of meat and meat products. A similar trend to that of juiciness was maintained for tenderness score. The nonirradiated aerobically packaged sample had a lower score, while vacuum packaged irradiated sample had the significantly ($P<0.05$) higher score. Tenderness score was non significant on 5th day of observation and on 10th day IRAP and IRVP sample had a better score. Throughout the study period vacuum packaged irradiated sample had a better score. In case of irradiation collagen shrinks in its dry stage and become soluble in water if irradiated wet and indeed irradiation causes softness and tenderness of texture as an immediate effect (Coleby *et al.*, 1961) in the present study also tenderness was increased in irradiated sample. Murano *et al.* (1998) reported a similar observation in irradiated ground beef patties whereas Ohene-Adjei *et al.* (2004) reported a decrease in tenderness in loin chops. In process of cutlet preparation cooking and mincing led to changes in collagen structure while on irradiation a definite change in structural pattern of collagen will take place and thereby a reduction in background toughness of meat might be the cause for increased tenderness.

The score for overall acceptability rated by panelists are actually of the product of the different attributes. On the day of preparation and on 5th day of storage there was no significant difference with respect to overall acceptability among different treatment groups. On 10th and 15th day of observation the nonirradiated sample had a lower score than that of irradiated counterparts. Many authors reported non significant difference due to irradiation, Tarowski *et al.* (1984) in beef, Dempster *et al.* (1985) in beef burger, Alur *et al.* (1988) in pork meat products, Wheeler *et al.* (1999) in ground beef patties, Badr *et al.* (2004) in rabbit meat and Kuttinarayanan *et al.* (2005) in cutlet, beef and minced beef. Whereas Naik *et al.* (1994) in buffalo meat and Johnson *et al.* (2004) in diced chicken and frankfurters showed a better score in irradiated samples than nonirradiated on storage. The overall acceptability was in agreement with other organoleptic scores and vacuum packaging combined with irradiation definitely increased the keeping quality and maintained the organoleptic qualities of ready-to-fry cutlet.

From the above results it can be inferred that irradiation had a definite role in enhancing the shelf life in any type of packaging system under chiller condition. Keeping at room temperature had a very little effect on enhancing the shelf life. Irradiated sample can be kept at chiller conditions upto 45 days of storage without spoilage as against 15 days in case of aerobically packaged nonirradiated samples. The keeping quality can be further extended without compromising organoleptic and microbial quality by using vacuum packaging technology in PA-PE pouches. This simple use of vacuum packaging technology will enhance the keeping quality by 5 days in combination with low dose irradiation will extend the shelf life beyond 60 days. Moreover irradiation technology as evidenced by 70 to 80 per cent reduction in bacterial load definitely reduces the dreadful pathogenic microorganism like coliform, *Listeria*, *E. coli*, *Salmonella*, *Staphylococcus, etc.*, and thereby provides food safety. Hence, irradiation method of preservation in combination with vacuum packaging can be recommended as a suitable method for the preservation of this highly perishable meat snack under chiller condition.

Summary

SUMMARY

Indian conventional snacks like beef cutlet has become mega trend due to change in culinary habits of people. They are having a very short shelf life, so these products are stored in frozen form, which is one of the most expensive method of preservation. Many of the meat preservation techniques will not destroy pathogenic and spoilage causing organism. In order to overcome these disadvantages irradiation technology can be tried. PFA in 1998 approved the gamma irradiation of meat and meat products including chicken at a low dose of 2.5 to 4.0 kGy. Packaging can be useful tool in maintaining product quality and further extension of shelf life. Therefore this study is aimed at increasing the keeping quality of beef cutlet employing gamma irradiation in combination with different packaging systems without affecting its qualities

The most popular and fast moving ready-to-fry beef cutlets were prepared using ingredients such as beef, potato, onion, tallow, condiments, spices, salt, whipped egg and bread crumbs in Department of Livestock Products Technology, Mannuthy. Formed beef cutlets in five numbers were aerobically and vacuum packaged in each HDPE and PA-PE packets, respectively. The packaged beef cutlets were subjected to gamma irradiation doses of 0 or 2.5 kGy using Gamma Chamber 5000. Samples were kept at room temperature and in chiller storage. The irradiated and nonirradiated cutlet sample under different packaging systems were analysed for various quality parameter viz., physical, physiochemical, microbiological and organoleptic qualities on the day of preparation and on day 5, 10, 15, 20, 30, 45, 60 and 70 of chiller storage or until spoilage whichever was earlier. Samples kept at room temperature were studied with physical qualities to assess the shelf life.

In room temperature aerobically packaged irradiated beef cutlet can be stored for 30 to 34 h as against 15 to 17 h in case of nonirradiated samples. Similarly, vacuum packaging irradiated beef cutlet can be stored for 39 to 42 h as

against 19 to 21 h in case of nonirradiated samples. In chiller storage aerobically packaged irradiated beef cutlet can be stored for 50 to 55 days as compared to the shelf life of 12 to 15 days in case of nonirradiated (NRAP) samples. Combination of vacuum packaging and irradiation had keeping quality of 66 to 71 days when assessed for spoilage on the basis of physical signs like change in colour, odour consistency, slime formation and mould growth.

The proximate composition like moisture, fat, protein, total ash, calcium and phosphorous content of irradiated and nonirradiated samples were analysed on the day of preparation. Irradiation at 2.5 kGy did not significantly affect any of the above proximate composition of the beef cutlet. Similarly, the pH of the beef cutlet sample did not show any significant difference due to aerobic or vacuum packaging or by irradiation on the day of preparation. TBARS values which indicate extent of rancidity had no significant effect either due to packaging or irradiation and recorded the lowest value of 0.22 ± 0.01 mg mal / kg in nonirradiated samples, and 0.26 ± 0.02 mg mal / kg in irradiated samples on the day of preparation in both packaging. As storage period increase the TBARS values increased but without treatment effects. The trend of tyrosine value which indicated protein spoilage of meat product was also similar to that of TBARS values. Initially a non significant value of 6.97 ± 0.39 was recorded in IRAP and IRVP samples. As storage period enhanced there was an increase in tyrosine value without any treatment effect indicating that irradiation has not brought any significant change in TBARS as well as tyrosine values.

Due to irradiation aerobic plate count of both IRAP and IRVP samples had significantly ($P<0.05$) reduced and this significant difference continued during its subsequent storage. It was observed about 76 per cent reduction due to irradiation on the day of preparation. As storage period enhanced the count had gone up and reached 4.69 ± 0.34 on 45^{th} day and 4.50 ± 0.45 on 60^{th} day of storage in IRAP and IRVP samples, respectively. In case of psychrotrophic count picture was similar to the aerobic plate count. The initial count of log 3.24 ± 0.31 was reduced to log 0.84 ± 0.38 in IRAP and IRVP sample accounting 74 per cent reduction due

to irradiation. As storage period enhanced there remain a significant effect due to irradiation without any effect of packaging. The yeast and mould count was reduced by 70 per cent due to irradiation at 2.5 kGy and there was no significant effect due to different packaging system. Storage had a significant effect in increasing the count of yeast and mould.

The organoleptic qualities of the beef cutlet were assessed with help of nine point Hedonic scale. The colour scores on the day of preparation were non significant either due to packaging or irradiation. The maximum colour score of 8.39 ± 0.11 was observed in IRAP and IRVP samples. As storage enhanced it revealed a non significant lower score either due to irradiation or packaging. The flavour score of the sample were non significant on the day of preparation. Similar to colour it revealed a lower scoring due to storage in all the four treatment groups and maintained a very good score of the product even after 60 days of chiller storage. The juiciness was increased due to irradiation both in IRAP and IRVP samples. A non significant increase of 8.54 ± 0.07 in IRVP samples was observed as compare to 8.34 ± 0.08 in IRAP samples. IRVP samples maintained a very good juiciness score of 7.15 ± 0.11 on 60^{th} day of storage.

The original score of tenderness 8.25 ± 0.06 was increased significantly ($P<0.05$) to 8.43 ± 0.06 in IRVP sample due to irradiation. Tenderness score was not having any significant effect due to packaging during initial 15 days of storage and a very good score of 7.81 ± 0.05 was maintained in case of IRVP samples on 60^{th} day of storage. These clearly indicate irradiation had significant effect on tenderness score of the product. The overall acceptability of the product was not affected either due to irradiation or packaging. It was observed a good score of 8.69 ± 0.03 in IRAP samples on the day of preparation, even upto 30^{th} and 20^{th} day of storage the IRVP and IRAP samples retained a score of more than 8.

Beef cutlet contains highly perishable meat and potato, which are originally preserved by incorporating certain spices and condiments. Inorder to increase the shelf life the only available system is low temperature preservation, which has one or other limitations. Moreover these methods of preservation will

not destroy many of the pathogenic and spoilage microorganisms, which are incorporated during various process of preparation of ready-to-fry cutlet. Irradiation of the cutlet after packing in HDPE and PA-PE packets were tried and found that pH, proximate composition, tyrosine value, TBARS and organoleptic qualities such as colour, flavour and overall acceptability were not significantly affected due to irradiation or packaging. The aerobic plate count, psychrotrophic count and yeast and mould count were significantly reduced in both packaging system due to irradiation. The tenderness, juiciness and keeping quality of the product was significantly increased due to irradiation in both type of packaging. Irradiation had significantly increased the keeping quality of vacuum packaged beef cutlet to more than 60 days compare to 45 days in aerobically packaged samples. In addition to preservation, this technique also plays an important role destroying spoilage causing and pathogenic microorganisms. Hence, irradiation method of preservation in combination with vacuum packaging and storage at chiller temperature can be recommended to increase the shelf life of meat and meat products.

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PRESERVATION OF MEAT CUTLET EMPLOYING GAMMA RADIATION UNDER DIFFERENT PACKAGING SYSTEMS

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ABSTRACT

Ready-to-fry beef cutlets were prepared in the Department of Livestock Products Technology, College of Veterinary and Animal Science, Mannuthy. They were packaged under aerobic condition in HDPE packets and under vacuum in PA-PE packets. Half number of samples was subjected to irradiation employing gamma irradiation at 2.5 kGy. Samples were stored under room temperature (25-30°C) and in chiller (3-4°C). Samples were analysed for proximate composition on the day of preparation and for pH, TBARS, TV, microbiological and organoleptic qualities on day 0, 5, 10, 15, 20, 30, 45, 60 and 70 of chiller storage. Shelf life of beef cutlet was assessed on the basis of physical signs of spoilage.

The nonirradiated samples kept at room temperature were spoiled within 21 h, whereas irradiated sample had the keeping quality of 34-42 h (IRAP and IRVP). In chiller condition the NRAP sample spoiled within 12-15 days, whereas irradiated sample had a shelf life of 50-55 days. The shelf life was 19-22 and 66-71 days in NRVP and IRVP samples, respectively.

The proximate composition, Ca and P content were not affected due to irradiation. The pH of the sample was not affected due to irradiation in different treatments, storage and packaging. TBARS and tyrosine value were unaffected by packaging and irradiation, whereas on storage the values were increased.

Aerobic plate count, psychrotrophic plate count, yeast and mould count were significantly reduced due to irradiation, while packaging had not shown any significant effect. About 76 per cent reduction in aerobic plate count, 74 per cent reduction in psychrotrophic count and 70 per cent reduction in yeast and mould count was noticed. As storage period enhanced the counts were increased. Since the products are stored under chiller condition the survived bacteria might have been multiplied and count has gone up.

The organoleptic qualities were assessed with help of 9 point Hedonic scale. The colour and flavour of the product were unaltered due to irradiation or

packaging on the day of preparation. The juiciness and tenderness score had increased due to irradiation with the highest values of tenderness in IRVP samples. The overall acceptability was not affected due to irradiation or packaging on the day of preparation. A gradual decrease in overall acceptability and other score were observed due to storage with IRVP sample scoring the highest.

The irradiation preservation of beef cutlet was beneficial for enhancing the keeping quality of beef cutlet under chiller conditions without affecting the qualities. Microbial count like aerobic plate count, psychrotrophic count, yeast and mould count were significantly ($P<0.05$) reduced due to irradiation at 2.5 kGy, the lowest limit prescribed by PFA. Vacuum packaging of the product combined with irradiation has shown about 25 per cent increase in keeping quality compare to ordinary packaging and 4 times increase compared to nonirradiated samples. Irradiation of the product combined with chiller storage requires less electrical energy for preservation of the product. Considering the extended shelf life, wholesomeness of the product, reduced microbial load and energy saving aspects vacuum packaging followed by irradiation can be advocated as a suitable method for preservation of meat and meat products.