The Journal of Animal & Plant Sciences, 28(5): 2018, Page: 1385-1390
ISSN: 1018-7081

INFLUENCE OF GAMMA IRRADIATION ON SHELF LIFE AND PROXIMATE ANALYSIS OF FRESH TOMATOES (*SOLANUM LYCOPERSICUM*)

N. Munir, A. Manzoor, R. Haq and S. Naz*

Department of Biotechnology, Lahore College for Women University, Lahore, Pakistan.
*Corresponding author: drsnaz31@yahoo.com

ABSTRACT

Tomato (*Solanum lycopersicum*) from the family Solanaceae is the one of the most important and readily consumed fresh vegetable of the world. In tomato, post-harvest quality loss and shelf life is a problem of great concern. The shelf life of tomato is very less as the rottening starts within one week after the harvest. Therefore, it is very important to find out an effective means for increasing the shelf life of tomatoes. Gamma radiation is an important sterilization method to eradicate diverse bacteria and fungi that cause rottening of fruits and vegetables without affecting their nutritional components. The present research was conducted to optimize the gamma radiation dose for tomatoes that did not affect the nutritional value of tomatoes. On the basis of increased shelf life as well as proximate analysis of radiated and non-radiated tomatoes it can be suggested that 1kGyis optimum dose for tomatoes. The treatment of samples with 1kGy had no significant effect on nutritional composition, texture, color and firmness of tomatoes and also helps to increase the shelf life of tomatoes.

Key words: Gamma irradiation, proximate analysis, post-harvest losses, sterilization.

INTRODUCTION

Tomato (*Solanum lycopersicum*.) belongs to the family Solanaceae, is one of the most important and extensively used tropical crops consumed worldwide. It is used in varied ways like cooking, salads and as a sauce. It is rich in lycopene (responsible for red coloration), water and vitamin C that are essential nutrients for human beings (Mozumder *et al*., 2012). The various varieties of tomatoes are being cultivated in all five provinces of Pakistan over an area of about 52,300 hectares. The annual production of tomatoes in Pakistan is estimated at around 25270 hg/ hectare in 2011-12 (FAO, 2013).It has been found that 100g of tomatoes contain0.9 g of protein, 3.9 g of carbohydrate, 0.3 g of fat and 94.5 g of water (Rao and Agarwal, 2000).

Tomato is a climacteric fruit having respiratory peak during their ripening process. Being a climacteric and delicate vegetable, tomatoes have a very short life span usually 1-2 weeks (Sammi and Masud, 2007). An important issue both in the research of storage technology and in the industrial practice is the role and effect of the stage of ripeness of tomato fruits after harvesting. Actually, post-harvest decay of fruits and vegetables is activated by inappropriate storage conditions, pathogenic attacks, mechanical injuries and environmental stresses (Zhang *et al*., 2011). Number of chemical and physical processes takes place in vegetables during shelf storage. Water comprises 90% of the fresh weight of tomato fruit and the size of the fruit is influenced by the availability of water to the plant. The large amount of water also makes the fruit delicate. The rapid quality loss at relatively short period of 4-7days is an efficient means of storing the fruits to reduce post-harvest losses and improve the quality and acceptability in the consumer market. Packaging and quarantine treatment like gamma radiation can markedly extend the storage life of many fresh fruits and vegetables through the inhibition of physiological deterioration and reducing weight loss (Khalaf *et al*. 2014). This needs to develop a technology for extending the shelf life of tomatoes without altering the nutritional as well as ornamental beauty of the fruit and vegetable. Gamma irradiation has been successfully used as an alternative treatment for microbial disinfection (Usall *et al*., 2015).

Microbial spoilage of fruits and vegetable is known as rot, which exhibits as change in texture, colour and most of the time off odour hence there is a dire need to develop methods to overcome the post-harvest losses of fruits and vegetables (Jeong and Jeon, 2018). Tomatoes which is the third most important vegetable crop on the basis of its market value (Law, 2011), coupled with high nutritive status and high-water content which makes it very vulnerable to spoilage microbes during storage, harvesting and transportation (Spadaro and Gullino, 2004). It has been reported that gamma radiation is a significant treatment that can increase the shelf life of tomatoes Gamma irradiation doses of 250,500 and 750 Gray have been compared with the control samples on 1st,8th and 13^{th}day of irradiation preserved at 4,12 and 250C and found effective in combating theloss (Akhter and Khan 2012).).It has been reported that gamma radiation is a significant treatment that can increase the shelf life of vegetables and fruits tomatoes (Kumar *et al*, 2014, Wenwen *et al*., 2015).

The main problem of less shelf life as a result various microbe that may result in rottening of the fruit, the aim of the present work was to optimize a dose of gamma irradiation for fresh tomatoes that improved the shelf life of the tomato without altering its nutritional components.

MATERIALS AND METHODS

The samples of fresh and firm red tomatoes having uniform shape and size were purchased from a local market of Lahore. The samples were sent to Pakistan Atomic Radiation and Services (PARAS) for Co-60 gamma irradiation. The doses 0.5, 0.75 and 1.0kGy were applied to the tomatoes (Akhter and Khan 2012). During the present work, Harwell Amber 3042 dosimeter was used for dose measurement. The measurement uncertainty was 3% at 95% confidence level. The dose uniformity ratio for irradiated sample of tomatoes during the present work was 1.0 that was achieved by multi-sided irradiation. Un-irradiated control was kept stored in refrigerator at 4°C.

Fresh irradiated and non-irradiated tomatoes were submitted to 10 panelists for the organoleptic evaluation. The ranking method used for scoring based on the hedonic scale with 9 scores ranging from “Like very much” to “Dislike very much” (Table 1). Percent decay was calculated by visual observation of each sample as described by Zheng *et al*. (2007).All the samples were analyzed to find out moisture content, ash, fat, protein and carbohydrates at day 7, 14 and 21. . Official methods of AOAC manual (2005) were used for proximate analysis of irradiated and non-irradiated sample (Table 2).

Official AOAC method (to determine the moisture content) was repeated to follow the 3 weeks. Percentage of moisture was calculated by

M.C = (Ww-Wd)/Ww) x 100

To determine the ash content, sample was first ignited and then placed in Muffle furnace at 500°C–550°C temperature for 4 to 6 hours till the sample become ash. Weight of ash was calculated by:

Weight of ash = weight of crucible + ash – weight of crucible

% of ash was calculated as Ash % = wt. of ash (g)/wt. of sample * 100

For the determination of crude fat Soxhlet apparatus was used. In a Soxhlet apparatus the extraction was carried out for 6 hours with 500 ml of ethanol.

Loss of weight was being calculated as:

Loss in weight = wt. of thimbles + demoisture sample – (weight of thimbles – fat free sample)

Fat % = loss in weight (g)/wt. of sample * 100 % of fibre was calculated by

% of fibre = wt. of sample (g) - loss in weight (g)/wt. of sample * 100

Kjeldahl method was used for estimation of protein content and carbohydrate content was determined by the differential method.

%Carbohydrate=100-(%Moisture+%Ash+%Fat+%Crude protein +% Crude fiber)

Table 1. Hedonic scale for the organoleptic evaluation.

Attribute: Flavor/ Color/ Odor/ Texture		
S. No.	**Degree of preference**	**Sample #**
1	Like very much	9
2	Like much	8
3	Like moderately	7
4	Slightly like	6
5	Neither like or dislike	5
6	Slightly dislike	4
7	Dislike moderately	3
8	Dislike much	2
9	Dislike very much	1

Table 2. Methods used for proximate analysis of tomatoes.

Components	**Method reference**
Moisture content	AOAC 934.01, 934.06, 964.22 (Hot air oven)
Ash content	AOAC 923.03, 942.05, 945.46(Muffle furnace)
Crude Fat	AOAC 922.06, 925.12, 989.05, 954.02(Soxhlet Method)
Crude Fiber	AOAC 985.29 or 991.43 (Heating mantle and Muffle furnace)
Protein content	AOAC 991.20(Kjeldahl Method)
Carbohydrates	AOAC 985.29 or 991.43

Statistical Analysis: The data for the various parameters including percentage decay, moisture content, ash, fat, protein and carbohydrates was recorded in triplicates at day 7, 14 and 21 and analyzed by Univariate Analysis of Variance using SPSS version 17.

RESULTS AND DISCUSSION

Shelf life of tomato: Throughout the present work, the shelf life of tomato was significantly enhanced after gamma radiation treatment. The effect of gamma irradiation on the shelf life of tomatoes was significantly increased (Fig. 1). Results showed that radiation doses 0.75 and 1.0kGy were efficient in extending the storage life of tomatoes while very lower dose had no significant effects on extending the shelf life. The treated samples with 1kGy had a shelf life of 21 days as compared to control that were spoiled after 9 days. Moreover, the fruit retained its red color after gamma irradiation treatment. In a similar study, Jeong*et al*., (2015) achieved shelf life extension of pepper by subjecting them to different doses of gamma radiation. During their work Santor*et al*., (2016) also reported enhanced shelf life after treatment with gamma radiation at a dose of 3.2kGy.

Decay of tomato: The effect of gamma radiation on percentage decay of the tomato was also observed. It was observed that gamma radiation resulted in less decay of the fruit. After week 1 no decay was recorded in the samples treated with 1kGy. Increase in radiation dose from 0.5 to 0.75 and1kGy slowed down the decay.Efficacy of gamma irradiation on minimizing decay of fruits and vegetables may be associated to it stability of penetration deep into tissues and destroying spoilage microorganism harbored in wounds or inside host tissues, thus preventing or minimizing the decayprocess by inhibiting the growth of these microbes (Jeong*et al*., 2015). During their work Abad *et al*. (2017) reported 48% reduction in Weight loss of golden-yellow and purple-red tamarillo (*Solanum betaceum* Cav.) fruit subjected to gamma irradiation and the application of an edible coating.

Organoleptic properties of tomato: Tomato fruits were assessed for flavour, odour, colour and texture after treatment with gamma radiation and effect of time interval. It can be inferred from the Table 3 that dose 1kGy indicated no effect on the organoleptic qualities of tomatoes.Losses in firmness as a result of irradiation have been attributed to changes in cell wall components.Prakash *et al*.(2000). Magee *et al*. (2003**)** also reported radiation-induced softening in case of tomato. In tomato, irradiation has been reported to cause no change in color thus in addition to its use as quarantine treatment it also allows them to be harvested when fully ripe (Adam *et al*., 2014).

Proximate analysis of control and gamma irradiated tomatoes: During the present work moisture content, ash content, crude fiber, protein content, fat content and carbohydrate content of control and irradiated samples were compared (Table 4).

Moisture content: Moisture in control sample reduced gradually from 97 to 90.7 g100g^{-1}after two weeks. On the contrary, moisture content in irradiated samples was less as compared to the control (Table 4). The irradiated samples with 0.75-and1kGy retained 90 g100g-^{1}even after week 3. During storage period of fresh fruits, the changes in metabolic activities may result in changes in moisture content (Dionesio, 2009). Hussain *et al*. (2008) also reported that radiation doses 1.2-1.4kGy resulted in a reduced weight loss of peach (*Prunus persica*cv. Elberta) from 6 to 20 days at room temperature and refrigerator respectively. During storage period of fresh produce, respiration rate and senescence process increases, which alter moisture contents of produce and may cause weight loss. Adam *et al*. (2014) showed reduced weight loss, respiration rate and delayed softening in gamma irradiated tomatoes. It has also been reported that gamma radiation has resulted in softening of persimmon fruits (Byung-Oh *et al*., 2015).

Ash content: Ash content decreased with the storage period and also depends upon the gamma radiation dose. In control sample ash content decreases from 0.9 to 0.5 g 100-1 g at week 2. In irradiated sample of 0.5kGy dose ash content decreases significantly among all irradiated sample. In irradiated samples at 0.75 and 1kGy the value of ash content did not show much reduction. The amount of ash was also reported as 0.5% to 1.1% (Hanif *et al*., 2006) however a higher amount of ash (3.21%)has been reported byRodriguez *et al*.(2015).

Protein content: The effect of different doses of gamma irradiation on protein content of tomatoes was compared and analyzed. It was observed that in control samples, during week1, a greater amount of protein was noted in control sample as compared to irradiated tomatoes. However, a low content of protein variation was recorded after gamma radiation with the passage of time. After week 3 samples that were irradiated with 1kGy had 0.62 g100g-1 protein content. Protein content in tomatoes was 2.25% determined by by Suárez *et al*. (2008). The amount of protein content in tomatoes has been found to be 0 ranging from 0.89 to 1.13% (Jorge *et al*., 2017).

Fiber content: There was a significant effect of time on crude fiber of stored tomatoes but the effect of gamma radiation on crude fiber was non-significant. The crude fiber was decreased slightly with the passage of time in irradiated samples. The samples that were irradiated at 1kGy possessed crude fiber ranging from 0.85 g100g-1 to 0.61 g100g-1 for three-week analysis. High doses of irradiation applied to fruits and vegetables may result in depletion of carbohydrates (Mostafavi*et al*., 2012).

Fat content: It is evident from the data that fat content was found in trace amounts in tomato and on the storage, it was a little bit reduced in both irradiated and control sample. Its value in control sample was 0.004 g100g-1 that did not change as a result of treatment with gamma irradiation during the first week. During the second week its value decreased to 0.003 g100g^{-1} in the irradiated sample with 1kGy Fats in trace amount present in tomatoes (Suarez *et al*., 2008).

Carbohydrate content: The effect of gamma radiation on carbohydrate content of tomatoes was evaluated by differential method. The amount of carbohydrates increased gradually in control sample. During the second week, all irradiated samples showed a little amount of carbohydrates decreased but in week 3 the carbohydrate content of irradiated samples was increased slightly as reported earlier (Law, 2011).

Table 3.Organoleptic evaluation of gamma irradiated and non-irradiated tomatoes at day 7, 14 and 21.

Dose (kGy)	Mean organoleptic score± Standard Error								
	Color			Texture			Flavor		
	Day 7	Day 14	Day 21	Day 7	Day 14	Day 21	Day 7	Day 14	Day 21
Control	6.03 ± 0.05^{d}	3.06 ± 0.05^{f}	ND	5.10 ± 0.15^{c}	2.0 ± 0.03^{e}	ND	5.00 ± 0.01^{c}	4.0 ± 0.03^{d}	ND
0.5	8.1 ± 0.1^{b}	5.0 ± 0.1^{e}	ND	8.0 ± 0.05^{a}	4.0 ± 0.05^{d}	ND	7.9 ± 0.03^{a}	5.3 ± 0.03^{c}	ND
0.75	9.0 ± 0.05^{a}	7.0 ± 00.02^{c}	ND	7.9 ± 00.05^{a}	6.0 ± 0.02^{b}	ND	8.0 ± 0.02^{a}	7.0 ± 0.02^{a}	ND
1	9.0 ± 0.01^{a}	$6.1\pm .0.05^{d}$	$7.0\pm. 0.01^{c}$	8.0 ± 0.01^{a}	$8.0\pm .0.01^{a}$	$7.0\pm. 0.01^{a}$	7.0 ± 0.01^{b}	8.0 ± 0.01^{a}	7.0 ± 0.01^{a}
Effect of time (with 4 and 19 df)	*	*	*	*	*	*	*	*	*
Effect of Gamma Radiation (with 4 and 19 df)	*	NS	NS	NS	NS	NS	NS	NS	NS
Effect of time x Gamma Radiation (with 4 and 19 df)	*	*	*	*	*	*	*	*	*

Each value is the mean of three replicates with standard error (Mean± SE) mean with same superscript are not significantly different by Duncan's new multiple range test ($P < 0.05$)

*, NS Significant at 1% level (*) or non-significant (NS) according to F test with df mentioned against each

ND the value could not be determined due to the decay of fruits.

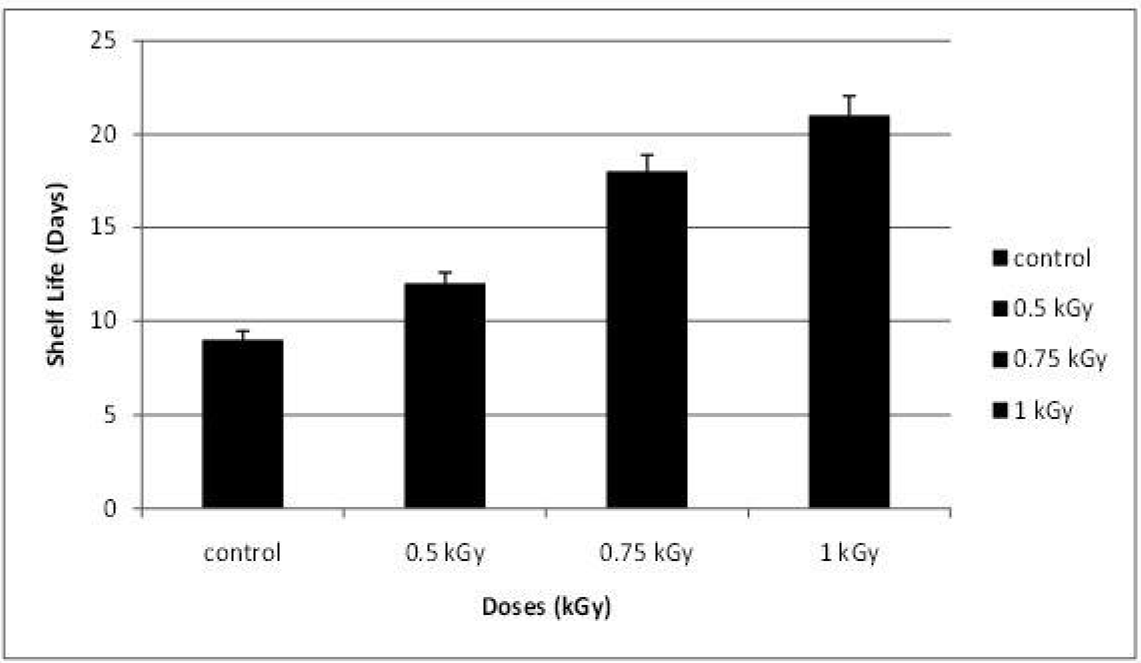

Fig. 1.Effect of gamma irradiation on shelf life of tomatoes.

Table 4. Evaluation of different nutritional components after treatment with gamma radiation at day 7, 14 and 21

Time	Radiation dose	Proximate Analysis					
		Moisture	Ash	Protein	Crude fibre	Fat	Carbohydrates
Day 7	**Control**	95.2+0.00632[a]	0.9 +0.2529[a]	0.16 +0.0252[a]	0.60+0.0252[a]	0.04 +0.005[a]	3.21 +0.01[a]
	0.5	94.6+0.244[bc]	0.9 +0.2529[a]	0.16 +0.0252[a]	0.61+0.0252[a]	0.04 +0.005[a]	3.21 +0.01[a]
	0.75	94.2+0.442[c]	0.88+0.0599[a]	0.14 +0.012[a]	0.60+0.0189[a]	0.04 +0.002[a]	3.23 +0.04[a]
	1	95+ 0.06829[ab]	0.9+0.00632[a]	0.15+0.0126[a]	0.62+0.0126[a]	0.04 +0.006[a]	3.25 +0.02[a]
Day 14	**Control**	ND	ND	ND	ND	ND	ND
	0.5	85+0.00632[c]	0.6 +0.00632[a]	0.07+0.0125[b]	0.60+0.0632[a]	3.23+0.03[a]	3.25+0.001[a]
	0.75	89+0.1897[b]	0.73+0.01897[a]	0.09+0.0126[a]	0.60+0.0632[a]	3.24+0.004[a]	3.25+0.002[a]
	1	90+0.1264[a]	0.89+0.2529[a]	0.09+0.00632[a]	0.61+0.0126[a]	3.27+0.002[a]	3.26+0.001[a]
Day 21	**Control**	ND	ND	ND	ND	ND	ND
	0.5	ND	ND	ND	ND	ND	ND
	0.75	ND	ND	ND	ND	ND	ND
	1	93+0.0189[a]	0.95+0.01897[a]	0.13 +0.0189[a]	0.63+0.1264[a]	0.002+0.002[a]	0.0003+0.0002[a]
Effect of time (with 4 and 19 df)		*	*	*	*	*	*
Effect of Gamma Radiation (with 4 and 19 df)		*	NS	NS	NS	NS	NS
Effect of time x Gamma Radiation (with 4 and 19 df)		*	*	*	*	*	*

All the values are sum of means of five parallel replicates. + indicates standard deviations+ SD) among the replicated. Means followed by different letters in the same columns differ significantly P=0.05 according to Duncan 's multiple range test.

Conclusion: It can be concluded from the present work that low dose of 0.5kGy did not result in enhanced shelf life but a dose of 1kGy enhanced the shelf life of tomatoes without affecting its proximate analysis. These findings also lead to conclude that nutrient destruction is not much when food is stored by ionizing radiation as compared to the conventional means of food storage.

Acknowledgements: Authors are thankful to Mr. Shoaib of Pakistan Radiation Services (PARAS), Lahore, Pakistan, for providing the ^{60}Co, gamma irradiator, facility.

REFERENCES

Abad, J., S.V. Chamorro., A. Castro and C. Vasco. (2017). Studying the effect of combining two nonconventional treatments, gamma irradiation and the application of an edible coating, on the postharvest quality of tamarillo (*Solanum betaceum* Cav.) fruits. Food Control. 72: 319-323

Adam MY, Elbashir HA, Ahmed AHR (2014) Effect of Gamma Radiation on Tomato Quality during Storage and Processing. Int. Res. J. Biol. Sci 6:20–25

Akhter, H. and S. A. Khan (2012). Effect of gamma irradiation on the quality (colour, firmness and total soluble solid) of tomato (*Lycopersicon esculentum* L.) stored at different temperature. Asian J. Agric. Sci. 6: 12-20.

AOAC. (2005). Official methods of analysis of the association of analytical chemists. Eighteenth Ed. AOAC, Washington.

Byung-Oh. K., C. Won-Seup, A. Dong-Hyun and C. Young-Je (2015). The change on cell wall composition and physiological characteristic of astringent persimmon fruits by gamma irradiation. Korean J Food Pres. 512-519

Dionesio, A.P., R. T. Gomes and M. Oetterer, M. (2009) Ionizing radiation effects on food vitamins: a review. Braz. Arch. Biol. Technol., 52(5): 1267–1278.

FAO. (2013). Forests for improved nutrition and food security. Rome. www.fao.org/forestry/ 27976-02c09ef000fa99932eefa37c22f76a055.pdf.

Hanif, R., Z. Iqbal, M. Iqbal, S. Hanif and M. Rasheed. (2006). Use of vegetables as nutritional food: role in human health. J Agric Biol. Sci., 1(1): 18-22.

Hussain, P.R., R.S. Meena, M.A. Dar and A.M. Wani (2008). Studies on enhancing the keeping quality of peach (*Prunuspersica)* by gamma irradiation. Radiat. Phys. Chem. 77 (4): 473-481.

Jeong M. A and R. D Jeon (2018). Applications of ionizing radiation for the control of postharvest diseases in fresh produce: recent advances. Plant Pathol. 67: 18-29

Jeong R. D, E. J. Shin, E. H. Chu. E. Park and H. Jun (2015). Effects of ionizing radiation on postharvest fungal pathogens. Plant Pathol. J. 31, 1–5.

Jorge, M. F, S. Oliveira, K.J. L. B. Junior, L. D. B. Da Silva and MI.M.Barbosa, M. Ivone and M. J. Barbosa (2017). Physicochemical characteristics, antioxidant capacity and phenolic compounds of tomatoes fertigated with different nitrogen rates. *Rev. Caatinga*. 30: 237-243

Khalaf H, A. Sharob, R. El Sadani , F. M. El Nashaby and S. Elshiemy S (2014). Antioxidant properties of some extracts from gamma irradiated tomato (*Lycopersiconesculentum* L.) pomace. Food and Dairy Sci. 5:247–263.

Kumar M, S. Ahuja, A. Dahuja,R. Kumar, B. Singh B (2014) Gamma radiation protects fruit quality in tomato by inhibiting the production of reactive oxygen species (ROS) and ethylene. J RadioanalNucl. 301:871-880

Law, O.K.E (2011). Comparison of growth, yield performance and profitability of tomato (*Solanum lycopersicon*L.) under different fertilizer types in humid forest soils. Int. Res. J. Agri. Sci. Soil Sci. 1(8): 332-338.

Magee, R.I., F. Caporaso and A. Prakash (2003). Effects of exogenous calcium salt treatments on inhibiting irradiation-induced softening in diced Roma tomatoes. J. Food Sci. 68(8): 2430-2435.

Mostafavi H. A, S.M. Mirmajless, S. M. Mirjalili, H. Fathollah, H. Askari H (2012). Gamma radiation effects on physico-chemical parameters of apple fruit during commercial post-harvest preservation. Rad. Physics Chem. 81, 666–71.

Mozumder, N., M. Rahman, M. Kamal, A. Mustafa and M. Rahman (2012). Effects of pre-drying chemical treatments on quality of cabinet dried tomato powder. J. Env. Sci. Nat. Resour. 5: 253-265.

Prakash, A., A.R. Guner, F. Caporaso and D.M. Foley (2000). Effects of low-dose gamma irradiation on the shelf life and quality characteristics of cut romaine lettuce packaged under modified atmosphere. J. Food Sci. 65: 549–553.

Rao, A.V. and S. Agarwal (2000). Role of antioxidant lycopene in cancer and heart disease. J. Am. Col. Nutri. 19: 563-569.

Rodriguez, A. J. Trebolazabala, I. Martinez Arkarazo, A. Diego, J.M. Madariaga. (2015). Metals and metalloids in fruits of tomatoes (*Solanum lycopersicum*) and their cultivation soils in the Basque Country: concentrations and accumulation trends. Food Chem., 173: 1083-1089

Sammi, S. and T. Masud (2007). Effect of different packaging systems on storage life and quality of tomato (*Lycopersiconesculentum*var. Rio-grande) during different ripening stages. Int. J. Food Safety. 9: 37-44.

Santor, M.P., A. Ferreira, M. JoãoTrigo, N. António, F.Fernanda M.A. Margaça and S. C Verde. (2016). Post-harvest treatment of cherry tomatoes by gamma radiation: Microbial and physicochemical parameters evaluation. Innov. Food Sci. Emerg. Tech. 36: 1-9

Spadaro, D and M.L. Gullino (2004). State of the art and future prospects of the biological control of post-harvest fruit diseases. Int. J. Food Micro. 91(2): 185-194.

Suarez, M., R. E. Rodríguez, D. C. Romero. (2008). Chemical composition of tomato (*Lycopersiconesculentum*) from Tenerife, the Canary Islands. Food Chem., 106 (3): 1046 - 1056.

Usall, J., C. Casals, M. Sisquella, L. Palou and A. De Cal (2015). Alternative technologies to control postharvest disease of stone fruits. Stewart Postharvest Rev.4, 2.

Wenwen D, W. Guoyan, G. Lijuan, M. Long, B. Li, S. Liu, L. Cheng, X. Pan, L. Zou (2015). Effect of Gamma Radiation on *Escherichia coli, Salmonella enteric* Typhimurium and *Aspergillus niger* in Peppers. Food. Sci. Tech. Res. 21: 241-245

Zhang, H., R. Li and W. Liu (2011). Effects of chitin and its derivative chitosan on postharvest decay of fruits: A Review. Int. J. Mol. Sci. 12: 917-934.

Zheng, Y., S. Y. Wang C. Y. Wang and W. Zheng (2007). Changes in strawberry phenolics, anthocyanins and antioxidant capacity in response to high oxygen treatments. LWT-Food Sci. Technol. 40: 49-57.