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Shelf life studies of irradiated mushrooms and tomatoes

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Abstract
The horticulture is an important and increasing sector, fruits and vegetables play an important role in providing essential nutrients. Post-harvest losses in fruits and vegetables are very high (20-40%). The need for novel processing technologies in the food industry is a direct result of consumer demand for fresh, high quality and healthy products that are free from chemical preservatives and yet are safe. Food irradiation technology has unique merits over conventional methods of preservation. The additional benefit of fruits and vegetables is due to a component in the food item that offers physical or biological i.e., functional benefits. Mushrooms are the only vegetative source of vitamin D along with all essential nutrients. Tomato is most important agricultural crop in India and predominant sources of Lycopene and contains antioxidant properties. Present study reveals that the application of gamma irradiation in low doses has satisfactorily increased the shelf life. Mushrooms and tomatoes irradiated at 0.75 kGy was more optimum in improving functional components than 0.25 kGy samples. The sensory evaluation scores of Mushroom and Tomato curry clearly indicates that the irradiation did not alter the sensory attributes. Gamma irradiation of Mushrooms and Tomatoes maintained the overall quality and sensory quality. Food irradiation promises to offer an effective means for minimizing the post-harvest losses and thereby increasing their availability, and stimulatory exports.

Keywords: Preservation, mushroom, quality, tomato, shelf life

Introduction

Horticulture is the fastest and important growing sector in India, but also there is a need of effectively preserve and conserve what is produced. The seasonal nature of production, long distances between production and consumption centers, the rising gap between demand and supply. Among horticulture produce fruits and vegetables placed a major role both as a regular diet and also as a healthy diet. Fruits and vegetables are vital sources of proteins, vitamins, minerals, dietary fibres and other micronutrients in daily diet. Apart from nutrition, they also contain a wide array of potential phytochemicals and antioxidants (e.g. flavonoids, glucosinolates and isothiocynates). In India, vegetables are valuable biological assets, especially genetic resources. Vegetables are important constituents of Indian agriculture and nutritional security due to their short duration, high yield, nutritional richness, economic viability and ability to generate on-farm and off-farm employment (Ranganathan, 2011) [11].

Fresh fruits and vegetables are highly sensitive to various stress factors due to improper handling and storage which causes physical damage leading to tissue breakdown. These can result in significant loss of nutritive value and in many cases the whole fruit or vegetable is lost (Kader, 1986) [2]. Minimizing these losses can increase their supply without bringing additional land under cultivation (Vanitha *et al.*, 2013) [3]. Improper handling and storage cause physical damage due to tissue breakdown. These losses are primarily due to insect infestation, microbiological contamination, and physiological changes due to sprouting, ripening and senescence. In horticultural commodities, the stages at which post-harvest losses occur can be divided into five such as production/harvest, post-harvest handling and storage, processing, distribution and consumption.

Vegetables are having the functional components which help in regulating the diseases. A food can be regarded as “functional” if it is satisfactorily demonstrated to affect beneficially one or more target functions in a body, beyond adequate nutritional affects. Functional foods can be divided into two broad categories. The first category consists of functional foods that naturally contain a component that offers additional benefits to the consumer. The other category of functional foods consists of processed foods in which a component is added to the food to give the additional benefits (Amanda and Wendy, 2012) [4].

Hence, there is a need to extend or preserve the shelf life of vegetables to satisfy the consumer need and also to reduce the huge economic losses. In the changing scenario of world trade, comparison with heat or chemical treatment, irradiation is more effective and appropriate technology to extend the shelf life of the fresh produce with minimal nutrient losses. The various processing methods are used not only to increase the edibility and palatability of fruits and vegetables but also to prolong their shelf life. Radiation processing is an interesting alternative to traditional food processing and preservation methods due to its limited effects on nutritional and sensory quality.

Presently, Mushroom has been recognized universally as a highly nutritive food and is getting more importance as medicinal/functional food. Mushrooms are potential sources of antioxidant and anticancer compounds. Mushrooms are excellent sources of most B-vitamins and the primary natural sources of ergo sterol or pro-vitamin-D. Mushrooms are internationally regarded as poor man's meat because they are good substitute for meat which peasants cannot afford. The demand for Mushrooms is growing day by day. Due to their perishable nature they are spoiled very quickly. The maximum shelf life of Mushrooms is 2-6 days at refrigeration (4^0c) temperature. There is a need to extend the shelf life of Mushrooms to meet the growing demand for Mushrooms by using advanced technology without affecting their functional components.

In some seasons, Tomato production is more and at the same time wastage is also more due to delay of transport or delay in proper utilization. There is a need to extend the shelf life of Tomatoes to increase their availability due to growing demand for these fruits. Tomatoes are rich in vitamin-C, Carotenoids, Lycopene, Antioxidants, vitamin-E, also rich in minerals like Potassium and Calcium. On the other hand Tomatoes are having high nutritional values. Tomatoes can make people healthier and decrease the risk of conditions such as cancer, osteoporosis and cardiovascular disease.

Hence, Mushrooms and Tomatoes were selected for the current study because of their nutrient and bioactive composition. The main aim of the current research is to study the effect of irradiation at different dose rates on shelf life and quality of Tomatoes and Mushrooms.

Methodology

Vegetable selection

Mushroom: Button Mushroom (*Agaricus bisporus*) is the most popular variety, fetches high price, still dominating the Indian and International market.

Tomatoes: Tomato has high significant popularity in today's market, both as a processed ingredient and as a fresh fruit.

Sample collection and preparation

Fresh mature Mushrooms (*Agaricus bisporus)* of similar size and free from physical defects were obtained from commercial Mushroom growers located at Hyderabad. Local variety of fresh Tomatoes (*Solanum lycopersicum*) was collected from farms at the day of harvest.

Packaging and labeling: The high density polyethylene (HDPE) covers were selected for radiation processing in the current study. Mushrooms were cleaned with soft clean cloth and then packed in HDPE covers each with 200g due to light weight and also to avoid the damage of Mushrooms during storage and processing. Tomatoes were cleaned with water and wiped with soft clean cloth and then packed in HDPE covers each with 500g. The labeling was done according to the treatment applied for the samples.

Radiation processing of vegetables: Irradiation has potential to be used for meeting quarantine requirements for international trade in fresh fruits and vegetables and is a useful treatment as a critical control point in a Hazard Analysis and Critical Control Point (HACCP) based food production process (Olson, 1998) [5].

Equipment: The irradiation was done by using gamma chamber in irradiation plant at Quality control lab, Acharya N.G. Ranga Agricultural University; Hyderabad. The equipment used for radiation processing was Gamma (γ) Irradiation chamber (cobalt -60).

Doses given: In the present study, the low dose levels (0.25 kgy and 0.75 kgy) were employed to irradiate Mushrooms and Tomatoes to investigate the effect of it in retaining the functional components.

Storage of Vegetables: The non-irradiated (NI) and irradiated samples (I1 and I2) of Mushroom and Tomato were stored at refrigeration temperature to know the effect of radiation processing on quality and shelf life studies.

Quality analysis: The selected parameters *viz*., functional, microbial and organoleptic analysis for Mushroom and Tomato were analyzed.

The Beta-carotene content in the vegetables was estimated by procedure followed by Zakaria *et al.*, (1979) [6]. The Lycopene content in the vegetables was estimated by method followed by Ranganna (2001) [7]. The vitamin-D content in the vegetables was estimated by using Ultra-High-Performance Liquid Chromatography/Tandem Mass Spectrometry First Action 2011, AOAC method No.2011.11 (LC-MS/MS). The Total Antioxidant Activity in vegetables was estimated by using TBARS method.

The total plate count of the vegetables was estimated by using the procedure given in BIS: 5402:2012. The Yeast and molds of the vegetables were estimated by using the procedure given in BIS: 5403:1999. The Listeria *Monocytogenes* in the vegetables were analyzed by using the Indian standards (BIS 14966 (Part 1): 2001) [11]. The Salmonella species in the vegetables were analyzed by using the Indian standards (BIS: 5887(P-3):1999) [10].

Shelf life Studies

The quality analysis was carried out for all the samples during storage. The analysis was carried out at initial and final phase of the experimental period to determine the quality and shelf life of the foods.

Organoleptic evaluation: Sensory evaluation can be defined as the quality of a product which is assessed by means of human sensory organs. The evaluation is said to be sensory or subjective or organoleptic. Sensory quality is a combination of different senses of perceptions coming into play in choosing and eating as food appearance, which can be judged by the colour, size, shape, uniformity and absence or defects of first importance in food selection (Lowe, 1955) [13].

The non-irradiated and irradiated samples of both Mushroom and Tomato were subjected to sensory evaluation to assess the acceptability. Mushroom and Tomato curry was prepared and the products were subjected to organoleptic analysis. Home makers in the age group of 30-40 were chosen as panel for sensory evaluation. The analysis was done by using Hedonic rating scale for sensory evaluation. The testing was done on 5 point scale of 'like very much' to 'dislike very much'.

Results and Discussion

Vitamins and antioxidants are important functional components which affects during processing. The predominant functional components such as vitamin-C, vitamin-D and total antioxidants activity of Mushrooms were analyzed. Vitamin-C (mg/100g) in vegetables has varietal and functional factors. A sharp decrease in vitamin-C (Table 1) content was observed in non-irradiated Mushrooms (6.42mg to 5.67mg), Mushrooms irradiated at 0.25 (5.20mg to 4.87mg) and 0.75 kGy (4.58mg to 4.00mg) from initial to final phase of the experimental period.

Mushrooms are the only vegetative source of vitamin-D. The decrease of vitamin-D was more in non-irradiated (2.77µg to 1.97µg) when compared to irradiated Mushrooms at 0.25(1.44µg to 1.28µg) and 0.75 kGy (3.92µg to 3.02µg) from initial to final phase of the experimental period. The increase of vitamin-D was more in Mushrooms irradiated at 0.75 kGy followed by 0.25 kGy and non-irradiated Mushrooms. Similar trend of results was observed by Ko *et al.*, (2008) [14], in their study on effect of UV-B exposure on the concentration of Vitamin-D_2 in sliced shiitake Mushroom and white button Mushrooms. The concentration of vitamin-D_2 was increased to 36.7, 68.6 and 106.4 for pileus, middle and gill parts of shitake Mushroom respectively. Irradiating slices of white button Mushroom was a more efficient way of increasing the vitamin-D_2 content than irradiating the gill or pileus of whole Mushrooms, due to the larger exposure area.

The antioxidants are recognized as bio-active compounds that act against possible ill effects of free-radical damages in humans. The high increasing trend of total antioxidant activity was observed in irradiated Mushrooms at 0.25 kGy (35.80% to 52.02%), whereas a very minute increase was there in irradiated Mushrooms at 0.75 kGy (41.73% to 52.05%) when compared with the non-irradiated (43.02% to 45.60%) from initial to final phase of experiment. An another reason for the increase of total antioxidant activity might be due to the fact that the irradiation disrupt the cell wall and liberate antioxidant compounds from insoluble portion of Mushroom, which in turn, increase the pool of bio accessible antioxidant compounds.

Table 1: Effect of Gamma Irradiation on functional components of Mushrooms during shelf life period

Treatments	Total Antioxidant Activity		Vitamin-D (µg/100g)		Vitamin-C (mg/100g)	
	Initial	Final	Initial	Final	Initial	Final
NI	43.02±0.19	45.60±0.04	2.77 ±0.05	1.97± 0.05	6.42±0.03	5.67±0.05
I_1	35.80±0.09	52.02±0.18	1.44± 0.02	1.28± 0.03	5.20±0.04	4.87±0.06
I_2	41.73±0.343	52.05±0.17	3.92 ±0.02	3.02± 0.02	4.58±0.04	4.00±0.02

The retention of total antioxidant activity and vitamin D was maximum in Mushrooms irradiated at 0.75 kGy followed by 0.25 kGy and non-irradiated Mushrooms.

Shelf life studies of Tomato

The predominant functional components such as vitamin-C, total antioxidant activity, lycopene and β-carotene were analyzed in Tomatoes. Vitamin-C is a powerful antioxidant helps lessen oxidative stress to the body. The decreasing trend of vitamin-C content was observed in both non-irradiated Tomatoes (20.96 mg to 20.41mg) and Tomatoes irradiated at 0.25 (12.96mg to 10.55mg) and 0.75 kGy (12.81mg to 9.07mg) from initial to final phase of the experimental period (Table 2). The vitamin-C content decreased in all the samples on storage. Vitamin-C is a heat liable vitamin, the effects of irradiation is influenced by exposure to oxygen, storage and temperature, as well as the pH of the food matrix or storage medium. It is known to be readily oxidized to dehydro ascorbic acid on irradiation.

Antioxidants apply as inhibitor of the oxidation process even at relatively small concentration and thus have diverse physiological role in the body. The high decreasing trend of total antioxidant activity was observed in non-irradiated Tomatoes (40.62% to 22.98%) than Tomatoes irradiated at 0.25 (33.33% to 29.22%) and 0.75 kGy (38.52% to 34.03%) from initial to final phase of experimental period.

Takeoka *et al.*, (2001) [15], investigated the Processing Effects on Lycopene Content and Antioxidant Activity of Tomatoes. In this study, four carotenoids, trans-lycopene, phytofluene, phytoene, and beta-carotene, were quantified in Tomato products. Samples of raw Tomatoes, Tomato juice after hot break scalder, and final paste were obtained from two different processing plants over two years. Antioxidant activity was observed in each of the three fractions, and Tomato paste had a greater antioxidant activity in all fractions than fresh Tomatoes. Changes in the antioxidant activity of Tomato products are complex and depend on the specific compounds being studied. Initial results suggest that losses in antioxidant activity associated with decreases in lycopene concentration during processing may be accompanied by increases in antioxidant activity of other components, particularly polyphenolics.

The most important source of beta-carotene is Tomatoes. The results reveal that a decrease in beta-carotene was noticed in both non-irradiated (6.87mg to 5.09mg) and irradiated samples at 0.25(4.48mg to 3.72mg) and 0.75 kGy (6.33mg to 5.26mg) from initial to final phase of the experimental period. During storage the decrease of beta-carotene was observed in all the samples, maximum retention of beta-carotene was in Tomatoes irradiated at 0.75 kGy. Lukton and Mackinney, (1956) [17] reported that the decrease in beta-carotene was due to destruction caused by secondary reaction and depends on the amount of free radicals formed during processing.

Table 2: Effect of Gamma Irradiation on Functional Components of Tomatoes during shelf life period

Treatments	Total antioxidant activity		Beta-carotene (mg/100g)		Lycopene (mg/100g)		Vitamin-C (mg/100g)	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final
NI	40.62±0.06	22.98±0.17	6.87±0.04	5.09±0.03	21.94±0.09	18.62±0.11	20.96±0.06	20.41±0.11
I_1	33.33±0.11	29.22±0.10	4.48±0.16	3.72±0.09	44.20±0.15	41.21±0.11	12.96±0.05	10.55±0.07
I_2	38.52±0.16	34.03±0.09	6.33±0.18	5.26±0.06	67.81±0.03	55.65±0.03	12.81±0.9	9.07±0.05

Lycopene is the red carotenoid found predominantly in Tomatoes and in a few other fruits and vegetables. The decrement of lycopene content was noticed in both non-irradiated (21.94mg to 18.62mg) and Tomatoes irradiated at 0.25(44.20mg to 41.21mg) and 0.75 kGy (67.81mg to 55.65mg) from initial to final phase of the experimental period. Lurie *et al.*, (1996), reported that, relatively high temperature (38°C) inhibited lycopene production, while low temperatures inhibited fruit ripening and lycopene production. Lower lycopene pigments in irradiated treatments indicate delayed bio Synthesis and delayed accumulation of lycopene pigments.

The maximum retention was observed in irradiated Tomatoes at 0.75 kGy than the 0.25 kGy and non-irradiated Tomatoes for moisture, total antioxidant activity, lycopene and beta-carotene.

Microbial analysis

Gamma irradiation decreases the microbial load of the foods, there by leading to an enhancement of shelf life. The presence of total plate count, yeast and molds, listeria *monocytogenes* and salmonella were assessed.

The data reveals that there is a slight decrease in total plate count and yeast and molds of Mushrooms and tomatoes in irradiated samples when compared with non-irradiated samples immediately after irradiation. The listeria *monocytogenes* and salmonella was absent in both non-irradiated and irradiated samples of Mushrooms and tomatoes during the experimental period. Microbial growth (Total plate count, yeast and molds) seems to be higher in non-irradiated Mushrooms and Tomatoes than in irradiated samples during experimental period. Ionizing radiation can be effective in controlling the growth of food spoilage and food borne pathogenic bacteria. Low dose radiation could be effective method of eliminating or controlling the pathogenic bacteria organisms.

At the final phase of the experimental period the microbial load was decreased among all samples when compared with the initial values which might be due to the effect of storage conditions. The decreasing trend of microbial load was more in irradiated samples when compared with non-irradiated samples of Mushrooms and Tomatoes.

Wani *et al.*, (2007) [19], stated that among the range of irradiation treatments of 0-2.5 kGy given to pears, 1.4-2.5 kGy recorded the minimum yeasts and mold counts. The yeast and mold counts of pears were markedly reduced by the irradiation treatment which further decreased with increase in the irradiation dose. The yeast and mold counts of control samples were 6.3 log cfu/g while that of irradiated sample was 4.1-6.1 log cfu/g after 20 days under ambient conditions.

Bari *et al.*, (2005) [18], investigated the effectiveness of irradiation treatments in inactivating listeria *monocytogenes* in fresh vegetable at refrigeration temperature. Ionizing radiation can be effective in controlling the growth of food spoilage and food borne pathogenic bacteria. This study reports on an investigation of the effectiveness of irradiation treatment to eliminate Listeria *monocytogenes* on laboratory inoculated broccoli, cabbage, Tomatoes and mung bean sprouts. Irradiation of broccoli and mung bean sprouts at 1.0 kGy resulted in reduction.

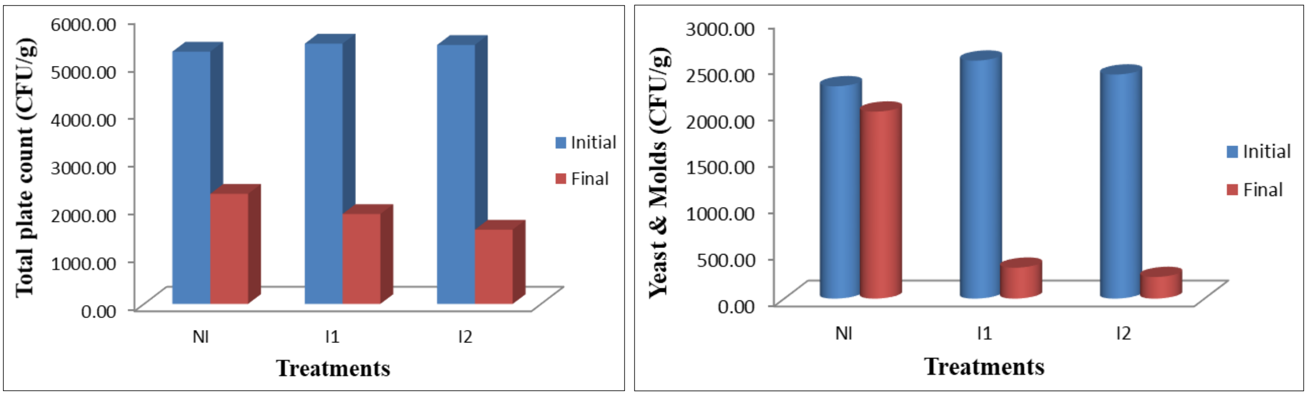

Fig 1: Effect of Gamma Irradiation on Total plate count and Yeast and molds in Mushrooms

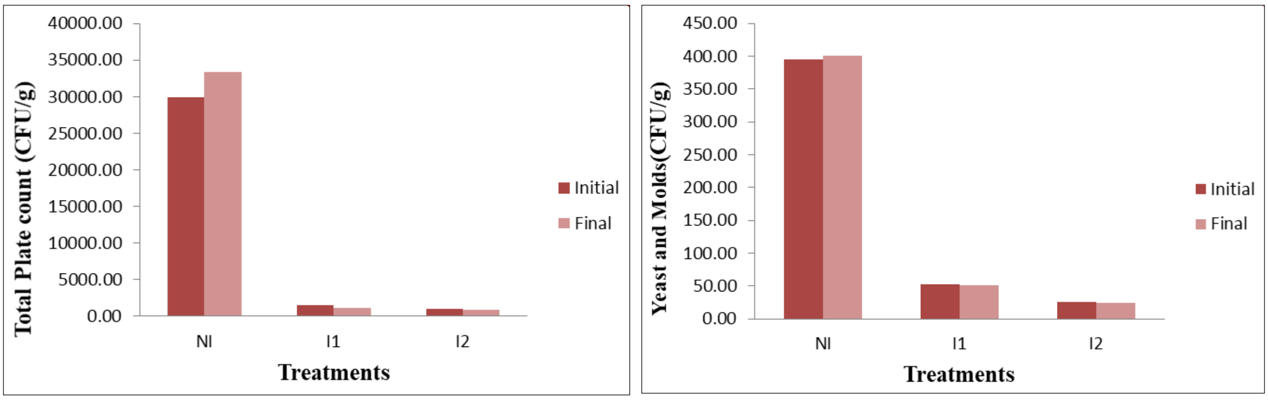

Fig 2: Effect of Gamma Irradiation on Total plate count and Yeast and molds in Tomatoes

The absence of pathogenic organism's listeria *monocytogenes* and salmonella in Mushrooms was observed throughout the experimental period. The irradiated Tomatoes significantly reduced microbial load (total plate count, yeast and molds). During storage the gradual decrement of microbial load was observed in irradiated Tomatoes. Radiation can also damage or break large molecules such as DNA and enzymes. These effects prevent bacteria from reproducing and suppress the pathogen population's growth, effectively "killing" germs in the food.

Organoleptic evaluation of Mushroom and Tomatoes

Mushroom and Tomato curry was assessed and sensory evaluation scores were recorded at initial and final phase of the experimental period. The mean scores for appearance, color, flavor, texture, taste and overall acceptability was noted.

Mushrooms

The data pertaining to the sensory evaluation of Mushrooms for irradiated and non-irradiated samples at initial and final phase of the experimental period was analyzed (table 3).

There is a slight significant difference in the sensory quality of appearance with t=29.0 between the treatments which indicates that the physical quality retains better in treated samples whereas the other attributes such as color, taste, texture and flavor also revealed that negligible change observed among the treated and non-treated samples with significant difference t=17.32, t=28.00, t=11.023 and t=26.00 respectively. With regard to overall acceptability, a positive difference was observed in treated samples than non-treated samples with the statistical value t=15.50.

Table 3: Mean Scores for Sensory Evaluation of Mushroom Curry

S. No	Code/Item	Appearance		Color		Taste		Texture		Flavor		Overall Acceptability	
		Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
1	NI	4.7	4.6	4.3	4.4	4.6	4.5	4.8	4.7	4.5	4.4	4.3	4.4
2	I1	4.8	4.8	4.4	4.3	4.5	4.4	4.7	4.6	4.4	4.3	4.4	4.5
3	I2	4.7	4.7	4.2	4.2	4.4	4.4	4.6	4.5	4.3	4.1	4.5	4.4
	t-test p-value	t =29.0** (p=0.000)		t =17.32** (p=0.000)		t=28.00** (p=0.000)		t= 11.023** (p=0.000)		t=26.00** (p=0.000)		t=15.50** (p=0.000)	

**significant at 0.01 level (*p*<0.01)

Tomato: The data pertaining to the sensory evaluation of Tomatoes based on appearance, color, taste, texture and overall acceptability of the irradiated and non-irradiated samples at initial and final phase of the experimental period was analyzed (table 4).

There is a slight significant difference in the sensory quality of appearance with t=17.0 between the treatments which indicates that the physical quality retains better in treated samples whereas the other attributes such as color, taste, and texture also revealed that negligible change observed among the treated and non-treated samples with significant difference t=15.921, t=8.222 and t=5.965 respectively. With regard to flavor and overall acceptability, a positive difference was observed among the final stage values of treated samples than in non-treated samples with the statistical value t=10.39 and t=14.70.

Table 4: Mean Scores for Sensory Evaluation of Tomato Curry

S. No	Code / Item	Appearance		Color		Taste		Texture		Flavor		Overall Acceptability	
		Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
1	NI	4.7	4.3	4.4	4.7	4.5	4.4	4.3	4.4	4.6	4.3	4.4	4.6
2	I1	4.8	4.4	4.3	4.6	4.4	4.3	4.4	4.3	4.8	4.4	4.3	4.5
3	I2	4.7	4.2	4.2	4.5	4.3	4.1	4.5	4.1	4.7	4.2	4.2	4.4
	t-test p-value	t =17.0** (p=0.000)		t =15.921** (p=0.000)		t=8.222** (p=0.000)		t= 5.965* (p=0.013)		t=10.39** (p=0.000)		t=14.70** (p=0.000)	

**significant at 0.01 level (*p*<0.01); *significant at 0.05 level (*p*<0.05);

Irradiation process extends the shelf life of Mushrooms and Tomatoes, which is very beneficial for distribution and storage of fresh commodity. Radiation technology is a promising technology for minimizing the losses especially post-harvest losses and thereby increasing the availability of fresh produce and stimulating exports by extending the shelf life. The retention of functional components was also more in irradiated samples at 0.75 kGy when compared to other samples of mushrooms and tomatoes.

The sensory evaluation scores for Mushroom and Tomato curry clearly indicates that the gamma irradiation treatment did not alter the sensory attributes. It is clearly evident from the study that food irradiation is a promising method with certain advantages. Gamma irradiation of Mushrooms and Tomatoes maintained the overall quality without detriment to their Physico-chemical and sensory quality. Food irradiation promises to offer an effective means for minimizing the post-harvest losses and thereby increasing their availability, and stimulatory exports.

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