EFFECT OF HURDLE TECHNOLOGY, CHITOSAN AND GAMMA RADIATION ON QUALITY PARAMETERS OF CHICKEN FRY

SHIJIN A.

Thesis submitted in partial fulfilment of the requirement for the degree of

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Department of Livestock Products Technology
COLLEGE OF VETERINARY AND ANIMAL SCIENCES
MANNUTHY, THRISSUR-680651
KERALA, INDIA

DECLARATION

I hereby declare that this thesis entitled **"EFFECT OF HURDLE TECHNOLOGY, CHITOSAN AND GAMMA RADIATION ON QUALITY PARAMETERS OF CHICKEN FRY"** 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.

Mannuthy
06-08-2008

SHIJIN A.

CERTIFICATE

Certified that this thesis, entitled **"EFFECT OF HURDLE TECHNOLOGY, CHITOSAN AND GAMMA RADIATION ON QUALITY PARAMETERS OF CHICKEN FRY"** is a record of research work done independently by **SHIJIN A.**, under my guidance and supervision and it has not previously formed the basis for the award of any degree, diploma, associateship or fellowship to her.

Mannuthy
06.08.08

Dr. P. Kuttinarayanan
(Chairman, Advisory Committee)
Professor and Head,
Department of Livestock Products Technology,
College of Veterinary and Animal Sciences,
Mannuthy-680 651.

CERTIFICATE

We, the undersigned members of the Advisory Committee of **Shijin A.**, a candidate for the degree of Master of Veterinary Science in Livestock Products Technology, agree that the thesis entitled **"EFFECT OF HURDLE TECHNOLOGY, CHITOSAN AND GAMMA RADIATION ON QUALITY PARAMETERS OF CHICKEN FRY"** may be submitted by **SHIJIN A.**, in partial fulfillment of the requirement for the degree.

06.08.08

Dr. P. Kuttinarayanan
(Chairman, Advisory Committee)
Professor and Head,
Department of Livestock Products Technology,
College of Veterinary and Animal Sciences,
Mannuthy-680 651.

Dr. George T. Oommen
(Member, Advisory Committee)
Professor,
Department of Livestock Products Technology,
College of Veterinary and Animal Sciences, Mannuthy-680 651.

Dr. Jose John Chungath
(Member, Advisory Committee)
Professor and Head,
Department of Veterinary Anatomy and Histology,
College of Veterinary and Animal Sciences, Mannuthy-680 651.

Dr. B. Sunil
(Member, Advisory Committee)
Associate Professor,
Department of Veterinary Public Health,
College of Veterinary and Animal Sciences, Mannuthy-680 651.

4/9/08

External Examiner
Dr. P PRABHAKARA REDDY
Professor & Head

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Shijin

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Introduction

INTRODUCTION

Rapid urbanization, nuclear family set up and change in life style has lead to a surge in demand for processed and convenience food products. A variety of value added, ready-to-cook and or ready-to-serve meat products such as lollipops, fingers, patties, nuggets and sausages have stormed Indian urban markets. These products have limited shelf life at ambient temperature and have to be stored under refrigeration. Freezing, the most common method of preservation is energy consuming, expensive and it does not eliminate food borne pathogens. Lowering the energy demand and improving safety of the preserved food products is therefore desirable.

Shelf stable foods can be preserved by using hurdle technology. Hurdle technology advocates the intelligent use of combinations of different preservation factors or techniques (hurdles) in order to achieve multi target mild, but reliable preservation effects. The different hurdles inherent in a shelf stable product control microbial spoilage and food intoxication (Leistner and Gorris, 1995). Several hurdles are used minimally in optimum combination which contribute to improvement in sensory qualities, microbial stability and energy saving which pose either no or minimal legal problems due to lower levels of additives in the products. In recent decades, food irradiation has become one of the most discussed technologies for the food safety and extension of shelf life. Irradiation has become popular since all other methods of preservation either add something to meat or remove some meat constituents, whereas irradiation method of preservation kills susceptible microorganisms 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 microorganisms. 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. There is a need to improve the quality and safety of meat to enhance the export potential.

Radiation preservation accelerates lipid peroxidation and that also needs to be controlled. Synthetic antioxidants such as butylated hydroxy toluene, butylated hydroxy anisole and others are being currently used to prevent oxidative changes in foods. But with increasing dislike of consumers for synthetic antioxidants, efforts to find natural antioxidants as replacements are gaining momentum. Edible coating of food with various polysaccharides, proteins and lipids has been reported to extend the shelf life of foods and could be used in conjunction with irradiation. The de-acetylated form of chitin known as chitosan is an abundant polysaccharide found in the shells of crab and shrimps. Chitosan (poly (β (1-4) N acetyl-D-glucosamine) has been reported to possess antimicrobial and antioxidative properties that can be exploited to develop eco-friendly coating for irradiated shelf stable foods. As chitosan exhibits antimicrobial activity in the laboratory against a range of food borne filamentous fungi, yeast and bacteria, it has attracted attention as a potential food preservative of natural origin.

Since gamma radiation of meat and meat products including chicken has been permitted by PFA Act, a combined effect of hurdle technology, irradiation and application of low level of edible chitosan coating combined with vacuum packaging was undertaken

- To assess the shelf life of vacuum packaged ready-to-eat chicken fry under room temperature and chiller storage.
- To assess the effect of 0.5 per cent chitosan and low dose gamma radiation on quality parameters of chicken fry.
- To study the changes in proximate composition of ready-to-eat chicken fry due to chitosan application and irradiation and its cost of production.

Review of Literature

REVIEW OF LITERATURE

As per WHO, wholesomeness means, conducive to health including the aesthetic aspects of the food. In order to produce and market the food item, definitely there will be time gap in the marketing channel. The production, processing and marketing which requires handling, will lead to addition of contamination. The food, especially the meat produced in surplus seasons are preserved for future use and preservation of meat dates centuries back right from sun drying and various methods has been used for meat preservation from time to time. The most common method is chilling and freezing of meat which requires high level of energy input. Many of the meat preservation methods except canning doesn't destroy total microbial load present in meat and nobody can say meat is totally wholesome. Considering the wholesomeness of meat, irradiation of meat and meat products was recognized as a method of meat preservation.

2.1. RADIATION PRESERVATION OF 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).

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).

Radiation energy is measured in terms of rads where 1 rad is equal to 100 ergs of energy absorbed in 1 gram of matter. The newly introduced standard irradiation unit is Gray (Gy) where 1 Gy is equal to 100 rads. (Dempster, 1985).

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

Thayer *et al.* (1986) stated that from 1940 through 1953, exploratory research in food irradiation in United States was sponsored by the Department of Army, the Atomic Energy Commission and private industry.

The usage of irradiation to control the spoilage of food was demonstrated in the early decades of the 20^{th} century. However, no commercial development occurred due to various reasons (Urbain, 1989).

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

Radiation preservation generates free radicals that may induce lipid peroxidation and other oxidative changes as well as influencing the sensory qualities of meat (Wong *et al.*, 1995).

In 1905, United States and British patents were issued for the use of ionizing radiation to kill bacteria in foods. Many research works were conducted on the physical, chemical and biological effects of ionizing radiation (ACSH, 1998).

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

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).

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

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).

A joint FAO/IAEA/WHO Study Group on high dose irradiation met in Geneva from 15th to 20th September 1997 and concluded and clearly established the wholesomeness of any food irradiated up to an overall average dose of 10 kGy (WHO, 1999). As far as India is concerned, even now the PFA Act has not amended and dose rate of 2.5 to 4 kGy is still continuing.

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 commercially (http://nucleaus.iaea.org., 2003).

Lee (2004) stated that irradiation processing of food increased microbial safety and enhanced shelf life of the food. He also stated that if irradiation is done properly it acts as a safe process for destroying food borne pathogens.

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.

2.2. FOOD PRESERVATION BY HURDLE TECHNOLOGY

Hurdle technology was developed several years ago as a new concept for the production of safe, stable, nutritious, tasty and economic foods. It advocates the intelligent use of combinations of different preservation factors or techniques (hurdles) in order to achieve multi-target, mild but reliable preservation effects. These hurdles establish a series of preservative factors that any microorganisms present should not be able to overcome the changes like temperature, water activity, p^H, redox potential, preservatives, and so on (Leistner and Gorris, 1995). They have also reported more than 50 different hurdles for preservation of various foods.

In a study conducted by Karthikeyan *et al.* (2000) on the application of hurdle technology for the development of keema and its stability at ambient temperature, it was observed that different hurdles like water activity, p^H, vacuum packaging, preservatives and heat treatment improved the shelf life without affecting the physico-chemical, microbiological and sensory characteristics of the product.

Hurdle technology can be used in industrialized as well as in developing countries for the gentle but effective preservation of foods. The physiological responses of microorganisms during food preservation (i.e., their homeostasis, metabolic exhaustion, stress reactions) are the basis for the application of advanced hurdle technology (Leistner, 2000).

Chawla and Chander (2004) studied the microbiological safety of shelf-stable meat products prepared by employing hurdle technology and demonstrated that the different hurdles employed like irradiation, reduced water activity and vacuum packaging could significantly reduce the growth of *Clostridium sporogenes, Staphylococcus aureus* and *Bacillus cereus* in intermediate moisture mutton kababs.

2.3. CHITOSAN

Chitosan can be obtained from crustacean shells (shrimps, crab and crayfishes) either by chemical or microbiological processes and also can be produced by some fungi (*Aspergillus niger, Mucor rouxii, Penicillium notatum*) (Knorr, 1984).

Chitosan (poly (β (1-4) N acetyl-D-glucosamine) is the deacetylated form of chitin which is a natural biopolymer. The preparation of chitosan is from shell fish waste by various processes like deproteinisation, demineralization and decolouration to yield chitin which is further deacetyleted to produce chitosan (Kurita, 1986).

Polysaccharides, a class of natural macromolecules have the tendency to be extremely bioactive and are generally derived from agricultural feed stock or crustacean shell waste. Chitin and chitosan are derived from shell waste and chitin is next to cellulose in availability (more than 10 gigatons) (Ramesh and Tharanathan, 2003).

Devlieghere *et al.* (2004) reported that various methods of preparation of chitosan result in differences in the deacetylation degree, distribution of acetyl groups, chain length and conformational structure of chitosan and will have an influence on solubility, antimicrobial activity and other properties.

Kanatt *et al.* (2004) reported the production of irradiated chitosan and its use as a natural antioxidant for minimizing lipid peroxidation of radiation processed lamb meat.

Rinaudo (2006) reported that solubility of chitosan is related to decetylation, ionic concentration, and pH, nature of the acid used for protonation, distribution of acetyl groups along the chain and conditions of isolation and drying. Chitosan is usually soluble in acidic solutions and is tested in acetic acid by dissolving it in 1 per cent or 0.1 M acetic acid.

Chitosan is a de-N-acetylated analog of chitin and is a hetero polysaccharide consisting of linear β-1, 4-linked GlcN and GlcNAc units. The

molecular weight is as high as 10^6 Daltons. The heterogeneous conditions during acetylation provide a block wise distribution of acetyl groups in chitosan. GlcN and GlcNAc units determine the physicochemical and biological properties of chitosan (Prashanth and Tharanathan, 2007).

2.3.1. Food Applications of Chitosan

Gennedios and Hanna (1997) reviewed the application of edible coatings on meat, poultry and sea foods and opined that edible coatings can improve the quality of fresh, frozen and processed meat, poultry, and sea food products by retarding moisture loss, reducing lipid oxidation and discolouration. The various food coatings like lipids, polysaccharides and protein based edible coatings enhanced the product appearance in retail packages by eliminating dripping. They also acted as carriers of food additives such as antimicrobial and antioxidant agents.

Shahidi *et al.* (1999) reported the application of chitosan in food industry as an antimicrobial agent having bactericidal and fungicidal properties. Also stated the use of chitosan as an edible film and coating to extend the shelf-life and improve the quality of fresh, frozen and fabricated foods.

Develieghere *et al.* (2004) reported that chitosan can be applied as a coating on fruits and vegetables and observed that *Bacillus cereus* was very sensitive to chitosan while *Listeria monocytogenes* and different lactic acid bacteria were less susceptible.

Chitosan and its derivatives have got application in food industry as a protective, fungistatic and antibacterial agent. It can be used as a dietary fibre and to reduce cholesterol as it can bind to lipids (Rinaudo, 2006).

Prashanth and Tharanathan (2007) reviewed on the antimicrobial and antioxidant properties of chitosan and its use in food industry and reported that chitosan had a broad-spectrum antimicrobial activity against both gram-positive and gram-negative bacteria and fungi.

2.4. EFFECT OF CHITOSAN AND IRRADIATION ON MEAT AND MEAT PRODUCTS

2.4.1. Shelf Life

According to Dempster (1985) low dose irradiation can destroy microorganisms of public health significance and extend 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, and the shelf life of irradiated minced meat at 1.0 kGy and 2.5 kGy was acceptable for 2 and 4 weeks respectively at 0 to 3°C storage. In contrast, non-irradiated meat chunks and mince were spoiled within one week at the same storage condition.

Extended chiller storage was observed for ground beef patties for 14, 21 and 42 days when irradiated at 1.0, 3.0 and 5.0 kGy, respectively (Roberts and Weese, 1998).

Sagoo *et al.* (2002) found that dipping of chilled pork sausages in 1 per cent chitosan solution increased its shelf life from 7 to 15 days, when stored at 7°C.

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 effect on consumer acceptance and sensory characteristics and were acceptable up to 32 days under refrigeration compared to 14 days in case of non-irradiated samples.

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 non-irradiated samples (Al-Bachir, 2005).

In a study conducted by 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 was extended by more than 2 weeks at 0 to 3°C compared to corresponding non-irradiated samples.

Rao *et al.* (2005) observed an extended shelf-life of intermediate moisture mutton kababs by application of chitosan and irradiation from 7 days to 28 days in the sample when stored at ambient temperature.

Jenifer (2006) found that irradiation of minced beef at 1.0, 2.0 and 3 kGy has increased the keeping quality up to 10, 25 and 33 days respectively at chiller temperature.

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.

According to Sunil *et al.* (2007) 1.0 and 1.5 per cent chitosan application can extend the shelf-life of minced buffalo meat by three and five days respectively in chiller storage compared to that of the control.

2.4.2. Packaging and Irradiation

A doubling in the shelf life in vacuum packaged beef cuts irradiated at 2.0 kGy was observed when compared to non-irradiated samples by Niemand *et al.* (1981). The control samples had an acceptable shelf life of approximately three weeks, whereas that of irradiated samples was more than eleven weeks at 4^0C storage.

Lee *et al.* (1983) found that 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.

In a study conducted by Smith *et al.* (1983) it was found 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 for 0 to 28 days.

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

According to Monk *et al.* (1995) vacuum packaging and irradiation of fresh ground beef at 1.5 and 2.5 kGy extended the shelf life by more than 15 and 21 days, respectively compared to 4 days in non-irradiated.

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 non-irradiated samples.

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

Lacorix *et al.* (2000) conducted irradiation of pork and reported that irrespective of packaging treatment and dose of radiation, all pork samples could be stored at 4 ± 1°C without bacterial spoilage for 43 days.

In a study conducted by Balamatsia *et al.* (2006) it was found 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.

Sabapathy and Bawa (2007) reported that the changes that might occur in packaging materials due to irradiation generally depend on the type of radiation and energy level, as well as the composition, physical state, temperature and

environment of the absorbing material and the contact between food and the packaging material.

2.4.3. Physical Qualities (Colour and Odour)

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 those stored under vacuum or modified atmosphere containing 20 per cent carbon dioxide and 80 per cent nitrogen (Seideman *et al.*, 1979).

According to Narsimharao and Sreenivasmurty (1986) unacceptable odour in fresh meat was developed by 6 days at 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 non-irradiated 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, and the shelf life of irradiated mince was 2 and 4 weeks. In contrast, non-irradiated 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.

Rodriguez *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 micro flora and enhancing the shelf life under refrigeration.

According to Zhao *et al.* (1996) odour scores for pork in air permeable packages were higher initially then decreased after 2 weeks of storage. The odour scores between irradiated and non-irradiated 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 minimized oxidative change in turkey patties and produced minimal amount of volatile compounds that might be responsible for off odour during storage (Ahn *et al.*, 2000). .

Badr (2004) reported that panelist preferred both irradiated and non-irradiated rabbit meat, as the samples were having high acceptance as judged by appearance and odour until rejection. Non-irradiated 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.

2.4.4. Physicochemical Qualities

2.4.4.1. Proximate Composition

According to Sakala *et al.* (1987), 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 non-irradiated (65.0 %) and irradiated (64.0 %) chicken meat at 100, 200, and 300 k rads.

In a 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 did not observe significant difference in the values of proximate composition between irradiated and non-irradiated patties up to 5 weeks in chiller storage.

Wu *et al.* (2000) studied the moisture loss and lipid oxidation of pre-cooked beef patties stored in edible coatings and observed 66 per cent reduction in relative moisture loss in chitosan coated beef patties after three days of storage.

In a study conducted by Du *et al.* (2001a) on the cooked patties prepared from chicken meat and packed in oxygen permeable or impermeable bags and irradiated at 0 or 3 kGy, it was found that the average moisture, fat and pH were not affected by irradiation.

Daoud *et al.* (2002) studied effect of gamma irradiation (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.

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 (Lee, 2004).

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 volatiles (Al-Bachir, 2005).

Rana Raj (2006) observed that irradiation at different doses did not significantly affect ($P<0.05$) proximate composition like moisture, ether extract, protein, crude fiber, ash, nitrogen free extract, gross energy, calcium and phosphorous content of intermediary moisture pet food.

2.4.4.2. 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.

Darmadji and Izumimoto (1994) observed that decrease in TBA value of minced beef depended on chitosan concentration. At concentrations of 0.2, 0.5 and 1.0 per cent, the TBA value decreased by 10, 25, and 40 per cent respectively during storage at 4°C.

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 non-irradiated.

Shahidi *et al.* (1999) reviewed about the antioxidant properties of chitosan in muscle foods for reducing the TBA values and warmed-over-flavor in cooked poultry and uncured meat.

Alasnier *et al.* (2000) determined the changes incomposition and amount of free fatty acids and TBARS in chicken breast and thigh muscle between 1 and 14 days of storage at 4°C and reported that lipolysis did not promote lipid oxidation.

In a study conducted by 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 zero. Irradiation effect on TBARS of both vacuum and aerobic packaged cooked meat was not as significant and consistent as that of day zero, indicating that irradiation had only a minor impact on the oxidation of cooked meat lipids during storage.

Du *et al.* (2001b) reported that at day 0, the TBARS of aerobically packaged turkey and pork patties were 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 and had only a minor effect.

In a study conducted by Kamil *et al.* (2002) on the antioxidative activity of chitosans of different viscosity in cooked comminuted flesh of herring (*Clupea harengus*) observed lower peroxide values, TBARS and total volatile aldehydes than the control samples. Low viscosity chitosan (14cP) exhibited the strongest antioxidative effect.

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

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.

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

Aerobic packaging and irradiation 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).

Kanatt *et al.* (2004) reported the production of irradiated chitosan and its use as a natural antioxidant for minimizing lipid peroxidation of radiation processed lamb meat. They found that irradiated chitosan was more effective in minimizing lipid peroxidation than non-irradiated chitosan as measured by TBA number and carbonyl content.

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 non-irradiated 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 0 or 14 days of refrigerated storage (Zhu *et al.*, 2004).

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

Rao *et al.* (2005) developed shelf stable intermediate moisture foods using active edible chitosan coating and irradiation and found that chitosan coating reduced TBARS values by 24 and 28 per cent in irradiated mutton kababs and intermediate moisture bacon respectively.

2.4.4.3. Tyrosine Value

Proteolysis measured in terms of tyrosine equivalent and total amino acid content, was found to proceed more rapidly in breast muscle of chicken from vacuum packs than from oxygen permeable packs, may be due to difference in proteolytic activity between two types of micro flora (Jones *et al.*, 1982).

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).

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 films 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 film for oxygen led to lower proteolysis and hence the lowest tyrosine values.

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.

In a study conducted by Balamatsia *et al.* (2006) it was found that volatiles amines, both trimethyl amine nitrogen (TMA-N) and total volatile basic nitrogen (TVB-N) values for aerobically packed non-irradiated chicken increased steeply, while aerobically packed irradiated sample showed lower TMA-N and TVB-N values ($P<0.05$) 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 zero. As storage days increased, tyrosine value increased with significant change among the treatments.

2.4.5. Microbiological Analysis

2.4.5.1. Aerobic Plate Count (APC)

According to Niemand *et al.* (1981) 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 and thereafter control samples maintain level of approximate log 8 bacteria/g whilst the number in radurized samples slowly increased until it reached unacceptable by 11 weeks.

Basker *et al.* (1986) showed that irradiation of raw whole chicken carcass by 2 to 4.5 kGy reduced the initial total aerobic mesophilic count by a factor of 10^3 to 10^4, and during subsequent storage at 4°C for 30 days the total count gradually rose to the initial value of non-irradiated samples.

Irradiation dose required for inactivating 90 per cent of the colony forming units (cfu) of common foods borne pathogens associated with meat and meat products were in the range of 1.0 to 4.0 kGy (Thayer, 1993).

Darmadji and Izumimoto (1994) studied the effect of chitosan in meat preservation and observed that 0.5-1.0 per cent chitosan inhibited the growth of spoilage bacteria in meat during incubation at 30°C for 48 hours or at 4°C for 10 days.

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.

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

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

Shahidi *et al.* (1999) described the antimicrobial activity of chitin, chitosan and their derivative against different bacteria and the concentration of chitosan required for bacterial inhibition depends on the degree of acetylation of chitosan.

In a study conducted by Lewis *et al.* (2002) found 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.

No *et al.* (2002) studied the antibacterial activities of chitosan and chitosan oligomers with different molecular weights on spoilage bacteria isolated from Tofu and observed 3 to 4 log cycle reduction in *Bacillus* species isolated from Tofu by treatment with chitosan.

Quattara *et al.* (2002) observed significant results ($P<0.05$) by combining γ-radiation and edible coating on APC of shelf stable foods like pre-cooked shrimps.

Dipping the chilled pork sausages in 1 per cent chitosan solution reduced the total viable count by 1-3 log cfu g^{-1} when stored at 7°C and increased the shelf life of chilled skinless sausages from 7 to 15 days (Sagoo *et al.*, 2002).

In a refrigerated storage (0-3°C) of irradiated (3 kGy) ethnic Indian meat products, non-irradiated 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. Control samples of mutton shammi kababs spoiled in less than a week, while irradiated samples spoiled after 28 days of storage. Non-irradiated 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).

In a study to determine the antimicrobial effects of chitosan films and chitosan films enriched with essential oils Zivanovic *et al.* (2005) found that application of pure chitosan films reduced pathogen counts on bologna from 1-3 log when stored at 10°C for 5 days.

Chouliara *et al.* (2006) noted that the APC 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). *Pseudomonas* showed 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 undetectable.

Kim *et al.* (2007) found that chitosan significantly inhibited the growth of *Salmonella enteritidis* up to 9 log cfu/ml during storage of chitosan coated eggs at 25°C for 4 weeks.

Kutinarayanan (2007b) studied the effect of low dose gamma radiation on quality parameters of buffalo beef and observed that irradiation at a dose of 2.5 kGy significantly reduced the aerobic plate count and about 2.5 log reduction was noticed.

Prashant and Tharanathan (2007) reported that chitosan caused extensive cell surface alterations and it covered the outer membrane of bacteria with vesicular structures resulting in the loss of the barrier functions and stated that chitosan is useful in the preservation of meat and meat products.

In a study conducted by Sunil *et al.* (2007) on the antimicrobial activity of chitosan on minced buffalo meat, a significant ($P< 0.05$) reduction in APC in meat mince with 0.5 per cent and 1.0 per cent chitosan was observed on day eight of storage. Addition of chitosan resulted in one log reduction in *Staphylococcus aureus* counts on day six of chiller storage.

2.4.5.2. Psychrotrophic Count (PC)

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 by 70 days storage.

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

Irradiated (100 krad) vacuum packaged pork loins showed less psychrotrophic count of 0.7 to 1.9 log cfu per g than non-irradiated 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 micro flora during early storage, *Serratia liquefaciens* increased with storage time and *Enterobacter aerogenes* appeared at late storage period during 12 days 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) observed 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.

In a study conducted by Gomes *et al.* (2003) found that psychotropic bacterial counts were higher for non-irradiated samples in mechanically deboned chicken meat up to day eight in refrigeration than irradiated samples. However, psychrotrophic bacterial count exceeded the recommended limit of 6.48 log cfu

per g after six days in non-irradiated, 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).

Salke Dinkar Babanrao (2007) observed a significant reduction ($P<0.05$) in psychrotrophic count due to irradiation and vacuum packaging of beef cutlets under chiller storage.

2.4.5.3. Yeast and Mould Count (Y&M)

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 (Niemand *et al.*, 1983).

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 by irradiation with 2.5 kGy. They also stated that *Sporobolmyces roseus* exhibited least resistance whereas *Trichosporon* and *Candida* showed 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 irradiated at less than 5.0 kGy, but not in samples treated with more than 5 kGy and stored at $4^{\circ}C$ 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.

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 toxins from moulds, *Staphylococcus aureus* and *Clostridium botulinum* were extremely resistant to irradiation and could not be effectively eliminated at approved dose of irradiation of 10 kGy (Doyle, 1999).

Shahidi *et al.* (1999) opined that chitosan reduced the invitro growth of numerous fungi with exception of *Zygomycetes* which contain chitosan as a major component of its cell wall.

Sagoo *et al.* (2002) observed that dipping the chilled pork sausages in 1 per cent chitosan solution reduced the yeast and mould count by 1-3 log cfu/g when stored at 7°C.

Gamma irradiation studies 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.

Sebti *et al.* (2005) found that 0.1 per cent chitosan inhibited the total growth of *Aspergillus niger* for 10 days.

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.

According to Chouliara *et al.* (2006) yeast was 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 survived 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 of yeast and mould count in minced beef by irradiation at 2.0 kGy.

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

2.4.6. Organoleptic Qualities

2.4.6.1. Colour

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

Darmadji and Izumimoto (1994) opined that addition of chitosan to meat resulted in better sensory attributes and had good effect on the development of red colour of meat during storage. There was an increase in a* and b* values of all chitosan added meat samples during storage.

In a sensory evaluation of irradiated ground beef (1.0, 2.5 and 5.0 kGy) conducted, revealed 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 (Lefebvre *et al.*, 1994).

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 which quickly dissipated after opening vacuum pouches.

Zhao *et al.* (1996) observed colour of irradiated pork was significantly less desirable than un-irradiated 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.

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.

The 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 (Jo *et al.*, 2000).

Zhu *et al.* (2003) reported that irradiation up to 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 had no significant effect on flavour, texture or colour of ground beef.

2.4.6.2. Flavour

A higher ranking was observed for appearance and odour for minced beef by Niemand *et al.* (1981) throughout the storage period 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.

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

According to Zhao *et al.* (1996) odour of irradiated products was as less desirable than non-irradiated but score did not change during 4 weeks of storage. For non-irradiated pork in air permeable packages, odour score were high initially, then decreased after 2 weeks of storage. Score between irradiated and non-irradiated 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 *et al.* (2000) did not observe any dose dependant odour preferences of pork patties with vacuum packaging but panelist preferred odour of aerobic-packaged non-irradiated samples to that of irradiated ones at day zero. Non-

irradiated patties stored for 1or 2 weeks in vacuum and aerobic packaging showed lower odour preferences than those of the day zero.

Dietary conjugated linoleic acid treatment had not shown any 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.

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 non-irradiated. But no difference was detected between irradiated (1.0 kGy) and non-irradiated 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 twice higher than that of non-irradiated samples and irradiation did not show significant effect on colour and texture of ready-to-eat turkey breast rolls.

Arthur *et al.* (2005) observed no difference in flavour of irradiated (1 kGy) and non-irradiated 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.

2.4.6.3. 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.

According to Smith *et al.* (1983), seven 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 having 20% CO_2 80% N_2 or 40% CO_2 60% N_2. There was no difference in juiciness, flavor, 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, odour, 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).

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

2.4.6.4. 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 (Forrest *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 packed 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.

Kanatt *et al.* (2006) observed that irradiation treatment did not cause any significant changes in the textural properties and sensory qualities of ready to eat shrimps.

2.4.6.5. Overall acceptability

Darmadji and Izumimoto (1994) reported that addition of chitosan to meat resulted in an increase in overall sensory attributes. There was a decrease in rancidity and spoilage flavours of beef mince prepared with chitosan thereby causing a more acceptable taste.

In a consumer acceptance study 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 (Hashim *et al.*, 1995).

Sawant (1998) observed the spoilage changes of un-irradiated 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 non-irradiated kababs on storage.

Johnson *et al.* (2004) reported that overall acceptance of flavour, juiciness, tenderness and mouth feel of non-irradiated 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.

According to Kanatt *et al.* (2005) overall sensory scores for appearance, flavour and texture of irradiated samples (1, 2 and 3 kGy) of various meat products (chicken chilly, mutton shammi kababs and pork salami) were different from its non-irradiated 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.

Kuttinarayanan *et al.* (2006b), conducted a study on the keeping quality and organoleptic studies of beef fry preserved by employing gamma radiation and found that physicochemical characters (p^H, thiobarbituric acid reacting substance and tyrosine value) and organoleptic evaluation (with respect to colour, flavor, tenderness, juiciness and overall acceptability) using nine point hedonic scale didn't reveal any marked difference between irradiated and non-irradiated sample even after 28 days of storage at chiller temperature.

2.5. COST OF PRODUCTION

The cost structure for the preparation of ready-to-cook quail meat patties was calculated by Kamna (1994) and the cost of production was Rs. 78.4 per kilogram of quail meat patty.

Sangilimadan (1997) calculated the cost of ready-to-cook duck meat sticks prepared by two different recipes and obtained Rs. 5.63 and Rs. 5.73 as the cost of one duck meat stick prepared by the different recipes.

In a study conducted by Murugan (1998) on the assessment of the quality of tenderized chicken meat pickle, and found that the cost of production of one kg chicken pickle prepared using untenderized and tenderized meat as Rs. 60.27 and Rs. 60.45 respectively.

The cost of production of low fat turkey loaf was calculated by Naseera (2007) and obtained Rs.160.00, Rs.179.00, Rs.167.00 and Rs.164.00 for added fat product, low fat product, low fat with carrageenan and low fat with non fat dry milk respectively.

Materials and methods

MATERIALS AND METHODS

The study on the effect of low dose gamma radiation and chitosan on shelf-life and quality changes of ready-to-eat chicken fry under vacuum packaging was conducted at the Department of Livestock Products Technology, College of Veterinary and Animal Sciences, Mannuthy, during the period November 2007 to April 2008.

Six batches of chicken fry were prepared, packaged, irradiated at 2.5 kGy and stored at room temperature (25-30°C) and chiller conditions (1-4°C). Samples were analysed for physical, physicochemical, microbiological and organoleptic qualities on the day of preparation and on day 5, 10, 15, 20, 30, 40, 50, 60 and 70 of storage or until spoilage, whichever was earlier. The samples were also analysed for proximate composition on the day of preparation.

3.1. PREPARATION OF CHICKEN FRY

Broiler chicken weighing approximately 1.9 to 2.0 kg were procured from the local market, slaughtered and dressed under hygienic conditions at the Department of Livestock Products Technology. The cleaned and washed carcasses were made into cuts of uniform size of about 30 mm cubes. Gizzard, liver and spleen were not included with the cuts.

The composition of the marinade is given in the table 1 and the flow chart for preparation of chicken fry is given in the figure 1. The marinade was prepared by mixing the ground spices with other ingredients. The cut-up parts of chicken were uniformly coated with the marinade and kept at room temperature for 1½ hours. The marinated cuts were deep fat fried in double refined deodorised vegetable oil.

3.1.1. Coating with Chitosan

Chitosan (poly β (1-4) N acetyl-D-glucosamine) having more than 85 per cent deacetylation (Marine Chemicals, Cochin) was dissolved in one per cent glacial acetic acid in order to prepare 0.5 per cent solution weight by volume. The ready-to-eat chicken fry was divided into two batches and one batch was coated

with 0.5 per cent chitosan solution. The other half was coated with one per cent glacial acetic acid alone.

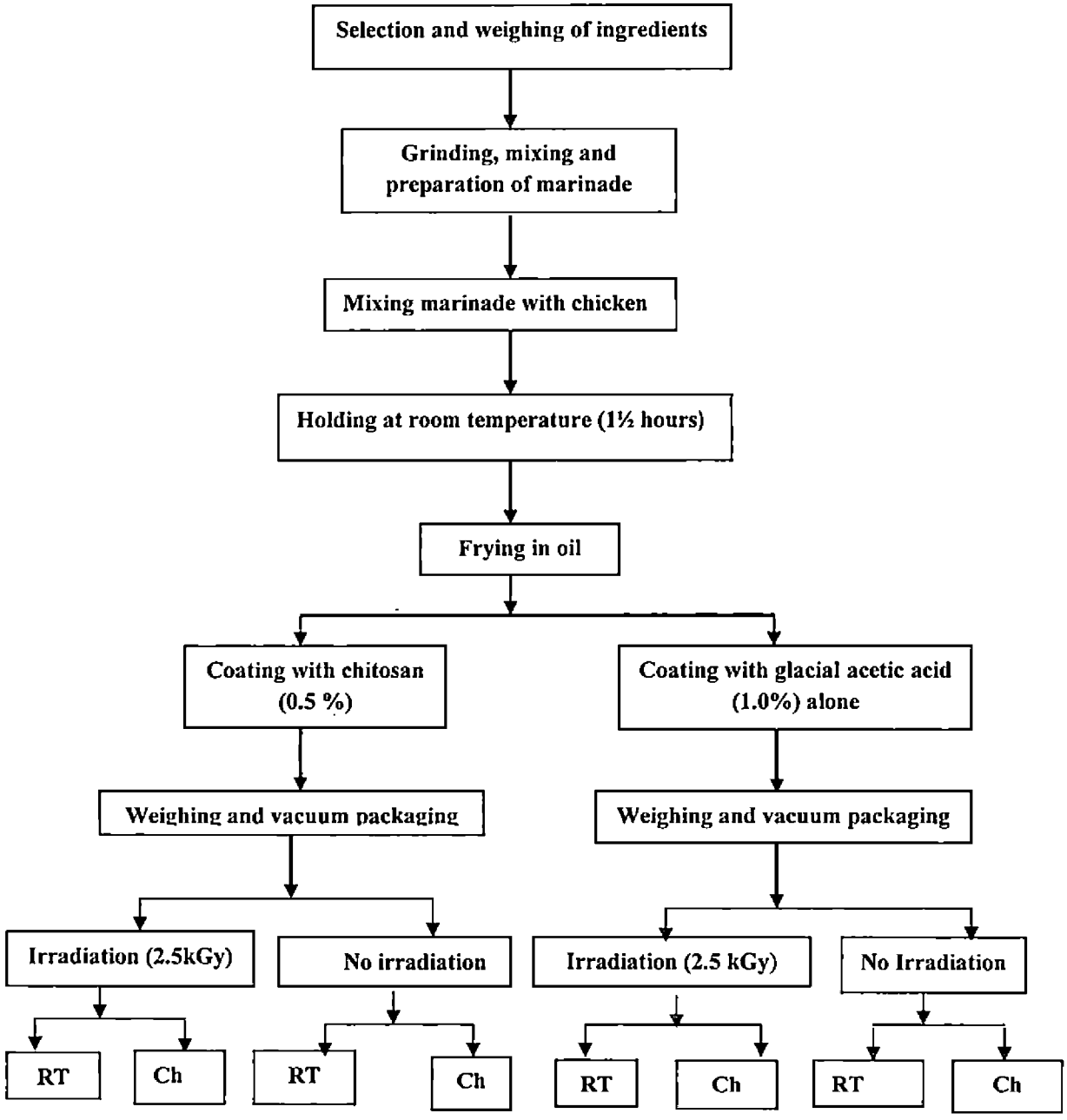
3.2 VACUUM PACKAGING

The prepared chicken fry was packaged at a rate of 80 grams per packet 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) and sealed under vacuum (740 mm of Hg) using a single chamber vacuum packaging machine (Sevana, Kochi).

Table 1. Composition of the marinade for chicken fry

Ingredients	Quantity(g)
Chicken	1000
Turmeric powder	1.40
Salt	17.0
Pepper	5.0
Anise	3.3
Clove	1.0
Cinnamon	1.0
Red Chilly powder	5.0
Coriander powder	3.0
Shallots	25.0
Ginger paste	25.0
Garlic paste	15.0
Tomato	160.0
Corn flour	15.0
Plain flour (Maida)	25.0

Figure 1. Flow chart for the preparation of chicken fry



RT : Room temperature (25-30°C)

Ch : Chiller (1-4°C)

3.3. GAMMA RADIATION

The vacuum packaged samples were subjected to gamma radiation at 2.5 kGy at melting ice temperature using Gamma Chamber 5000, (BRIT-DAE, Mumbai) where ^{60}Co is the source of radiation. The non-irradiated control samples were designated as NIR, irradiated samples as IR, the chitosan coated samples as CH-NIR and chitosan coated irradiated samples as CH-IR.

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 1-4°C were analysed on day 0, 5, 10, 15, 20, 30, 40, 50, 60 and 70 or until spoilage for the following parameters.

3.4. PHYSICAL QUALITIES

Chicken fry packets stored at room temperature were opened on 0, 5, 10 and 15 days of preparation and examined for signs of spoilage, viz., change in colour, odour, consistency, and slime formation and mould growth. The samples kept at the chiller storage were examined on day 0, 5, 10, 15, 20, 30, 40, 50, 60 and 70 of preparation and recorded as spoiled or non spoiled with the help of the same physical parameters.

3.5. PHYSICO-CHEMICAL QUALITIES

3.5.1. Proximate Analysis

Chicken fry was analysed for its proximate composition, viz., moisture, fat, protein and ash content on the day of preparation. The composition was expressed as percentage of the chicken fry.

3.5.1.1. Moisture

The moisture content of the chicken fry was analysed as per AOAC (1990). A 30 g sample in an evaporating dish was kept in a hot air oven set at 100±2°C for 16 to 18 hours. The weight of the dried samples was taken after

cooling in a desiccator. The difference in the weight was the moisture content of the sample and expressed as percentage of the chicken fry.

3.5.1.2. Fat

Fat was estimated as per AOAC (1990). Fat content of three gram of moisture free sample was extracted in petroleum ether (boiling range 40-60°C) 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 chicken fry.

3.5.1.3. Protein

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

$$\text{Protein \%} = 6.25 \times \text{\% Nitrogen.}$$

3.5.1.4. Ash

Five gram of the sample in a silica crucible was ashed in a muffle furnace set at 600±20°C for 2.5 hours. Then the crucible with white ash was transferred to a desiccator, allowed to cool and weighed. The difference in weight is the total mineral content of the sample (AOAC, 1990) and expressed as percentage of the chicken fry.

3.5.2. Thiobarbituric Acid Reacting Substances (TBARS)

The TBARS were determined as per Alasnier *et al.* (2000).

Four grams of the sample was homogenised in 16 ml of 5 per cent trichloroacetic acid. Butylated hydroxytoluene (10µl of 0.1 per cent) was added to prevent oxidation due to homogenisation. The homogenate was filtered through Whatman No. 4 filter paper and 2 ml of filtrate was mixed with 2ml of 0.02M

thiobarbituric acid solution. The samples were kept in boiling water bath for 30 min and then cooled and centrifuged at 8000 rpm for 10 min to obtain a clear supernatant. The absorbance of the pink coloured supernatant was measured at 532 nm against a blank containing 2ml distilled water and 2ml 0.02M thiobarbituric acid solution in UV-Vis Spectrophotometer 119 (Systronics, India). The values were expressed as mg of malonaldehyde per kg (mg mal/kg) of the sample.

3.5.3. Tyrosine Value (TV)

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

3.5.3.1. Preparation of trichloroacetic acid extract

Twenty grams of sample was blended in 50 ml of cold 20 per cent trichloroacetic 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.

3.5.3.2. 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 chicken fry.

3.5.3.3. Standard Graph for Tyrosine Value

Accurately weighed 100 mg of L-tyrosine was dissolved in 500 ml of 5 per cent trichloroacetic acid 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 N 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 (Figure. 2).

3.6. MICROBIOLOGICAL ANALYSIS

Sealed packets of chicken fry were opened under aseptic conditions and 25 g of the sample was homogenized for 30 seconds at 230 rpm with sterile 225 ml of 0.01 per cent peptone water (diluent) in a stomacher (Seward Stomacher® 400 circulator) so as to form one in 10 dilution of the sample. Further serial 10 fold dilutions were prepared by transferring one millilite of inoculum to nine millilitre of the diluents. Selected serial dilutions were used to estimate the load of aerobic bacteria, psychrotrophic bacteria and yeast and mould and expressed as $\log_{10}$ cfu/g of sample. .

3.6.1. 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 of size 100×17 mm. 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 clockwise, anticlockwise, forward and backward movements. The inoculated plates were allowed to solidify at room temperature and incubated at 37°C for 24 hours in inverted position. At the end of the incubation period, the plates having colonies between 20 and 200 were selected and 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

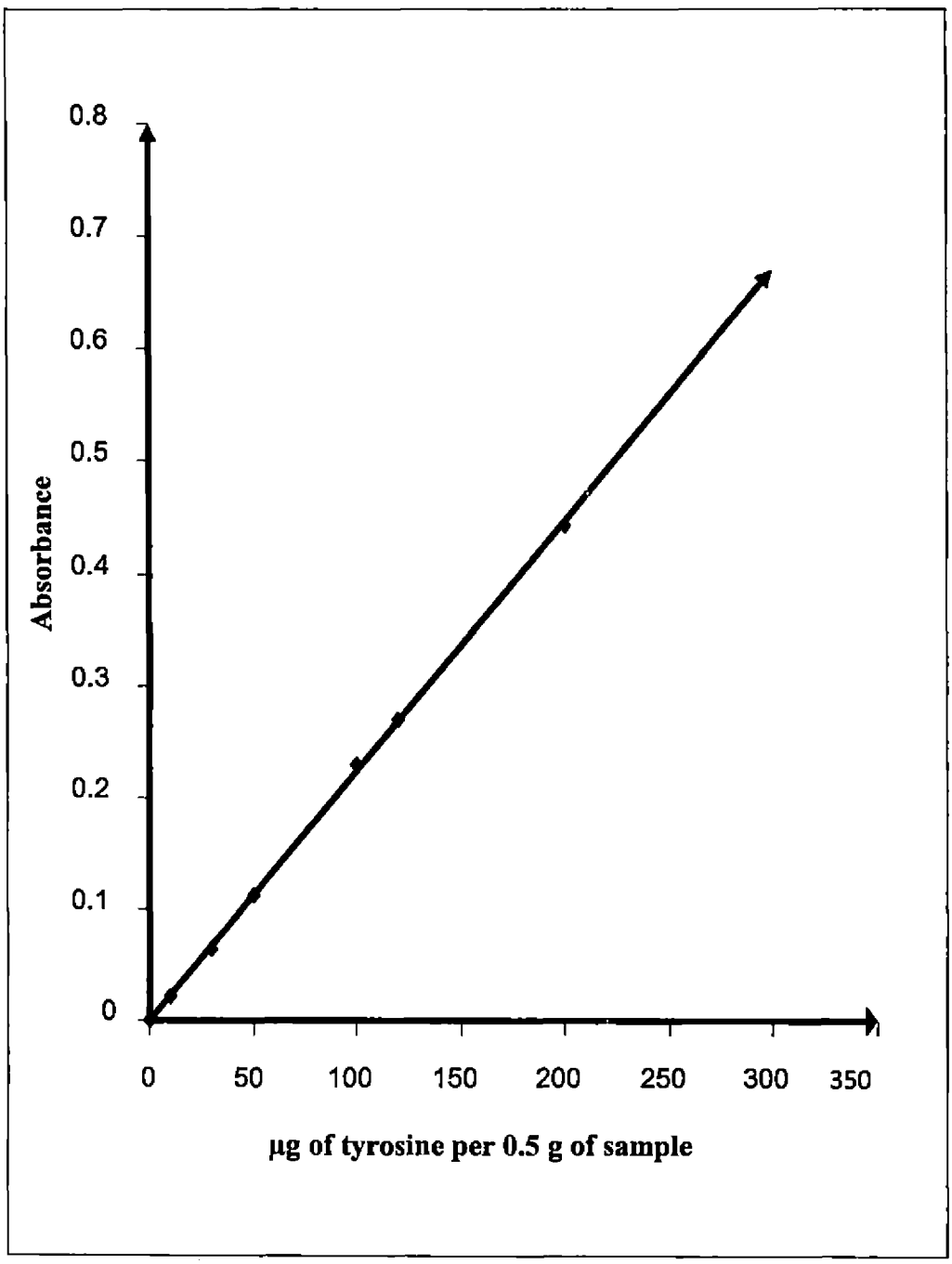


Figure 2. Standard graph for Tyrosine value

calculated by taking the average of duplicate plates and multiplied by the dilution factor and converted to $\log_{10}$ cfu/g of sample.

3.6.2. 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 7 ± 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.

3.6.3. 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 inoculum was transferred on to duplicate plates. To each plate 15 to 20 ml of sterile 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 average 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 chicken fry was conducted with the help of semi trained taste panelists drawn from the Department of Livestock Products Technology, Mannuthy. Uniform amount of the product from each group was selected and was heated to 65°C. The panelists were served with coded samples and a score card was also provided (Table 2). They were asked to rate in the nine point Hedonic scale (Badr, 2004). The individual scores were recorded and the average was taken as the score for the particular attribute.

Table 2. SCORE CARD FOR TASTE PANEL EVALUATION

Name of the Product: **Chicken Fry** 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:

3.8. COST OF PRODUCTION

The cost of production of chicken fry was calculated based on the prevailing cost of chicken and other ingredients used for the preparation.

3.9. STATISTICAL ANALYSIS

The data obtained on physicochemical, microbiological and sensory evaluation of samples were statistically analysed by one-way analysis of variance up to 20 days of storage period and thereafter by *t*-Test (Two samples assuming equal variances) as per Snedecor and Cochran (1994).

Results

RESULTS

Six batches of ready-to-eat chicken fry were prepared. Half of the prepared chicken fry was coated with 0.5 per cent chitosan in one per cent glacial acetic acid. The other half was coated with equal quantity one per cent glacial acetic acid. The whole samples were packed under vacuum in PA-PE pouches having 80g in each packet. Half of the packets from each treatment were irradiated at 2.5 kGy employing Gamma Chamber 5000. Sufficient numbers of packets from each treatment were stored under room temperature (25-30°C) and in chiller (1-4°C). Samples were analysed on the day of preparation for proximate composition like moisture, protein, fat, ash and carbohydrates. The stored samples up to spoilage were assessed for physicochemical characters like TBARS and TV, microbiological parameters like aerobic plate count, psychrotrophic count and yeast and mould count and organoleptic qualities.

4.1. PHYSICAL QUALITIES AND SHELF-LIFE

The samples kept both in chiller and room temperature were examined for the presence of signs of spoilage like odour, colour, slime formation and mould growth. The spoiled samples were discarded and were not subjected to any further analysis. The appearance of the meat product is the principal characteristic by which the consumer accepts the product. The shelf life assessed with the physical qualities like odour, colour, slime formation and mould growth are shown in table 3 and presented in figure 3.

It was observed that the control samples (NIR) had the shortest storage life compared to others in both room temperature and chiller storage. This was followed by chitosan coated non-irradiated samples (CH-NIR), irradiated (IR) and chitosan coated irradiated (CH-IR) samples. The study has shown that chitosan coated vacuum packaged and irradiated samples had the longest storage life of 73.16±0.33 days in chiller and 10±0.28 days at room temperature.

The non spoiled samples were subjected to various analysis on day 5, 10. 15, 20, 30, 40, 50, 60, and 70 or till its spoilage, whichever was earlier.

Table 3. Shelf life of chicken fry based on physical signs of spoilage (Days)

Treatment Groups	Room Temperature	Chiller Storage
NIR	5.33 ± 0.23	28.16 ± 0.33
IR	8.0 ± 0.28	67.33 ± 0.46
CH-NIR	7.33 ± 0.23	32.5 ± 0.46
CH-IR	10.0 ± 0.28	73.16 ± 0.33

4.2. PHYSICOCHEMICAL QUALITIES

The physicochemical qualities like proximate composition, TBARS and TV were assessed on the day of preparation and on days 5 and 10 in case of room temperature samples and up to 70^{th} day in case of chiller samples.

4.2.1. Proximate Composition

The ready-to-eat chicken fry were analysed for proximate composition like moisture, protein, fat and ash. The carbohydrates and other components were assessed by subtracting the sum of these from 100. The data is given in table 4.

On an average, the product had a non significant moisture content of 44.61±.01 (NIR). The moisture, fat, protein and ash were not significantly affected due to various treatments. Sample had a very good protein per cent of roughly 26 per cent and fat 20 per cent. Neither the ash nor the carbohydrates were significantly affected either due to irradiation or chitosan application. On an average the product had an energy level of 306 K Cal/100g.

Table 4. Proximate composition of chicken fry (Percentage)

Constituents	NIR	IR	CH-NIR	CH-IR
Moisture	46.61±0.01	46.56±0.02	46.63±0.02	46.57±0.01
Fat	20.23±0.02	20.31±0.01	20.25±0.06	20.31±0.01
Protein	26.73±0.01	26.81±0.02	26.76 ±0.05	26.79±0.09
Ash	1.83±0.01	1.82±0.01	1.83 ±0.03	1.82±0.06
Carbohydrate and others	4.60±0.01	4.5±0.04	4.53±0.07	4.51±0.06

4.2.2. Thiobarbituric Acid Reacting Substances (TBARS)

The TBARS values of the samples stored at chiller and room temperature are shown in table 5. On the day of preparation, the irradiated sample had significantly higher value of 0.96±0.04 mg mal/kg and lowest was recorded in non irradiated sample followed by chitosan applied samples. The trend continued up to 5th day. The highest value of 1.24±0.05 mg mal/kg was recorded in non spoiled sample in CH-IR group.

Throughout the storage period, the chitosan coated irradiated sample had lower value compared to other samples. Significantly higher values were not detected in CH-IR and CH-NIR samples compared to that of IR samples. Chitosan coated samples (CH-NIR) had higher values than CH-IR samples. The values observed on 10th day in room temperature sample were almost equal to that on day 70 in chiller storage. By 20th day, the non-irradiated samples had a value of 1.42 mg mal/kg which was higher than that of 70th day stored CH-IR samples. The trend of increase in TBARS due to storage is shown in figure 4. In all the samples, storage had a significant effect on TBARS values as revealed by the upward trend of the initial values in all samples.

Table 5. TBARS values of chicken fry (mg malonaldehyde /kg)

Treatment		Days of storage									
		0	5	10	15	20	30	40	50	60	70
NIR	RT	0.91 ± 0.04^{B}	1.21 ± 0.01^{B}	S	S	S	S	S	S	S	S
	Ch	0.91 ± 0.04^{b}	1.08 ± 0.09^{b}	1.25 ± 0.05^{c}	1.33 ± 0.05^{c}	1.42 ± 0.05^{c}	S	S	S	S	S
IR	RT	0.96 ± 0.03^{C}	1.28 ± 0.05^{C}	S	S	S	S	S	S	S	S
	Ch	0.96 ± 0.03^{c}	1.09 ± 0.05^{c}	1.23 ± 0.04^{b}	1.32 ± 0.05^{c}	1.41 ± 0.05^{c}	1.41 ± 0.05^{b}	1.44 ± 0.03	1.46 ± 0.05	1.53 ± 0.05	S
CH-NIR	RT	0.90 ± 0.07^{A}	1.18 ± 0.05^{B}	S	S	S	S	S	S	S	S
	Ch	0.90 ± 0.07^{a}	0.94 ± 0.05^{a}	0.98 ± 0.04^{c}	1.03 ± 0.08^{b}	0.19 ± 0.05^{b}	1.19 ± 0.08	S	S	S	S
CH-IR	RT	0.91 ± 0.05^{AB}	1.18 ± 0.05^{A}	1.24 ± 0.08	S	S	S	S	S	S	S
	Ch	0.91 ± 0.05^{ab}	0.95 ± 0.05^{a}	0.99 ± 0.05^{a}	1.04 ± 0.08^{a}	1.08 ± 0.07^{a}	1.08 ± 0.07^{a}	1.11 ± 0.06	1.13 ± 0.05	1.21 ± 0.01	1.24 ± 0.05

S: Spoiled, RT: Room Temperature, Ch: Chiller.

Identical superscripts in same column do not differ significantly (P>0.05).

4.2.3. Tyrosine Value (TV)

The data of tyrosine content of chicken fry is shown in table 6. On the day of preparation, the control samples had significantly higher values of 6.96±0.01 mg per 100 g compared to other treatment groups. The lowest value was recorded in CH-IR samples followed by IR samples. There was a significant increase in TV either by 5^{th} or 10^{th} day in CH-IR samples stored at room temperature.

Chiller storage had a significant effect on the TV with the lowest value in CH-IR group right from the day of preparation. The trend of increase in TV is shown in figure 5. A significantly higher value was recorded in CH-NIR samples on 30^{th} day and on 20^{th} day in case of NIR samples.

4.3. MICROBIOLOGICAL ANALYSIS

4.3.1. Aerobic Plate Count (APC)

The data of the APC of the samples stored in chiller and room temperature is shown in table 7.

The control sample had the highest value of 1.76±0.01 $\log_{10}$ cfu/g on the day of preparation followed by chitosan coated samples. Irradiation had a significant effect ($P<0.05$) on the APC of chicken fry. Chitosan coating followed by irradiation totally made the samples bacteria free. Storage has significantly increased the count both under chiller and room temperature conditions. The control samples on 20^{th} day attained a count of 5.21±0.08 $\log_{10}$ cfu/g followed by chitosan coated samples on 30^{th} day during chiller storage (5.22±0.09). Even after 70^{th} day of storage in CH-IR samples and 60^{th} day in IR samples, such a significant count was not noticed. The trend of growth of aerobic organisms is shown in figure 6. It was observed 100 per cent reduction due to chitosan coating followed by irradiation where as irradiation alone has reduced the bacterial count by 53 per cent. Under room temperature storage, the count enhanced up to 2 to 3 times by 10^{th} day where as in chiller storage a slow and steady increase was observed up to the spoilage of the samples.

Table 6. Tyrosine values of chicken fry (mg/100 g)

Treatment		Days of storage									
		0	5	10	15	20	30	40	50	60	70
NIR	RT	6.96 ± 0.01^{D}	7.53 ± 0.08^{C}	S	S	S	S	S	S	S	S
	Ch	6.96 ± 0.01^{d}	7.22 ± 0.08^{d}	7.47 ± 0.01^{d}	7.77 ± 0.01^{d}	8.02 ± 0.02^{d}	S	S	S	S	S
IR	RT	6.14 ± 0.09^{B}	7.27 ± 0.07^{B}	S	S	S	S	S	S	S	S
	Ch	6.14 ± 0.09^{b}	6.22 ± 0.07^{b}	6.52 ± 0.05^{b}	6.72 ± 0.08^{b}	6.94 ± 0.08^{b}	7.04 ± 0.09^{b}	7.18 ± 0.01	7.47 ± 0.01	7.68 ± 0.09	S
CH-NIR	RT	6.83 ± 0.01^{C}	7.42 ± 0.05^{C}	S	S	S	S	S	S	S	S
	Ch	6.83 ± 0.01^{c}	7.15 ± 0.01^{c}	7.43 ± 0.01^{c}	7.65 ± 0.01^{c}	7.96 ± 0.01^{c}	8.02 ± 0.08	S	S	S	S
CH-IR	RT	6.05 ± 0.08^{A}	7.07 ± 0.08^{A}	7.23 ± 0.01	S	S	S	S	S	S	S
	Ch	6.05 ± 0.08^{a}	6.17 ± 0.01^{a}	6.43 ± 0.01^{a}	6.64 ± 0.01^{a}	6.84 ± 0.01^{a}	6.99 ± 0.01^{a}	7.13 ± 0.01	7.27 ± 0.01	7.43 ± 0.07	7.59 ± 0.04

S: Spoiled, RT: Room Temperature, Ch: Chiller.

Identical superscripts in same column do not differ significantly ($P>0.05$).

Table 7. Aerobic Plate Count of chicken fry. (log $_{10}$ cfu/g)

Treatment		Days of storage									
		0	5	10	15	20	30	40	50	60	70
NIR	RT	1.76±0.01^{B}	4.86±0.02^{D}	S	S	S	S	S	S	S	S
	Ch	1.76±0.01^{b}	2.94±0.09^{c}	3.65±0.08^{c}	4.43±0.01^{d}	5.21±0.08^{c}	S	S	S	S	S
IR	RT	0.85±0.22^{A}	3.38±0.07^{B}	S	S	S	S	S	S	S	S
	Ch	0.85±0.22^{a}	1.65±0.17^{b}	2.50±0.01^{b}	3.30±0.08^{b}	3.84±0.07^{b}	4.09±0.08	4.16±0.04	4.65±0.08	4.94±0.08	S
CH-NIR	RT	1.53±0.01^{B}	4.14±0.05^{C}	S	S	S	S	S	S	S	S
	Ch	1.53±0.01^{b}	2.41±0.07^{b}	3.13±0.19^{b}	3.97±0.04^{c}	5.02±0.02^{c}	5.22±0.09	S	S	S	S
CH-IR	RT	NIL	2.99±0.01^{A}	5.20±0.01	S	S	S	S	S	S	S
	Ch	NIL	1.51±0.02^{a}	2.14±0.08^{a}	2.65±0.08^{a}	2.95±0.05^{a}	3.27±0.01	3.82±0.02	4.07±0.01	4.18±0.02	4.49±0.05

S: Spoiled, RT: Room Temperature, Ch: Chiller.

Identical superscripts in same column do not differ significantly (P>0.05).

4.3.2. Psychrotrophic Count (PC)

The PC of chicken fry stored under chiller and room temperature is shown in table 8.

Initially the control sample had a count of 1.76±0.01 on the day of preparation. Chitosan coating has numerically reduced the count to 1.45±0.07. Irradiation had a significant effect ($P<0.05$) in reducing the PC of the samples. The samples kept at room temperature were spoiled by 5^{th} or 10^{th} day and has shown a drastic increase in PC during storage. In the samples stored under chiller conditions, the increase was slow and steady as shown in figure 7. Chiller storage had a significant effect and values reached 4 log counts by 60 and 70 days in IR and CH-IR samples respectively. The maximum count of psychrotrophic organisms was obtained in 30^{th} day of CH-NIR samples. In case of APC, 100 per cent reduction was noticed in CH-IR samples and 53 per cent reduction in IR samples. In case of PC, the reduction was not to that extend and a non significant reduction was obtained among IR and CH-IR samples (0.78 and 0.68 $\log_{10}$ cfu/g respectively).

4.3.3. Yeast and Mould Count (Y&M)

The yeast and mould count of chicken fry stored at different temperature is given in table 9.

Initially, a count of 2.13±0.01 $\log_{10}$ cfu/g was observed in the control samples. Chitosan coating, irradiation and their combination has significantly ($P<0.05$) reduced the counts similar to that of APC and PC. A drastic increase was noticed in yeast and mould count under room temperature storage where as in chiller samples, the growth was slow and steady. The samples that showed the signs of spoilage had a count in the range of 4 log and maximum count of 4.77±0.09 $\log_{10}$ cfu/g was obtained in NIR samples by 20^{th} day of storage. Irradiated samples kept up to 60 days in chiller had a count of 4.72±0.07 and for CH-IR samples; it was 4.38±0.03 $\log_{10}$ cfu/g. The trend of growth of yeast and

Table 8. Psychrotrophic Count of chicken fry. (log_{10} cfu/g)

Treatment		Days of storage									
		0	5	10	15	20	30	40	50	60	70
NIR	RT	1.76 ± 0.01^{B}	4.99 ± 0.02^{D}	S	S	S	S	S	S	S	S
	Ch	1.76 ± 0.01^{b}	2.45 ± 0.01^{c}	3.68 ± 0.08^{c}	4.39 ± 0.07^{d}	4.97 ± 0.08^{c}	S	S	S	S	S
IR	RT	0.78 ± 0.22^{A}	3.83 ± 0.06^{B}	S	S	S	S	S	S	S	S
	Ch	0.78 ± 0.22^{a}	1.73 ± 0.09^{b}	2.45 ± 0.09^{b}	2.74 ± 0.04^{b}	3.24 ± 0.01^{b}	3.52 ± 0.01	4.03 ± 0.01	4.13 ± 0.09	4.69 ± 0.08	S
CH-NIR	RT	1.45 ± 0.07^{B}	4.06 ± 0.01^{C}	S	S	S	S	S	S	S	S
	Ch	1.45 ± 0.07^{b}	1.89 ± 0.08^{b}	2.57 ± 0.09^{b}	3.89 ± 0.07^{c}	4.60 ± 0.01^{c}	4.96 ± 0.01	S	S	S	S
CH-IR	RT	0.68 ± 0.20^{A}	3.16 ± 0.01^{A}	4.38±0.26	S	S	S	S	S	S	S
	Ch	0.68 ± 0.20^{a}	1.24 ± 0.05^{a}	1.77 ± 0.09^{a}	2.16 ± 0.06^{a}	2.57 ± 0.07^{a}	3.05 ± 0.01	3.23 ± 0.01	3.53 ± 0.01	4.08 ± 0.07	4.25 ± 0.08

S: Spoiled, RT: Room Temperature, Ch: Chiller.

Identical superscripts in same column do not differ significantly (P>0.05).

Table 9. Yeast and Mould Count of chicken fry. (log_{10}cfu/g)

Treatment		Days of storage									
		0	5	10	15	20	30	40	50	60	70
NIR	RT	2.13 ± 0.05^{D}	4.96 ± 0.01^{C}	S	S	S	S	S	S	S	S
	Ch	2.13 ± 0.05^{d}	2.69 ± 0.05^{c}	3.90 ± 0.08^{c}	4.70 ± 0.07^{d}	4.77 ± 0.09^{c}	S	S	S	S	S
IR	RT	1.85 ± 0.07^{B}	4.30 ± 0.09^{B}	S	S	S	S	S	S	S	S
	Ch	1.85 ± 0.07^{b}	2.45 ± 0.04^{b}	2.93 ± 0.09^{b}	3.03 ± 0.07^{b}	3.62 ± 0.05^{b}	3.96 ± 0.01	4.15 ± 0.07	4.44 ± 0.08	4.72 ± 0.07	S
CH-NIR	RT	1.93 ± 0.01^{C}	4.43 ± 0.09^{B}	S	S	S	S	S	S	S	S
	Ch	1.93 ± 0.01^{c}	2.42 ± 0.06^{b}	2.86 ± 0.01^{b}	3.74 ± 0.01^{c}	4.23 ± 0.08^{c}	4.56 ± 0.08	S	S	S	S
CH-IR	RT	1.59 ± 0.08^{A}	3.35 ± 0.01^{A}	4.93 ± 0.09	S	S	S	S	S	S	S
	Ch	1.59 ± 0.08^{a}	2.28 ± 0.08^{a}	2.60 ± 0.07^{a}	2.80 ± 0.07^{a}	3.04 ± 0.01^{a}	3.12 ± 0.08	3.81 ± 0.08	3.96 ± 0.01	4.22 ± 0.01	4.38 ± 0.03

S: Spoiled, RT: Room Temperature, Ch: Chiller.

Identical superscripts in same column do not differ significantly ($P>0.05$).

mould is shown in figure 8. It was observed that storage and treatments had a significant effect on the yeast and mould growth of ready-to-eat chicken fry.

4.4. ORGANOLEPTIC EVALUATION

The organoleptic qualities of the product was evaluated subjectively with the help of nine point Hedonic scale.

4.4.1. Colour

The samples, on organoleptic analysis by the trained taste panelists showed that, the treatments had a significant effect compared to control samples on the day of preparation. A similar difference was observed during the entire storage period with the non-irradiated control samples having the minimum score. The highest score of 8.39±0.04 was observed for chitosan applied irradiated samples on the day of preparation and the data is shown in table 10. Storage has numerically reduced the colour score of the product. Application of chitosan alone did not have any significant effect compared to that of irradiation or chitosan coating followed by irradiation. At the verge of spoilage, all the samples recorded a score of above 7 indicating that the colour was still good. Even after storage up to 70 days, the CH-IR samples had a score of 7.37±0.05 and IR samples had a score of 7.34±0.05 on 60^{th} day of chiller storage. The reduction in colour score was gradual in chiller stored samples while it was a drastic for samples stored at room temperature. The fall in colour score is shown in figure 9. During the entire period of study, chitosan coated irradiated samples had a better colour score compared to the other treatments.

4.4.2. Flavour

The flavour score of ready-to-eat chicken fry is shown in table 11. Initially, the non-irradiated samples had a flavour score of 8.33±0.08. Due to irradiation and chitosan application a reduction in score was observed on the day of preparation. But as the storage period enhanced this difference was not so evident and the highest score was recorded for CH-IR samples followed by IR samples under chiller storage conditions. In case of room temperature stored

Table 10. Colour score of chicken fry

Treatment		Days of storage									
		0	5	10	15	20	30	40	50	60	70
NIR	RT	8.31±0.04	7.16±0.05	S	S	S	S	S	S	S	S
	Ch	8.31±0.04	8.24±0.03	8.10±0.06	7.54±0.08	7.03±0.08	S	S	S	S	S
IR	RT	8.36±0.08	7.32±0.09	S	S	S	S	S	S	S	S
	Ch	8.36±0.08	8.26±0.05	8.11±0.05	6.72±0.05	7.98±0.07	7.82±0.07	7.61±0.08	7.42±0.05	7.34±0.05	S
CH-NIR	RT	8.35±0.04	7.43±0.02	S	S	S	S	S	S	S	S
	Ch	8.35±0.04	8.23±0.07	8.17±0.04	7.98±0.01	7.66±0.01	7.02±0.01	S	S	S	S
CH-IR	RT	8.39±0.04	7.96±0.08	7.47±0.01	S	S	S	S	S	S	S
	Ch	8.39±0.04	8.32±0.06	8.26±0.04	8.11±0.07	8.01±0.07	7.94±0.08	7.85±0.05	7.63±0.01	7.49±0.08	7.37±0.05

S: Spoiled, RT: Room Temperature, Ch: Chiller.

Identical superscripts in same column do not differ significantly (P>0.05).

Table 11. Flavour score of chicken fry

Treatment		Days of storage									
		0	5	10	15	20	30	40	50	60	70
NIR	RT	8.33±0.08	7.32±0.01	S	S	S	S	S	S	S	S
	Ch	8.33±0.08	8.20±0.07	8.01±0.09	7.72±0.08	7.54±0.09	S	S	S	S	S
IR	RT	8.25±0.07	7.44±0.01	S	S	S	S	S	S	S	S
	Ch	8.25±0.07	8.23±0.04	8.20±0.04	8.17±0.04	8.06±0.07	7.93±0.06	7.83±0.05	7.56±0.05	7.27±0.01	S
CH-NIR	RT	8.30±0.04	7.55±0.07	S	S	S	S	S	S	S	S
	Ch	8.30±0.04	8.22±0.09	8.03±0.09	7.85±0.08	7.62±0.07	7.42±0.08	S	S	S	S
CH-IR	RT	8.28±0.04	7.85±0.07	7.63±0.06	S	S	S	S	S	S	S
	Ch	8.28±0.04	8.22±0.07	8.20±0.05	8.18±0.04	8.10±0.07	7.95±0.01	7.84±0.07	7.78±0.07	7.57±0.07	7.31±0.07

S: Spoiled, RT: Room Temperature, Ch: Chiller.

Identical superscripts in same column do not differ significantly (P>0.05).

samples, a drastic decline was noticed in flavour score by 5th day of storage. Such a trend was not noticed in chiller stored samples where the reduction was slow and steady (figure 10). Even after 60 days of storage in IR samples and 70 days in case of CH-IR, the samples had a comparatively good flavour score of above 7 indicating that the samples were not having any objectionable flavour. During the entire storage period, the NIR samples always recorded a significantly lower values compared to other treatments both in chiller and room temperature storage.

4.4.3. Juiciness

The juiciness score recorded with the help of nine point Hedonic scale is given in table 12. The initial score of 8.14±0.04 of non-irradiated control samples was improved due to chitosan coating, irradiation and its combination. The room temperature storage of the samples has significantly reduced the scores. A steady and slow decrease in juiciness was observed due to chiller storage. Irradiation has improved the juiciness scores significantly and effect of chitosan coating combined with irradiation was not significantly different from that of irradiation alone. But chitosan coating alone had significant effect compared to the control samples. The trend of change in juiciness score is given in figure 11. Even after storage of 60 days (IR) and 70 days (CH-IR), the samples maintained a good score of above 7. A similar score was observed in the control sample by 20th day and by 30th day in case of chitosan coated samples in chiller storage.

4.4.4. Tenderness

The tenderness score of the samples under different storage conditions is shown in table 13. It was observed that, initially the NIR samples had a tenderness score of 8.41±0.06 and this was significantly improved by irradiation and chitosan coating followed by irradiation. Similar to that of juiciness, chitosan application alone did not improve the score initially. The score was significantly reduced due to storage under room temperature. CH-IR samples always maintained a higher score during the entire storage period compared to the control samples. The samples stored up to the extended shelf-life always had a score of above 7. On day 70, the CH-IR samples had a score of 7.46±0.04 and 7.53±0.07

Table 12. Juiciness score of chicken fry

Treatment		Days of storage									
		0	5	10	15	20	30	40	50	60	70
NIR	RT	8.14±0.04	7.55±0.08	S	S	S	S	S	S	S	S
	Ch	8.14±0.04	8.10±0.08	7.95±0.01	7.42±0.05	7.01±0.07	S	S	S	S	S
IR	RT	8.42±0.04	7.80±0.05	S	S	S	S	S	S	S	S
	Ch	8.42±0.04	8.31±0.07	8.25±0.05	8.13±0.05	7.98±0.07	7.69±0.06	7.37±0.05	7.34±0.05	7.24±0.01	S
CH-NIR	RT	8.19±0.06	7.63±0.01	S	S	S	S	S	S	S	S
	Ch	8.19±0.06	8.04±0.08	7.83±0.09	7.59±0.07	7.31±0.07	7.20±0.05	S	S	S	S
CH-IR	RT	8.41±0.05	7.79±0.06	7.59±0.01	S	S	S	S	S	S	S
	Ch	8.41±0.05	8.33±0.08	8.25±0.01	8.14±0.06	8.02±0.08	7.96±0.01	7.77±0.04	7.58±0.01	7.32±0.08	7.25±0.09

S: Spoiled, RT: Room Temperature, Ch: Chiller.

Identical superscripts in same column do not differ significantly (P>0.05).

Table 13. Tenderness score of chicken fry

Treatment		Days of storage									
		0	5	10	15	20	30	40	50	60	70
NIR	RT	8.41±0.06	7.61±0.05	S	S	S	S	S	S	S	S
	Ch	8.41±0.06	8.33±0.05	8.17±0.05	8.06±0.07	7.75±0.09	S	S	S	S	S
IR	RT	8.45±0.09	7.66±0.01	S	S	S	S	S	S	S	S
	Ch	8.45±0.09	8.40±0.07	8.34±0.01	8.30±0.05	8.24±0.05	8.19±0.04	8.04±0.09	7.81±0.05	7.53±0.07	S
CH-NIR	RT	8.43±0.06	7.70±0.07	S	S	S	S	S	S	S	S
	Ch	8.43±0.06	8.33±0.05	8.21±0.07	8.15±0.05	8.03±0.01	7.64±0.01	S	S	S	S
CH-IR	RT	8.47±0.05	7.84±0.07	7.63±0.05	S	S	S	S	S	S	S
	Ch	8.47±0.05	8.42±0.05	8.31±0.05	8.29±0.04	8.22±0.06	8.19±0.04	8.08±0.08	7.85±0.08	7.65±0.09	7.46±0.04

S: Spoiled, RT: Room Temperature, Ch: Chiller.

Identical superscripts in same column do not differ significantly (P>0.05).

for IR samples on 60th day indicating the product was tender. The change in tenderness due to storage in chiller is shown in figure 12 indicating a steady decrease in tenderness values.

4.4.5. Overall Acceptability

The overall acceptability of the product indicates the general acceptability of the product. The non irradiated control samples had a very good score of 8.60 out of 9.0. This value was significantly improved by chitosan application (8.63), irradiation (8.65), followed by chitosan application and irradiation (8.68). Due to storage under room temperature the overall acceptability of the product was significantly reduced. The trend of reduction of overall acceptability of the product is shown in figure 13 indicating a slow and steady reduction in chiller stored samples. All the treatment groups have shown a downward trend in overall acceptability. Even after 60 days of storage (IR) and 70 days of storage (CH-IR), the samples had a score of more than 7 as shown in the data given in table 14. It was observed that either IR or CH-IR samples had a higher value than that of NIR and CH-NIR samples indicating irradiation has improved the overall acceptability and it was not affected by storage.

4.4.6. Kruskal-Wallis Rank Score

The Kruskal-Wallis (KW) rank score analysis of the organoleptic qualities showed that values analysed in all days of storage were significant from each other at 0.01 per cent level. The room temperature samples on 5th day of storage revealed that colour, flavor, juiciness, tenderness and overall acceptability scores of all the treatment groups were significantly different. The KW rank score analysed from 5th to 60th day of chiller storage showed higher values for colour in CH-IR samples (Table 15). In case of flavour and juiciness almost similar trend was noticed. The maximum score was recorded for IR samples on 10th and 20th day and during the rest of the storage period CH-IR samples had the maximum score. The tenderness scores were higher for IR samples on days 10, 15 and 30 while for the rest of the storage period both IR and CH-IR had equal scores. The

Table 14. Overall acceptability score of chicken fry

Treatment		Days of storage									
		0	5	10	15	20	30	40	50	60	70
NIR	RT	8.60±0.06	7.61±0.07	S	S	S	S	S	S	S	S
	Ch	8.60±0.06	8.38±0.08	8.24±0.01	8.08±0.07	7.85±0.06	S	S	S	S	S
IR	RT	8.65±0.05	7.68±0.04	S	S	S	S	S	S	S	S
	Ch	8.65±0.05	8.42±0.05	8.38±0.07	8.31±0.04	8.24±0.04	8.15±0.07	8.05±0.07	7.84±0.05	7.25±0.07	S
CH-NIR	RT	8.63±0.07	7.69±0.01	S	S	S	S	S	S	S	S
	Ch	8.63±0.07	8.45±0.05	8.25±0.01	8.15±0.09	7.91±0.09	7.85±0.05	S	S	S	S
CH-IR	RT	8.68±0.03	7.92±0.07	7.65±0.08	S	S	S	S	S	S	S
	Ch	8.68±0.03	8.45±0.08	8.35±0.01	8.27±0.08	8.21±0.07	8.17±0.04	8.08±0.08	7.92±0.08	7.76±0.01	7.56±0.08

S: Spoiled, RT: Room Temperature, Ch: Chiller.

Identical superscripts in same column do not differ significantly (P>0.05).

overall acceptability scores were maximum for IR samples on days 10, 15 and 30 and in other days CH-IR samples were better as revealed by the rank score testing.

Table 15. Kruskal-Wallis Rank Score

Days of storage	Organoleptic Qualities				
	Colour	**Flavour**	**Juiciness**	**Tenderness**	**Overall Accaptability**
5	CH-IR	CH-IR	CH-IR	CH-IR	CH-IR
10	CH-IR	IR	CH-IR	IR	IR
15	CH-IR	CH-IR	CH-IR	IR	IR
20	CH-IR	CH-IR	IR	CH-IR	CH-IR
30	CH-IR	CH-IR	CH-IR	IR	IR
40	CH-IR	CH-IR	CH-IR	CH-IR	CH-IR
50	CH-IR	CH-IR	CH-IR	CH-IR	CH-IR
60	CH-IR	CH-IR	CH-IR	CH-IR	CH-IR

NIR – Non-irradiated control samples, IR- Irradiated samples.

CH-NIR –Chitosan coated samples.

CH-IR – Chitosan coated irradiated samples.

4.5. COST OF PRODUCTION

The cost of production of chicken fry packaged in PA-PE pouches determined for both the control and treatment group containing 0.5 per cent

chitosan is presented in the table 16. The items included in calculating the cost of production were price of chicken, various ingredients including acetic acid and chitosan. The cost of production was Rs. 109.83 and Rs. 114.21 per kg for the control and treatment groups respectively.

Table 16. Production cost for one kg ready-to-eat chicken fry

Items	Control (Rs.)	Treatment (Rs.)
Chicken	59.84	59.84
Ingredients	11.50	11.50
Chitosan	–	3.19
Total	71.39	74.58
Cost per kg of final product	109.83	114.21

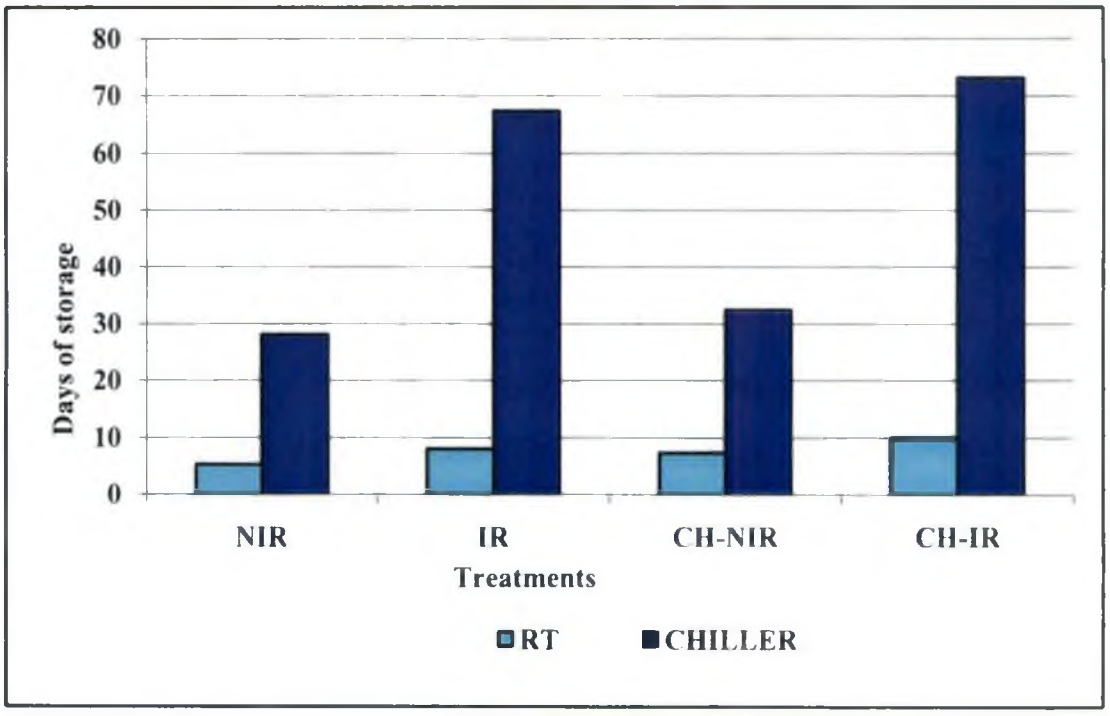


Fig. 3. Shelf life of chicken fry

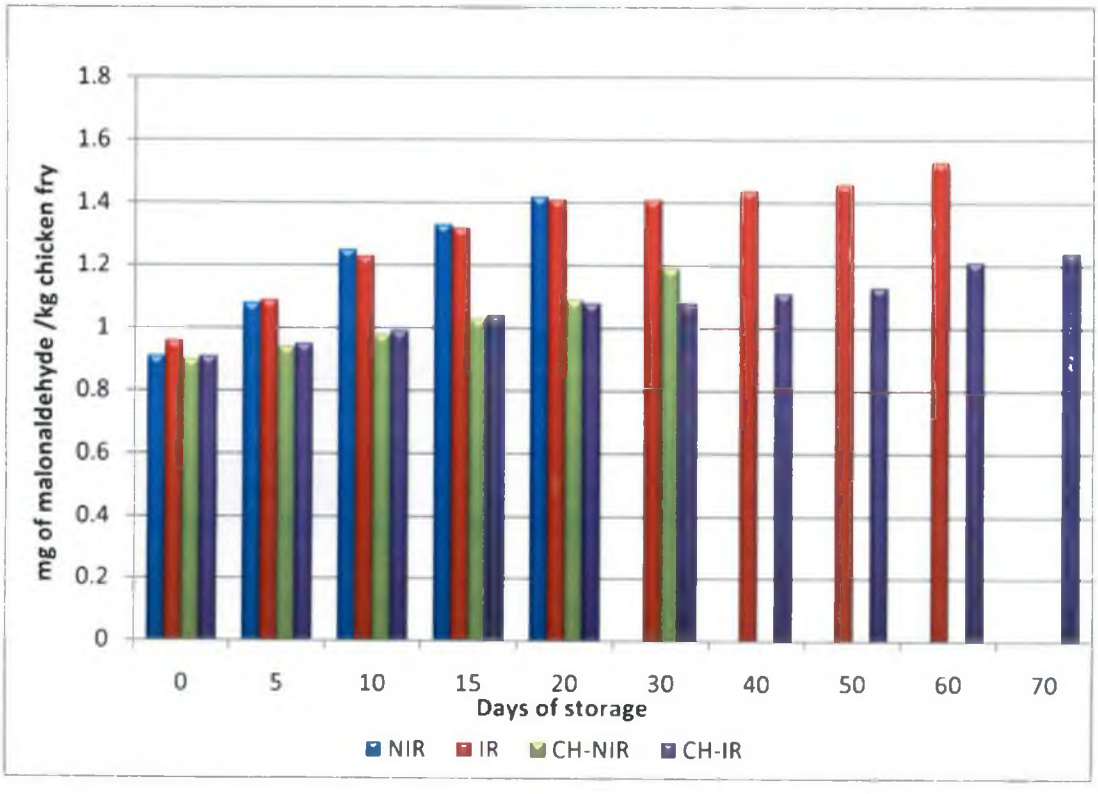


Fig. 4. TBARS value of chicken fry on storage

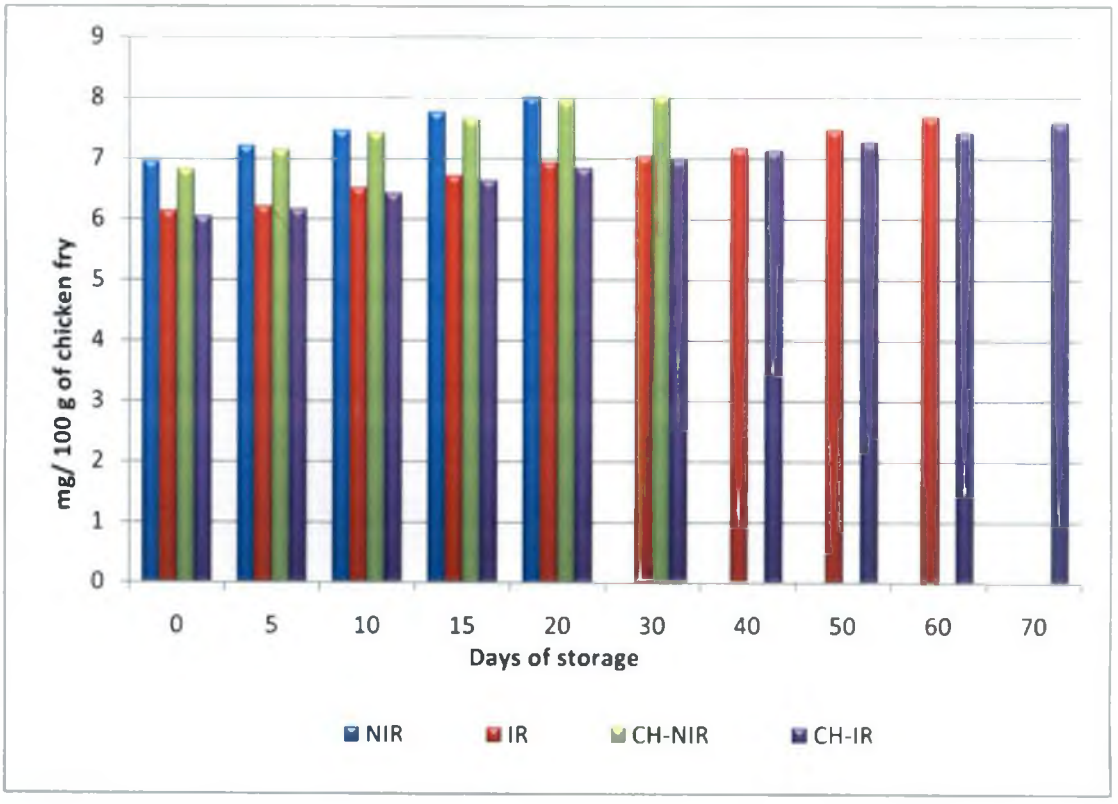


Fig.5. TV of chicken fry on storage

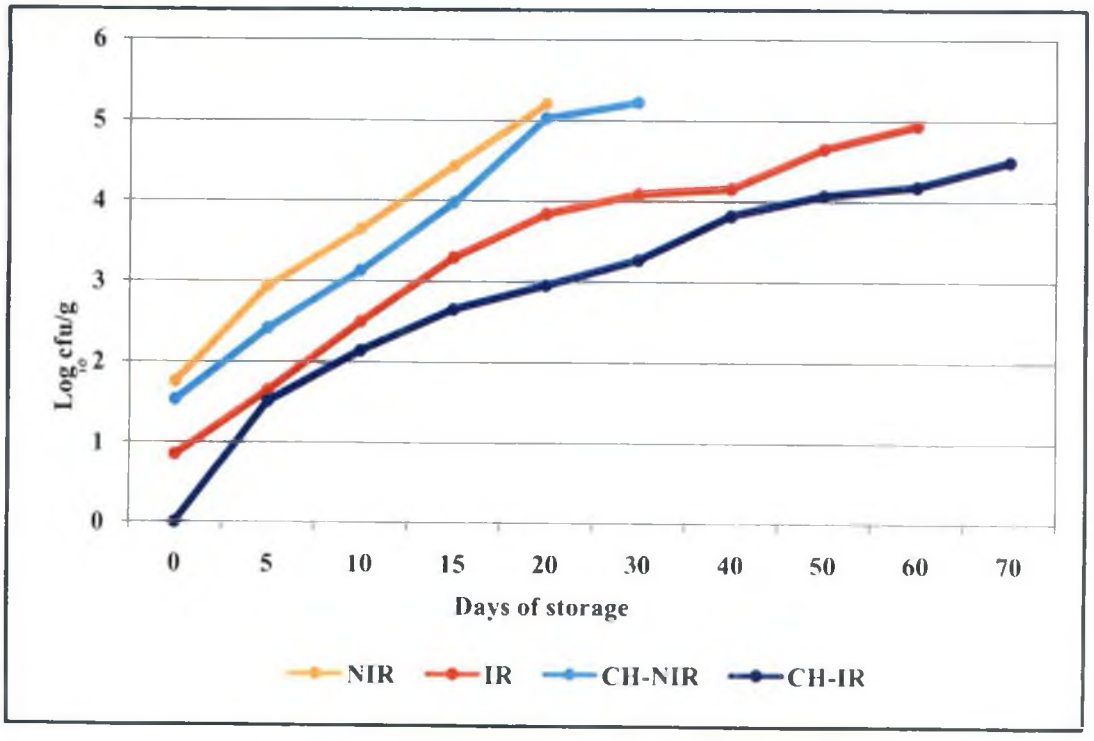


Fig.6. Aerobic plate count of chicken fry on storage

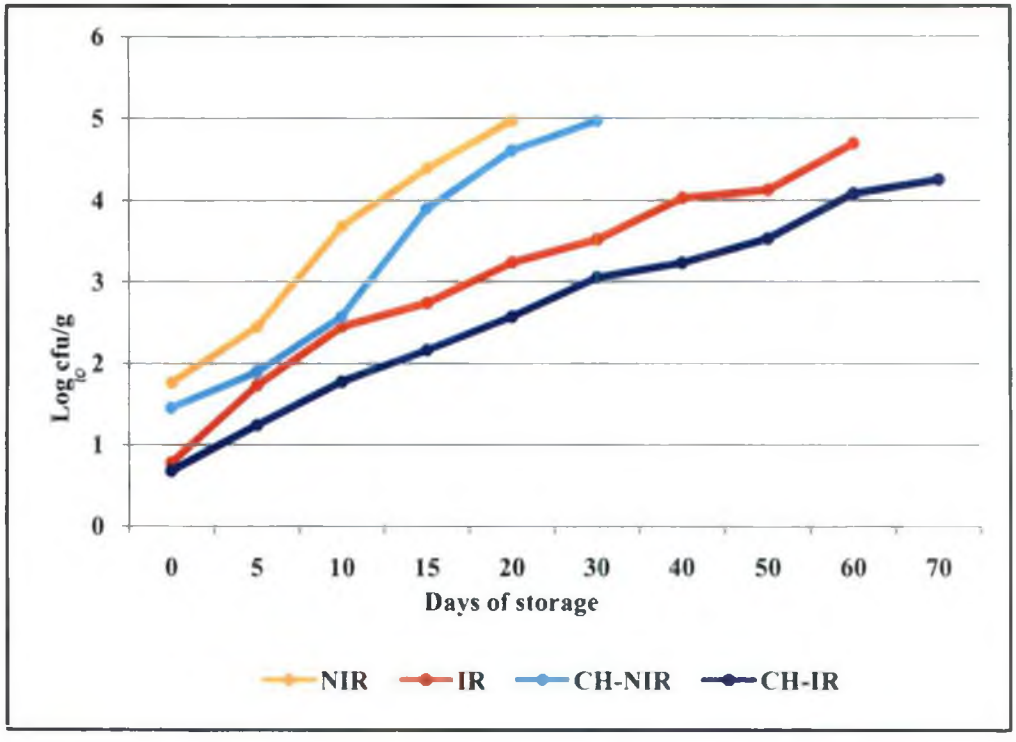


Fig.7. Psychrotrophic count of chicken fry on storage

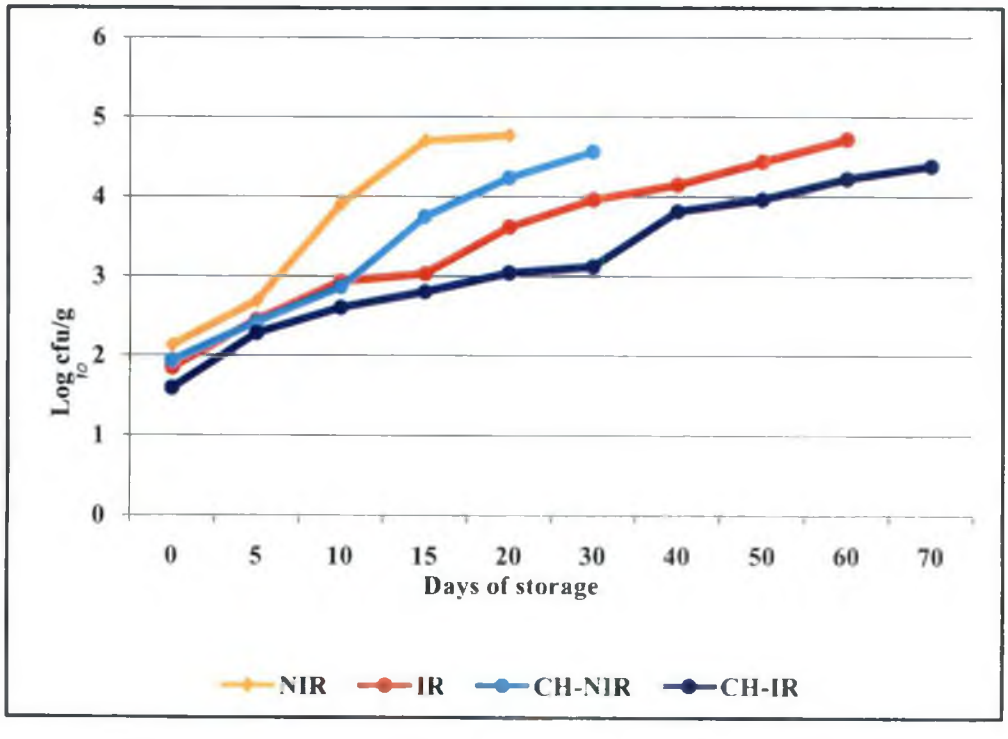


Fig.8. Yeast and Mould count of chicken fry on storage

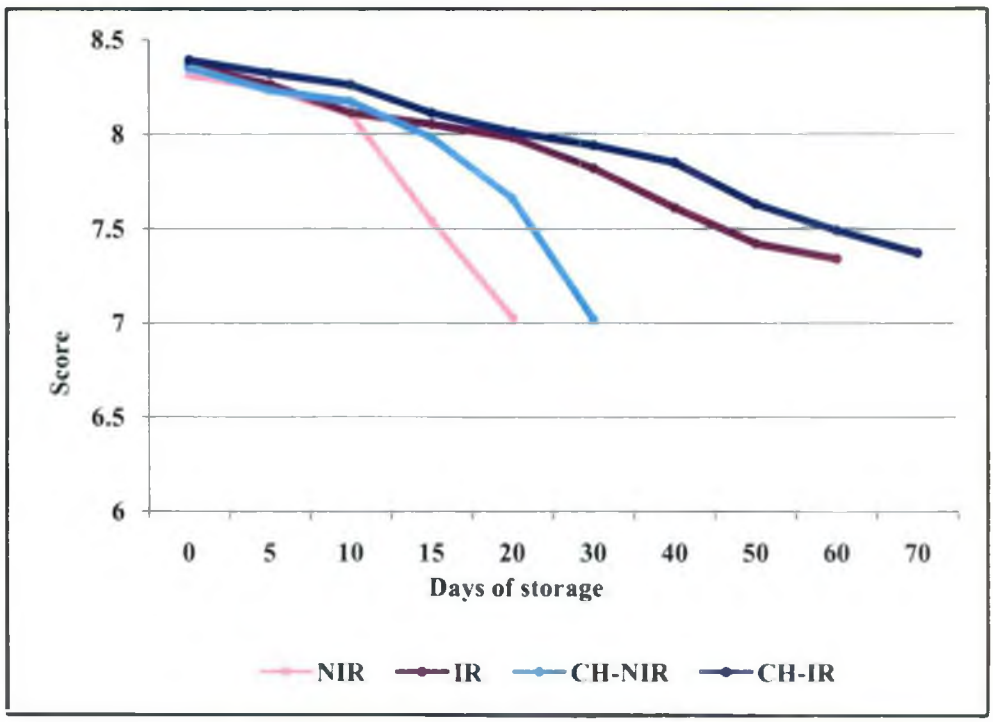


Fig.9. Colour score of chicken fry on storage

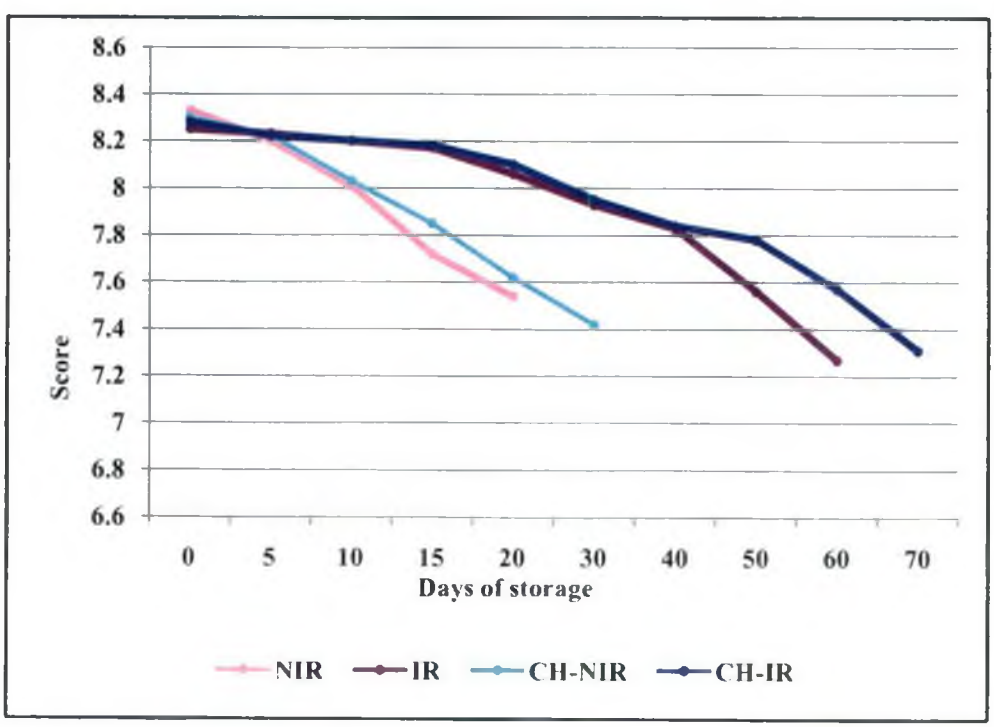


Fig.10. Flavour score of chicken fry on storage

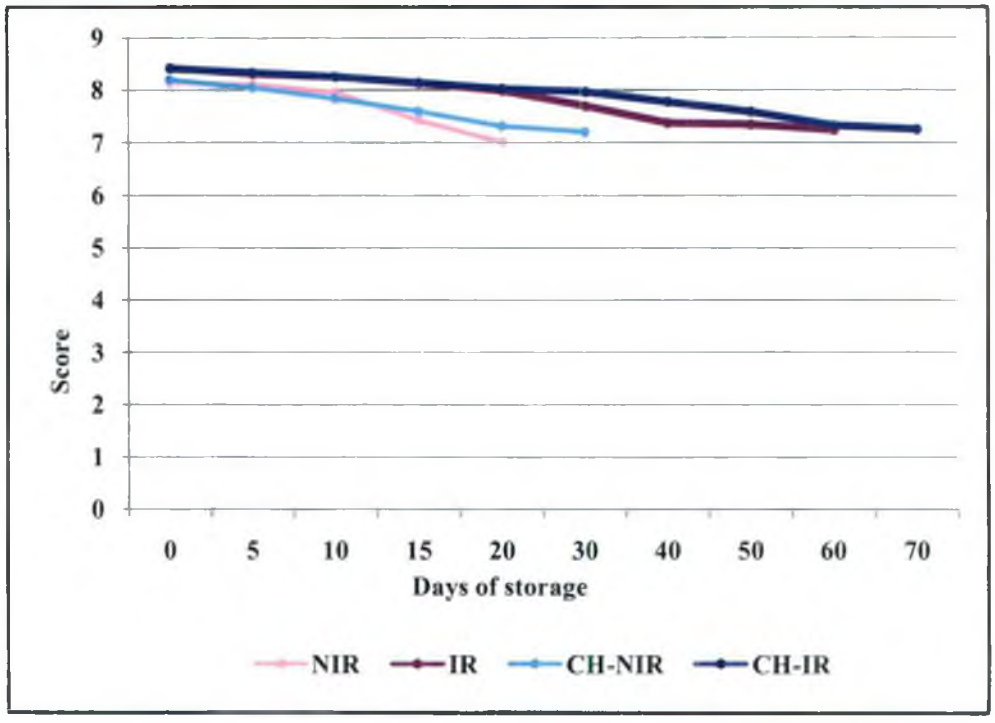


Fig.11. Juiciness score of chicken fry on storage

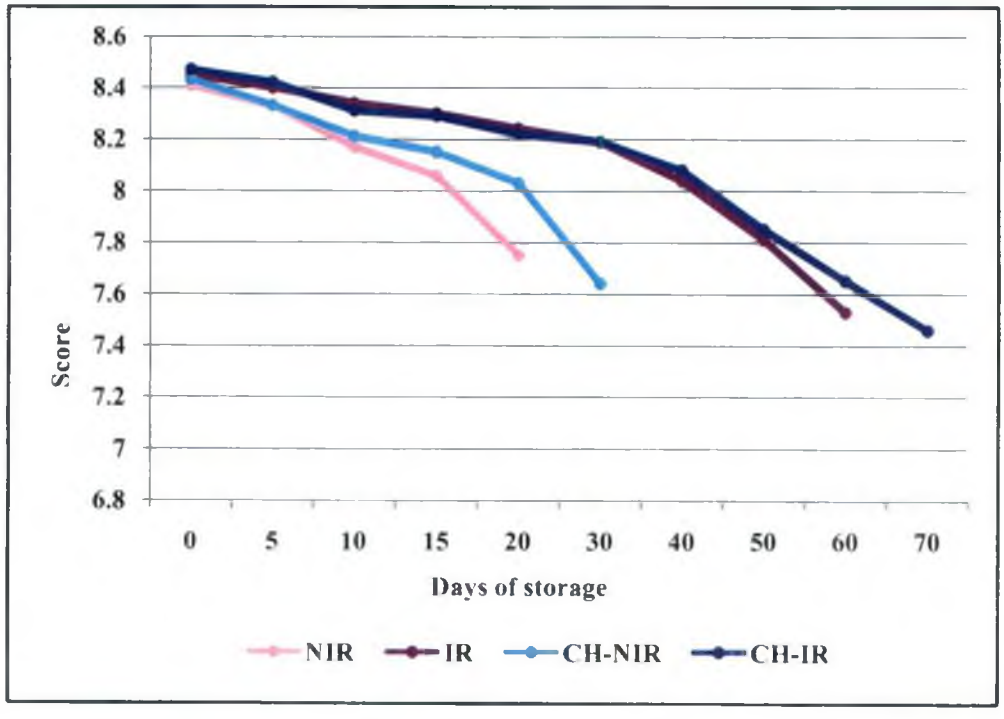


Fig.12. Tenderness score of chicken fry on storage

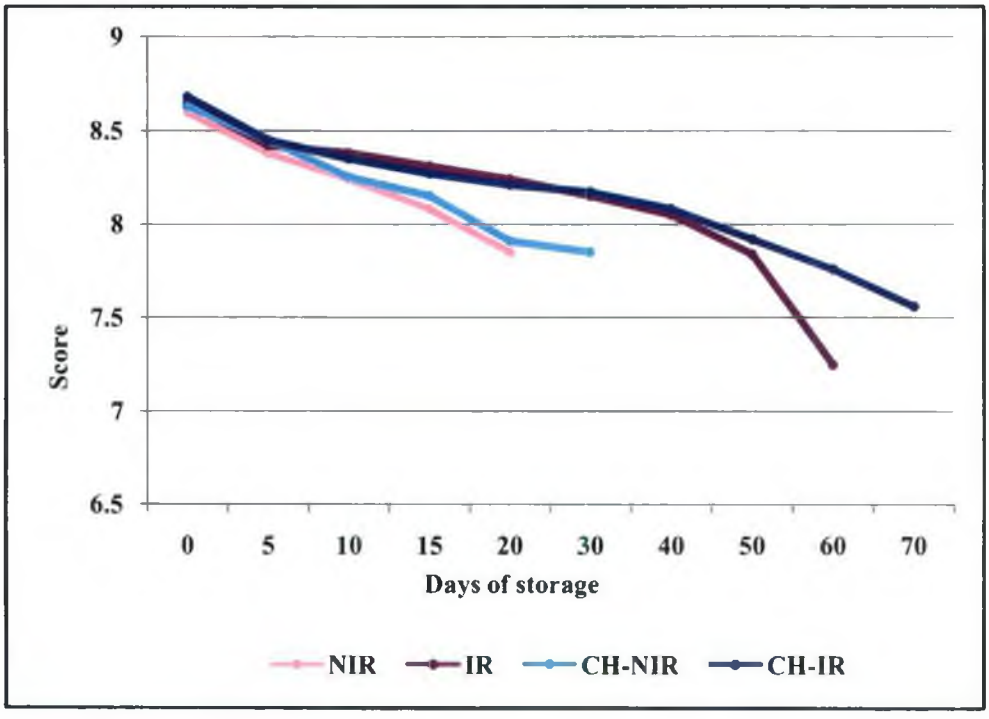


Fig.13. Overall Acceptability score of chicken fry on storage

Discussion

DISCUSSION

Broiler chicken having uniform weight of approximately 2 kg were procured and brought to the Department of Livestock Products Technology, College of Veterinary and Animal Sciences. They were slaughtered under hygienic conditions in the completely conveyorised poultry processing line and were made into cuts of uniform size. The marinade was prepared and applied in the ratio of 4:1. It was kept at room temperature for $1^1/2$ hours for marination. The marinated chicken was then deep fat fried (for about 8 to 10 minutes) to have uniform colour and appearance. Half of the product was coated with 0.5 per cent chitosan solution in one per cent glacial acetic acid. The other half was coated with equal quantity one per cent glacial acetic acid. The product was vacuum packaged in PA-PE pouches with approximately 80g in each packet and from each group, half of the packets were irradiated at 2.5 kGy using Gamma Chamber 5000. Sufficient number of packets were kept at chiller (1-4°C) and at room temperature (25-30°C).

5.1. PHYSICAL QUALITIES AND SHELF-LIFE

The maximum shelf-life was obtained for chitosan coated irradiated samples both under chiller storage and room temperature followed by irradiated samples. The NIR samples had a significantly lower shelf-life of 5.33±0.23 days at room temperature. Paul *et al.* (1990) reported 4 weeks of extended storage for minced beef by gamma radiation. Roberts and Weese (1998) observed 21 days of extended storage for ground beef patties when irradiated at 3 kGy. In the present study, the irradiated samples in chiller storage had a higher shelf-life. Similarly Johnson *et al.* (2004) recommended irradiation of 1 to 3 kGy to increase the shelf-life of frankfurters. Sagoo *et al.* (2002) advocated dipping of pork sausages in 1 per cent chitosan solution to extend the shelf life from 7 to 15 days under storage at 7°C. The present study obtained a greater storage period of 32.5±0.46 days in case of chitosan applied chiller stored samples. Kanatt *et al.* (2005) obtained two weeks of extended shelf life with a higher dose compared to non-irradiated samples where as in the present study, a lower dose of 2.5 kGy had a better

storage life than that reported by them. The extension of storage life was higher than the reports of Rao *et al.* (2005) in intermediate moisture mutton kababs, Jenifer (2006) in minced beef and Kuttinarayanan *et al.* (2006b) in beef fry. The initial microbial load of the product was very low due to the strict hygienic precautions followed. Even the NIR samples at room temperature had a storage life of 5.33±0.23 days and 28.16±0.33 days under chiller conditions. Irradiation, chitosan coating and chitosan coating followed by irradiation had a beneficial effect in extending the shelf life significantly than that of the control samples both at room temperature and chiller storage.

The colour and odour was not significantly different between various treatments as observed at the time of opening the vacuum packed samples. Ahn *et al.* (2000) reported that vacuum packaging was better than aerobic packaging for irradiation and subsequent storage of meat and meat products since it minimized the oxidative changes. Similarly, Thayer (1993) is also of the opinion that extension of shelf life can be attained with irradiation in combination with vacuum packaging or modified atmospheric packaging.

5.2. PHYSICOCHEMICAL QUALITIES

5.2.1 Proximate Composition

The proximate composition of the samples were estimated on the day of preparation. The samples had a very good protein per cent of above 26 per cent and above 20 per cent with respect to fat and had an average energy content of 305 K Cal/100g. The values did not vary significantly with irradiation or chitosan coating. Non significant effect due to irradiation were already reported by authors like Sakala *et al.* (1987), Heath *et al.* (1990), Katta *et al.* (1991) in chicken carcass, Wheeler *et al.* (1999) and Wu *et al.* (2000) in beef patties. Whereas Daoud *et al.* (2002) reported minor changes in chemical composition of minced beef due to irradiation at various doses. The present study is in agreement with the findings of Smith and Pillai (2004), Al-Bachir (2005) and Rana Raj (2006) in pet foods. With respect to amino acids, fatty acids and other vitamins there are

varying reports. The present study was limited to the estimation of proximate composition only.

5.2.2. Thiobarbituric Acid Reacting Substances (TBARS)

Estimation of thiobarbituric acid substances in meat and meat products will enlighten the extend of oxidative rancidity changes. The TBARS value recorded for IR samples on the day of preparation was higher than that of the other treatment groups. Application of chitosan had a significant effect in controlling the fat rancidity changes. Dempster *et al.* (1985) reported a significantly higher peroxide value for vacuum packed irradiated beef burgers and Murano *et al.* (1998) in ground beef patties. The role of chitosan in reducing the lipid oxidation and subsequently TBARS values has been reported by Darmadji and Izumimoto (1994) in beef and Shahidi *et al.* (1999) in muscle foods. In the present study, a higher value was observed due to storage and is in agreement with Murano *et al.*.(1998) in ground beef patties and Du *et al.* (2001a) in cooked chicken meat patties. The effect of chitosan in reducing the peroxide value and TBARS is also reported by Kamil *et al.* (2002). In the present study, both irradiation and storage had increased the TBARS values under vacuum conditions. Nam and Ahn (2003) reported aerobic packing and irradiation increase lipid oxidation whereas vacuum packaging reduces TBARS values. In this study chitosan was found to have significant effect in reducing TBARS values and is in agreement with Rao *et al.* (2005) who reported 24 to 28 per cent reduction in TBARS values by edible chitosan coating of the irradiated products. Similarly Kanatt *et al.* (2004) also reported the beneficial effects of chitosan in minimizing the lipid oxidation and reducing TBARS values. From the above results it can be inferred that irradiation will increase the lipid oxidation and rancidity to an extend of 6 per cent only which can be effectively controlled by chitosan application. But vacuum packaging alone cannot change the effects of irradiation on TBARS values.

5.2.3. Tyrosine Value (TV)

The tyrosine value indicates the protein breakdown of meat and meat products subjected to storage or any other treatment. Contradictory to the changes in TBARS, TV was maximum in NIR sample on the day of preparation. This may be due to the proteolytic changes that take place in the control samples. The lowest value was recorded in the chitosan coated irradiated samples and this trend continued during the entire storage period. Jones *et al.* (1982) reported estimation of tyrosine as a method to measure proteolysis and Lawrie (1998) stated irradiation of meat reduces the proteolysis. Jenifer (2006) also observed that irradiation of minced meat reduced the proteolytic changes and reported a low TV compared to non-irradiated samples. At room temperature storage, an increased TV was reported by Karthikeyan *et al.* (2000) and the result of the present study is in agreement with them. The effect of storage on TV was reported by Kuttinarayanan *et al.* (2005) as a normal biochemical change which is expected in refrigerated meat and did not observe significant effect due to irradiation on turkey meat samples initially. Dushyanthan *et al.* (2001) reported the beneficial effects of vacuum packaging in reducing the TV. Such an effect was not observed by the combined effect of chitosan coating and irradiation. Chitosan coated irradiated samples reported the lowest value followed by IR and CH-NIR samples compared to the non-irradiated control samples. The effect of irradiation and chitosan application continued up to 20^{th} day of chiller storage after which certain samples (NIR, CH-NIR) were spoiled due to various reasons. The content of tyrosine can be one of the criteria to say whether a sample is spoiled or not as evidenced by its higher value in the spoiled sample.

5.3. MICROBOLOGICAL ANALYSIS

5.3.1. Aerobic Plate Count (APC)

In India, irradiation of meat and meat products is aimed to destroy the microorganisms and to extend the shelf life as envisaged in PFA. The product under present study contains very low percentage of moisture which requires a

higher irradiation dose for the destruction of the microorganisms. But this study utilized a dose of 2.5 kGy and obtained about 53 per cent reduction in APC. Microorganisms are much more sensitive to irradiation in high moisture environment. In low moisture conditions the yield of radicals formed from water molecules by irradiation is much lower and so the level of indirect effect on DNA that they may generate is decreased. This may be the reason of low per cent of reduction in APC when compared to fresh meat which is having higher water content compared to the ready-to-eat chicken fry. There are reports of reduction by 100 per cent or above 90 per cent by Niemand *et al.* (1981), Thayer (1993), Alur *et al.*, (1998) and Chouliara *et al.* (2006). A lower reduction in APC in chicken carcass was reported by Basker *et al.* (1986) by a dose of 2 to 4.5 kGy and subsequent chiller storage and Niemand *et al.* (1981) reported 99.99 per cent reduction of aerobic bacteria in vacuum packed beef cuts by irradiation at 2kGy. The present values are not in agreement with Kanatt *et al.* (2005) who observed that even after 28 days the aerobic counts of irradiated samples did not reach to that of the control non-irradiated samples.

Under room temperature storage, the count was enhanced drastically by 5^{th} day in case of non-irradiated control samples and chitosan applied samples. Whereas chitosan coated and irradiated samples had significantly lower count under room temperature storage. A similar trend was observed for samples under chiller storage.

5.3.2. Psychrotrophic Count (PC)

The PC of ready-to-eat chicken fry was significantly reduced by irradiation at 2.5 kGy and chitosan coating combined with irradiation. Chitosan coating alone did not reduce the count significantly. It was also observed that the effect of chitosan coating combined with irradiation was not significantly different from that of irradiation alone. Niemand *et al.* (1983) reported complete elimination of *Pseudomonas* spp. by irradiation at 2.5 kGy in minced beef whereas Lambert *et al.* (1992) reported 2 log reduction in PC of fresh pork.

Lacroix *et al.* (2000) reported psychrotrophic organism are resistant to irradiation under aerobic conditions compared to vacuum packaging. None of the samples in this study had a count reported by Gomes *et al.* (2003) by 12 day storage under chiller conditions. This may be due to the low initial PC of the product. Badr (2004) obtained a lower keeping quality with an irradiation dose of 3 kGy for rabbit meat under chiller storage. In the present study, the per cent of reduction was comparatively lower (56 per cent) and this may be due to the low water activity of the food in which the yield of radicals formed from the water molecules is much lower and the effects on DNA that they may generate will also be less. There may be more number of organisms surviving after irradiation when compared to fresh meat.

Storage had a significant effect in increasing the bacterial load under room temperature. But in chiller storage, even after 70 days the count was well within the standards. This may be due to the low initial count in the product. It is observed that as the storage period increased, chitosan had an added advantage over irradiation which is evident from the data that CH-IR samples had an extended storage life of 10 days under room temperature and 70 days under chiller.

5.3.3. Yeast and Mould Count (Y&M)

The sample had an initial yeast and mould count of 2.13±0.05 log cfu/g. This was significantly reduced by application of different treatments with the lowest count in CH-IR followed by IR and CH-NIR. A similar trend continued till its spoilage. Niemand *et al.* (1983) reported vacuum packaging with or without irradiation had a significant effect in extending the shelf life. In the present study the non treated samples under room temperature had a shelf life of 5 days and in chiller an extension up to 20 days was noted under vacuum packaging. Irradiation has extended the shelf life by 3 times (60 days) and chitosan coating followed by irradiation beyond 70 days. Monk *et al.* (1995) reported 1.8×10 cfu reduction by 2.5 kGy in chicken breast and Balamatsia *et al.*

(2006) reported 100 per cent reduction in yeast and mould count of chicken meat when irradiated at 2 kGy which may be due to the higher water content of sample used by them for their study. Kuttinarayanan *et al.* (2006c) and Kuttinarayanan (2007a) reported a reduction of above 95 per cent in yeast and mould count in various meat and meat products by irradiation at a dose of 2 kGy. Product variation may be one of the reasons for not obtaining such a result in this study. Shahidi *et al.* (1999) reported the beneficial effect of chitosan in reducing the growth of numerous fungi and Sebti *et al.* (2005) stated that 0.1 per cent chitosan can inhibit the total growth of *Aspergillus niger.* Chitosan application followed by irradiation has significantly reduced the yeast and mould count of the chicken fry during the entire storage period.

Under room temperature storage a drastic increase in yeast and mould count was noticed in the stored product. It can be inferred from the above results that chitosan coated and irradiated chicken fry can be stored up to 10 days at room temperature and in chiller storage beyond 70 days without any signs of spoilage when packed under vacuum.

5.4. ORGANOLEPTIC QUALITIES

5.4.1. Colour

The sensory evaluation of the cooked product was conducted with help of nine point Hedonic scale. The purchaser always goes for a product by its appearance and the colour of the product affect a lot in its marketing. In the present study the non-irradiated control sample recorded a very good colour score of 8.31±0.04. This was significantly improved by chitosan coating, irradiation and their combination. Lefebvre *et al.* (1994), Fu *et al.* (1995), Murano *et al.* (1998), Zhu *et al.* (2003) and Smith and Pillai (2004) reported no change in colour due to irradiation in meat and meat products where as Zhao *et al.* (1996) reported less desirable colour due to irradiation in pork throughout its storage. The present study is in agreement with Jo *et al.* (2000) who reported a better colour in cooked

vacuum packed irradiated sausages. Darmadji and Izumimoto (1994) reported addition of chitosan to meat resulted in better sensory attributes. The present study is in agreement with their results. As storage period increased there was a significant reduction in the colour score under room temperature but in chiller conditions it was a slow and steady decrease. Even after 60 days of chiller storage in IR and 70 days in CH-IR, the colour score of the samples were fairly good.

5.4.2. Flavour

The combined perception received by the sense of taste and smell is recorded as flavour of a product. Contradictory to the colour scores, on the day of preparation NIR samples had a higher score compared to the other treatment groups. This trend continued and a gradual reduction was noticed throughout the chiller storage period. Zhao *et al.* (1996), Ahn *et al.* (1998), Zhu *et al.* (2003) and Zhu *et al.* (2004) reported flavour changes due to irradiation in various meat and meat products which is in agreement with the results of present study. Whereas Arthur *et al.* (2005) and Kanatt *et al.* (2005) did not observe any detectable odour or flavour changes in irradiated meat products. In the present study IR sample had the lowest score followed by CH-IR sample compared to NIR sample indicating that chitosan had a beneficial effect in preventing the radiation induced off odour in vacuum packed products. Ahn *et al.* (2000) reported as similar trend in vacuum packaged products on their day of preparation. As storage period increased, the flavour scores reduced due to various biochemical changes in the product. These changes were rapid in ambient temperature stored products as evidenced by the lower scores obtained by them. The flavour scores of the room temperature stored NIR samples on 5^{th} day was almost equal to that of 60^{th} day IR and 70^{th} day CH-IR chiller stored samples.

5.4.3. Juiciness

The juiciness of the product was significantly improved by the application of different treatments. IR samples had maximum score followed by

CH-IR samples on the day of preparation indicating irradiation and chitosan coating followed by irradiation has improved the juiciness score of the product. Murano *et al.* (1998) and Johnson *et al.* (2004) reported higher juiciness scores for irradiated products and the present study is in agreement with them. Luchsinger *et al.* (1996) and Abu-Tarboush *et al.* (1997) observed no significant change in juiciness due to irradiation. There was a drastic reduction in juiciness as storage period increased under room temperature whereas this was taken care of by the process of chilling in which the reduction was gradual. Even at the terminal end of chiller storage, the samples had a fairly good score of 7.25 out of 9.0 indicating the product cannot be considered as less juicy. NIR samples on 20th day of chiller storage had a comparatively lower score than the treatment groups indicating that irradiation, chitosan coating and their combination had a definite role in increasing the juiciness of the product.

5.4.4. Tenderness

The NIR samples obtained a very good tenderness score of 8.41±0.01 out of 9.0 in the Hedonic scale. This was significantly increased by irradiation and a combination of irradiation and chitosan coating but chitosan coating alone did not improve the score significantly. Hashim *et al.* (1995), Murano *et al.* (1998) and Arthur *et al.* (2005) reported increased tenderness due to irradiation and the present study results are in agreement with them. Coleby *et al.* (1961) reported shrinkage of collagen as the cause of immediate softness and tenderness of texture in meat foods. This may be the reason for a significantly higher tenderness score obtained for this product. Whereas Ohene-Adjei *et al.* (2004) reported a decrease in tenderness and Kanatt *et al.* (2006) observed no significant change in tenderness due to irradiation. The tenderness of the product was decreased drastically by 5th day of storage under room temperature which was similar to that of juiciness score as both the parameters are inter-related. In case of chiller stored samples, a slow and steady decline was noticed. The samples at the final stages of experimentation had a comparatively good score of 7.5 in all the treatment groups. The initial difference between treatments continued during

the entire storage period even though there was a little difference between the scores of IR and CH-IR groups.

5.4.5. Overall Acceptability

The overall acceptability is the product of the individual sensory qualities. The initial score of 8.6 out of 9.0 in the NIR samples were significantly improved due to irradiation, chitosan coating and its combination with the maximum score for CH-IR samples. Since many of the scores like colour, juiciness and tenderness improved significantly, the overall acceptability of the product also improved. Johnson *et al.* (2004) and Kanatt *et al.* (2005) reported a similar trend in irradiated products. Kuttinarayanan (2005) reported that many of the buyers did no observe any particular smell or taste difference to the products due to irradiation. Darmadji and Izumimoto (1994) reported the beneficial effects of chitosan in improving the overall sensory attributes and the observation in the present study is in agreement with their reports. Under room temperature, the overall acceptability of the product was significantly reduced. In chiller storage, even beyond 60 days (IR) and 70 days (CH-IR), the samples maintained a good score of above 7.0.

The Kruskal Wallis maximum value score in various days of storage is shown in table 15 .In case of colour the CH-IR samples always had the better score. Only on day 10, the IR sample recorded a better flavour and in all other days of chiller storage CH-IR samples had the highest score. With regard to juiciness, on 20^{th} day the IR samples had the highest value and for the rest of the storage days CH-IR samples were better. The tenderness and overall acceptability of the samples on 10^{th} , 15^{th} and 30^{th} day was the highest for IR samples and for all other days under observation the CH-IR samples scored the highest value indicating that either irradiated or chitosan coated irradiated samples were better than non-irradiated or chitosan coated samples.

5.5 COST OF PRODUCTION

The cost of production of any ready-to-serve or ready-to-cook food items in Kerala are highly varying since many of the raw materials are coming from outside the state. The cost of ready-to-eat chicken fry prepared in this study was Rs.109.83 per kg in case of control samples and was Rs. 114.21 per kg in case of chitosan coated irradiated samples. The difference was due to the cost of chitosan. The cost of control samples was comparatively higher than that of the previous reports since the cost of raw materials in the earlier studies were considerably low.

From the above results it can be inferred that ready-to-eat chicken fry preserved by hurdle technology including vacuum packaging and chitosan coating and irradiation will definitely have an extended shelf life of 67.33±0.46 days under chiller storage and nearly 8 days under room temperature. Coating of the product with chitosan at the rate of 0.5 per cent followed by irradiation can extend the shelf life up to 10 days under room temperature and 73 days in chiller.

A product having a shelf life of 10 days at ambient temperature can be marketed through retail outlets to cover at least half of the state and if cold chain is maintained it can be marketed throughout the state. Since the product is stored under chiller condition, it is a highly convenient ready-to-use product for any occasion in the nuclear families. The process of irradiation destroys many of the spoilage bacteria and fungi including the pathogenic organisms and hence the product is safe and can be popularized.

Summary

SUMMARY

Indian culture is cherished with various value added meat products right from salted and dried meat products. As far as chicken is concerned, throughout India various uniform products are available. To preserve and market the products, various methods of preservation are in use. The most common method of preservation of any meat product is freezing. To increase the market of the product, value addition is highly essential. The ready-to-eat products that are available have to be stored under deep freezer and the reprocessing of such deep frozen items is time consuming. In order to keep the processed food under chiller conditions the total microbial load of the product should be destroyed after processing and packing like in canning, which is a costly procedure. The alternate practical method for destroying food borne pathogens is radiation processing. Radiation preservation of meat in India is permitted by PFA in 1998 and it leads to improvement in the microbial quality and thereby extends the shelf life. But it is having its own disadvantages. The disadvantages of radiation preservation can be minimized with the use of different hurdles like chitosan application, vacuum packaging etc.

The study on the effect of low dose gamma radiation and chitosan coating on shelf-life and quality changes of ready-to-eat chicken fry under vacuum packaging was conducted in the Department of Livestock Products Technology, Mannuthy. The most popular and convenient chicken preparation, ready-to-eat chicken fry was prepared using ingredients such as chicken, spices and condiments, shallots, flour, salt etc Half of the prepared chicken fry was coated with 0.5 per cent chitosan in one per cent glacial acetic acid and were vacuum packaged in PA-PE pouches. The other half was coated with one per cent glacial acetic acid alone. Half of the packets from each group were irradiated at 2.5 kGy using Gamma Chamber 5000 and sufficient number of packets were kept at room temperature (25-30°C) and chiller (1-4°C). The irradiated and non-irradiated chicken fry under various treatment groups and storage were analysed for different quality parameters, viz., physical, physiochemical, microbiological and

organoleptic qualities on the day of preparation and on days 5, 10, 15, 20, 30, 40, 50, 60 and 70 or until spoilage whichever was earlier. The samples were subjected to proximate analysis on the day of preparation.

The samples kept at room temperature had an extended storage life of beyond 10 days for vacuum packaged CH-IR samples. Irradiation alone could extend the shelf life beyond 8 days. The IR and CH-IR samples had a storage life of nearly 67 and 73 days respectively in chiller storage indicating that combination of chitosan, vacuum packaging and irradiation had a significant effect in extending the shelf life under chiller storage and can be marketed throughout the state. Irradiation can definitely save the energy required for freezing and can destroy all most all the food borne pathogens. The spoilage of the product was assessed on the basis of physical signs like changes in colour, odour, consistency, slime formation and mould growth. Even chitosan application alone had a beneficial effect in extending the shelf life of the product by about 5 days in chiller storage and hence the importance of chitosan application cannot be over looked.

The proximate composition like moisture, fat, protein, total ash and carbohydrates of the samples were analysed on the day of preparation. Irradiation or chitosan application did not significantly affect any of the proximate composition. The samples had a very good protein per cent of above 26 per cent and above 20 per cent with respect to fat and had an average energy content of 305 K Cal/100g. The initial TBARS value of 0.91±0.04 mg mal/ kg was changed to 0.96±0.03 mg mal/kg due to irradiation under vacuum conditions but chitosan application has made it non significant. As storage period increased, the TBARS value has significantly increased indicating the fat changes under chiller conditions. The changes in TBARS values under room temperature storage were abrupt whereas under chiller it showed a slow and steady increase. TV, indicating the proteolytic changes in meat showed a comparatively higher value in control NIR samples compared to the treatment groups with lowest in CH-IR followed by

IR. Storage had a significant effect in increasing TV and room temperature storage has significantly increased the tyrosine content even by day 5.

The initial aerobic plate count of 1.76±0.01 log cfu/g on the day of preparation was significantly reduced by about 53 per cent by irradiation. The combined effect of chitosan coating and irradiation has totally destroyed the microorganisms on the day of preparation even though a survival rate was noticed on subsequent days. The storage had a significant effect in increasing the microbial population both in chiller as well as in room temperature conditions. The per cent of reduction noticed in present study (53 per cent) was low when compared to the previous reports in fresh meat which contain a higher per cent of moisture. Intermediate moisture food requires a higher dose of irradiation for total destruction of bacteria and the present study utilized only 2.5 kGy. The psychrotrophic count in the control NIR sample was significantly reduced in all treatment groups with the lowest count in CH-IR and IR samples. The storage had a significant effect in increasing the count of psychrotrophic organisms. The effect due to chitosan alone was not obvious and between IR and CH-IR samples the reduction in psychrotrophic count was not significant indicating that chitosan application alone was not that much effective in reducing the psychrotrophic count in chicken fry. For the yeast and mould count, the changes were similar to that of psychrotrophic count and recorded a significant reduction due to irradiation, chitosan coating and their combination. A mild decrease in count was noticed due to chitosan coating. Under chiller storage, the count has gradually increased and the increase was significant in each period of investigation.

The organoleptic qualities of the product were assessed with the help of nine point Hedonic scale. The colour score on the day of preparation was significantly improved due to irradiation, chitosan coating and their combined effect. The maximum score of 8.39 out of 9 was recorded for CH-IR samples. As storage period enhanced, it showed a downward trend both in chiller and room temperature storage. Even after 70 days of storage, the CH-IR samples recorded a fairly good score of 7.37 indicating that the sample is good. Contradictory to the

colour scores, the flavour score of the product on the day of preparation showed a decreased value in the treatment groups compared to NIR control samples. The juiciness of the product was increased due to irradiation, chitosan coating and their combination and maximum score was recorded in IR samples. Under room temperature storage, the score showed a drastic downward trend. But in chiller storage, even on days 60 and 70 a fairly good score was recorded for IR and CH-IR samples. Similar to the colour and juiciness scores, the tenderness score of the product was significantly improved due to irradiation and chitosan coating. CH-IR samples obtained a maximum score of 8.47 out of 9. As storage period increased, the score was found to decrease. As juiciness decreases the tenderness of the product also decreases. The overall acceptability of the product was increased due to irradiation, chitosan coating and their combination obtaining an excellent score of 8.65 and 8.68 for IR and CH-IR samples respectively. The overall acceptability was reduced due to storage especially under room temperature. The cost of chicken fry was Rs. 109.83 per kg in control samples and was Rs. 114.21 per kg in case of chitosan coated samples. The Kruskal-Wallis maximum value score during the study period showed the maximum score with respect to colour, flavour, juiciness, tenderness and overall acceptability for CH-IR and IR samples.

The ready-to-eat chicken fry containing about 46 per cent moisture is having a shelf life of about 5 days at room temperature. It can be increased by chitosan coating and irradiation and can be stored beyond 10 days at room temperature. Irradiated product is shelf stable for beyond 67 days and chitosan coating followed by irradiation can extend its shelf life to 73 days under chiller. The microbiological load of the product was significantly reduced by irradiation and chitosan coating making the product wholesome. The tyrosine value which indicate proteolysis were not significantly affected due to different treatments whereas TBARS values were affected and it was taken care of by the antioxidant effect of chitosan. The organoleptic qualities of the product were increased except flavour and the product was organoleptically acceptable up to 67 days in IR and 73 days in CH-IR group under chiller storage. 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 different hurdles like chitosan coating, vacuum packaging and storage at chiller temperature can be recommended to increase the shelf life of meat and meat products.

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EFFECT OF HURDLE TECHNOLOGY, CHITOSAN AND GAMMA RADIATION ON QUALITY PARAMETERS OF CHICKEN FRY

SHIJIN A.

Abstract of the thesis submitted in partial fulfilment of the requirement for the degree of

Master of Veterinary Science

Faculty of Veterinary and Animal Sciences
Kerala Agricultural University, Thrissur

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Department of Livestock Products Technology
COLLEGE OF VETERINARY AND ANIMAL SCIENCES
MANNUTHY, THRISSUR-680651
KERALA, INDIA

ABSTRACT

The study on the effect of low dose gamma radiation and chitosan coating on shelf-life and quality changes of ready-to-eat chicken fry under vacuum packaging was conducted in the Department of Livestock Products Technology, Mannuthy. Half of the prepared chicken fry was coated with 0.5 per cent chitosan in one per cent glacial acetic acid. The other half was coated with equal quantity one per cent glacial acetic acid. The whole samples were packed under vacuum in PA-PE pouches. Half of the packets from each treatments were irradiated at 2.5 kGy employing Gamma Chamber 5000. Sufficient numbers of packets from each treatment were stored under room temperature (25-30°C) and in chiller (1-4°C). Samples were analysed for proximate composition on the day of preparation and for TBARS, TV, microbiological and organoleptic qualities on day 0, 5, 10, 15, 20, 30, 40, 50, 60 and 70 of chiller storage, while those at room temperature on day 0, 5, 10 and 15 or until spoilage, whichever was earlier. Shelf life of chicken fry was assessed based on the physical signs of spoilage. The spoiled samples were not subjected to any further analysis.

The non-irradiated control samples had a shelf life of 5.33±0.23 days at room temperature and 28.16±0.33 days in chiller. The shelf life was extended to 7.33, 8 and 10 days for CH-NIR, IR and CH-IR samples respectively at room temperature. In chiller storage, the samples were consumable up to 67 days (IR) and 73 days (CH-IR).

The proximate composition of the product analysed on the day of preparation was not significantly affected due to irradiation or chitosan coating. The TV showed a decreasing trend due to irradiation whereas the TBARS values were increased and it was controlled by chitosan coating. Storage had a significant effect in increasing both these physicochemical qualities.

Aerobic plate count, psychrotrophic plate count and yeast and mould count were significantly reduced due to irradiation, chitosan coating and their combination. Whereas the extend of reduction due to chitosan coating alone was

not up to the combined effect of chitosan coating and irradiation. As storage period enhanced the counts increased. The increase was rapid in room temperature stored samples and it was slow and steady in chiller samples. As the storage period enhanced, in the chiller stored products, the survived bacteria might have multiplied and count has gone up beyond the initial count as evidenced by the higher count in terminal end of the storage period.

The organoleptic qualities were assessed with help of nine point Hedonic scale. The colour, juiciness, tenderness and overall acceptability of the product were improved by irradiation, chitosan coating and their combination. But flavour showed a decrease in score. A gradual decrease in organoleptic qualities was observed due to storage. Even after 60 and 70 days of chiller storage, the samples had an overall acceptability score of above 7 indicating the samples are preferred by the consumers. The cost of chicken fry was Rs. 109.83 per kg and addition of chitosan at a level of 0.5 per cent increased the cost of the same by Rs. 4.38 per kilogram.

The irradiation preservation of ready-to-eat chicken fry was beneficial for enhancing the keeping quality of the product under chiller conditions without affecting the qualities. Some of the bad effects of irradiation like increase in fat rancidity can be controlled by the beneficial coating with natural antioxidants like chitosan. 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. The hurdle technology combined with irradiation and chitosan coating has significantly increased the keeping quality of the product. Considering the extended shelf life, wholesomeness of the product, reduced microbial load and energy saving aspects, chitosan coating followed by irradiation can be advocated as a suitable method for preservation of ready-to-eat value added meat products.