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Impact of Low Doses of Gamma Irradiation on Off-Season Guava at Ambient Storage Condition

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A B S T R A C T

An experiment was conducted at Bidhan Chandra Krishi Viswavidyalaya to study the effect of different low doses of gamma radiation on shelf-life and post-harvest quality of off-season locally popular guava cultivar (Khaza) of West Bengal. Freshly harvested fruits in March 2016, stored at ambient storage condition were exposed to four doses gamma-radiation (0, 100, 200 and 300 Gy) using Cobalt-60 isotope with an energy and dose rate of 1.33MeV and of 4.94 kGy/h, respectively. Irradiation of guava fruits with 200 Gy gamma-radiations significantly increased the post-harvest life (93.8%) without any negative impacts in fruit quality (firmness, titratable acidity, soluble solids content and vitamin C) as well as sensory quality parameters (appearance, taste, texture and flavour) as compared to non-irradiated fruits. The same treatment also reduced physiological loss in weight and unmarketable fruit %. Irradiation treatments also helped to retain crispiness in guava by slowing down ripening process than non-irradiated fruits.

Introduction

Guava (*Psidium guajava*) is one of the major fruit of India, successfully cultivated on a wide range of soils and climatic conditions owing to its comparative tolerance to abiotic stress (Meena *et al.*, 2014).

Guava is considered as the fifth most important fruit crop of India occupying an area about 251 thousand hectares with the production of 40.83 million tonne (NHB, 2015). It is considered to be one of the exquisite, nutritionally valuable, remunerative crops and called as ‘apple of tropics’ due to higher content of vitamin C (75-260 mg), thiamine (0.03-0.07 mg), riboflavin (0.02-0.04 mg), phosphorus (22.5-40.0 mg), calcium (10.0-30.0 mg) and iron (20-25 mg) and also potential source of pectin (0.5-1.8% in 100 gm of pulp) (Shukla *et al.*, 2009). Demand of guava as fresh as well as processing products in domestic and international markets is showing an increasing trend. On the other hand, the export of guava is not sufficient from India, which can be boosted up with the increasing storability of the fresh fruits (Mandal *et al.*, 2012). Guava bear fruits at different times of the year but harvesting all the crops are not economically profitable. In

Indian condition, the maximum fruiting of guava are produced in the rainy season but fruits in this season are poor in quality, insipid, watery in nature and infested by number of disease pests, whereas winter fruits has superior quality but production is comparatively less (Adhikari *et al.,* 2015). Therefore, regulation of the natural flowering and fruiting behaviour of guava are needed to make guava cultivation more profitable and market oriented. Though several techniques are developed for crop regulation of guava, growers of West Bengal mostly practiced 'branch bending technique' mainly in summer or autumn to maximize the off-season production.

The guava fruit is highly perishable in nature under ambient condition; it is overripe within a week. Therefore, it needs immediate marketing and utilization after harvesting. During storage, fruits are subjected to number of physicochemical changes that affect their final texture and quality. Now-a-days several tools for ensuring the safety of fresh and fresh-cut produce are available, but low dose gamma irradiation is emerging as one of the most promising tool amongst them (Niemira and Fan, 2006). Due to the strong desire to reduce the use of chemicals applied to fruits and vegetables, the non-residual feature of ionizing radiation is one of the important advantages. Internationally, food irradiation has been considered a safe and effective technology by several international reputed organizations like World Health Organization (WHO), Food and Agriculture Organization (FAO), International Atomic Energy Agency etc. (El-Samahy *et al.,* 2000). Ionizing radiation treatment has been known to extend the post-harvest life of many tropical and sub-tropical fruits (Singh and Pal, 2009) by preventing growth of the microorganisms that cause food deterioration (Dionísio *et al.*, 2009). Fruit crops respond variably to similar doses of irradiation across cultivars, species and physiological status (Baghel *et al.,* 2005), so standardization of optimum doses of irradiation is essential for a particular fruit and its cultivar also.

Though in recent past some works were carried out to evaluate the response of gamma irradiation on guava but information till lacking particularly for offseason and locally famous guava cultivar in the Gangetic alluvial zone. Keeping all these points in backdrop, an experiment was performed to study the effect of different low doses of gamma radiation on shelf-life and post-harvest quality of off-season guava cultivar.

Materials and Methods

Experimental setup and radiation source

Locally popular guava (*Psidium guajava* L.) cultivar *Khaza* was collected from the farmers' field of Gyayeshpur, Nadia, West Bengal, India produced during the month of March 2016. Fresh guavas of uniform size and maturity without wounds or blemishes were selected for study. After collection, guavas were divided into different groups randomly for application of the irradiation treatment and packed in perforated polythene bags (LDPE) of 200 gauge thickness. After the following day of collection, guavas stored in the bags at ambient storage condition were exposed to different doses gamma-radiation (0, 100, 200 and 300 Gy) using Cobalt-60 isotope with an energy and dose rate of 1.33MeV and of 4.94 kGy/h, respectively. The radiation treatment was performed at Regional Nuclear Agriculture Research Centre, Bidhan Chandra Krishi Viswavidyalaya, West Bengal. The experiment was performed in completely randomized design (CRD) with four doses gamma-radiation and replicated five times under controlled laboratory condition. Twenty guava fruits were taken for each replication. So, total four hundred guava fruits were used for this experiment. After irradiation, the guavas were kept separately under ambient storage conditions (Temperature 25±2°C, Relative Humidity 85±4%) in a well-ventilated room.

Observations recorded

Evaluation of various quality parameters of fruits was started after three days of irradiation and assessment was continued upto 9th days of storage with an interval of 3 days. Physiological loss in weight (PLW) was calculated as cumulative % loss in weight based on the initial fruit weight (before storage) and loss of weights recorded at the time of periodical sampling during storage (Waskar *et al.,* 1999). Unmarketable fruit percentage determined by the following formula suggested by Sau *et al.,* (2016)

$$\text{The percentage of unmarketable fruit} = [\text{No. of unmarketable fruits} \div \text{Total no. of fruits}] \times 100$$

Fruit firmness of guava was determined by a screw type Penitrometer (Model FT- 327, Facchini, Italy) and the reading was expressed in kg cm^{-2}. For determination of the days required to reach break down point of crispiness or firmness, we have adjusted the reference reading of Penitrometer with organoleptic score value of firmness given by the panel members. In the connection of fruit firmness, the breakdown of crispiness was evaluated with mouth felling score given by ten members panel.

The total soluble solids (TSS) was estimated using digital refractometer (Model: ATAGO, RX 5000, Tokyo, Japan) and was expressed as °Brix. Titratable acidity were determined by titrating 5 mL of juice against 0.1 N NaOH (AOAC, 2002) and expressed as % value. Total sugars, reducing sugars were determined according to the method explained by Khan *et al.,* (2009) and were expressed as %. Ascorbic acid was determined by 2,6-dichloroindophenol titrimetric method as suggested by Rangana *et al.,* (1986).

To access various sensory parameters of irradiated and non-irradiated guava fruits, ten candidates (undergraduate and postgraduate students) were pre-screened from University based on availability, health and general food habits (Gunness *et al.,* 2009). Out of the original thirteen, ten candidates were selected based on their ability to discriminate between products on basic taste thresholds, to describe their perceptions, and their ability to participate in group discussions. With this ten selected candidates a panel of judges or evaluator was formed. They are asked to evaluate the physical appearance, taste, flavour and texture of guavas of different treatments and score them in 1-10 point score scale. Judges used filtered water as a palate cleanser between each evaluation; each session allowed enough time for assessment to reduce fatigue. Testing was carried out in individual laboratory rooms in the Quality Control Laboratory at the Bidhan Chandra Krishi Viswavidyalaya under daylight equivalent lighting conditions for minimizing any unforeseen error.

Statistical analysis

Results are represented in tables and figures as the means of five replicates. Data were subjected to one-way analysis of variance with the SAS statistical system 9.2 (SAS Institute, Cary, NC, USA), and all means of physical and bio-chemical properties were compared using Duncan's Multiple Range test. Significant differences were assessed at the $p \leq 0.05$ probability level.

Results and Discussion

Shelf life of guava

Shelf life of guava at ambient storage condition significantly improved with radiation treatment over non-irradiated fruits (Fig. 1). Irradiation of guava fruit with 200 Gy increased the post-harvest life of guava fruits

(93.8% higher than non-irradiated fruit) followed by 100 Gy gamma radiation (87.6% higher than non-irradiated fruit).

As guava is a climacteric fruit, its ethylene production rates increases during ripening and it is also reported that post-harvest irradiation treatment altering these ethylene production processes (Singh and Pal, 2009). Shelf life extension of guava may be due to suppressive effect ionizing radiation on respiration and ethylene production rates in fruits are also confirmed by researchers in different crops like strawberry (Majeed *et al.,* 2014), banana (Zaman *et al.,* 2007) and mango (Janave and Sharma, 2005).

Physiological loss in weight

The irradiation treatments significantly trimmed down the physiological loss in weight over non-irradiated fruits (Table 1). The lowest physiological weight loss (9.25 %) at 9^{th} days of storage was observed when guava fruits were irradiated with 200 Gy gamma radiations. Whereas after 9^{th} days of storage, the maximum physiological weight loss (12.90 %) was observed from the non-irradiated fruits. During storage period, respiration rate and senescence of fresh fruits increase, as result the moisture content of fruits gradually decreases which may cause physiological loss in weight (Ayranci and Tunc, 2003). It is also reported that respiration rate often decreases with irradiation treatment may arguably due to reduced metabolic activities of irradiated fruits (Benoit *et al.,* 2000; Boynton *et al.,* 2005).

Unmarketable fruit percentage

The data represented in Table 1, on percentage of unmarketable fruits suggested that unmarketable fruit % increased with progression of storage time. Irradiation of fruits with 200 and 100 Gy proved as better treatment with no unmarketable fruit at early days of storage (upto 3^{rd} day) and only 28.15 and 25.83% unmarketable fruits respectively at final days of storage (9^{th} day).

Irrespective of storage time, the maximum unmarketable fruit percentage was observed from non-irradiated fruits. Efficacy of gamma irradiation on minimizing decay of fruits may be associated to its deep penetration ability into tissues and by destroying spoilage microorganism harboured in wounds or inside host tissues (Barkai-Golan, 2001). Significant reduction in unmarketable fruits production by exposure of gamma irradiation also reported by Silva *et al.,* (2009) in strawberries and Hussain *et al.,* (2008a) in peach.

Fruit firmness

The reduction in fruit firmness of guava was significantly delayed by irradiation treatment (Table 2). At the end of 6^{th} days of storage, 3.35 times reductions in fruit firmness was observed in non-irradiated fruit while irradiated fruits recorded only 1.5-1.8 times decrease in firmness. Amongst the different irradiation treatments, 200 Gy dose were found superior in retarding firmness losses upto 9^{th} day of storage (2.98 times higher firmness over non-irradiated fruits). In irradiated fruits (irrespective of radiation doses) the crispiness (when firmness reading upto 6-6.5 kg cm^{-2}, by correlating score for crispiness and fruit firmness at that point) was lost after 5 days of storage whereas in non-irradiated fruits it lost within 3.33 days of storage (Table 2). The delay in fruit softening by gamma radiations may be attributed to the inhibitory effect of irradiation on ethylene production (Singh and Pal, 2009) which is one of the principle factors responsible for fruit softening and rapid changes in skin colour in guava (Reyes and Paull, 1995).

Fruit biochemical attributes

Fruit TSS content was significantly changed with application of gamma irradiation treatments during storage period (Table 3). At the first day of observation (3rd day of storage) the maximum TSS was observed in non-irradiated fruits (8.56 ± 0.04 °Brix), while significantly lower TSS recorded from the fruits received 200 Gy gamma irradiation (8.35 ± 0.02 °Brix). The increment of TSS over time was more rapid in non-irradiated fruits than fruits received irradiation treatments. Irrespective to all the treatments, TSS content reached to the peak after 6th day of storage, after that it gradually decreased. The initial increment in TSS was due to the enzymatic conversion of higher polysaccharides into simple sugars during ripening (Paull *et al.*, 1984) or due to hydrolysis of pectic substances (El Assi *et al.*, 1997), whereas the subsequent reduction in TSS was associated with the oxidative break-down of sugars due to fruit respiration (Hussain *et al.*, 2008b; Mahajan *et al.*, 2005). The lower TSS in gamma irradiated fruits may be due to delay in enzymatic conversion of higher polysaccharides.

Fig.1 Effect of gamma irradiation on shelf life (days) of guava. Vertical columns are treatment mean ±standard error (n=3). Vertical columns followed by the same letter are not significantly different (P≤0.05)

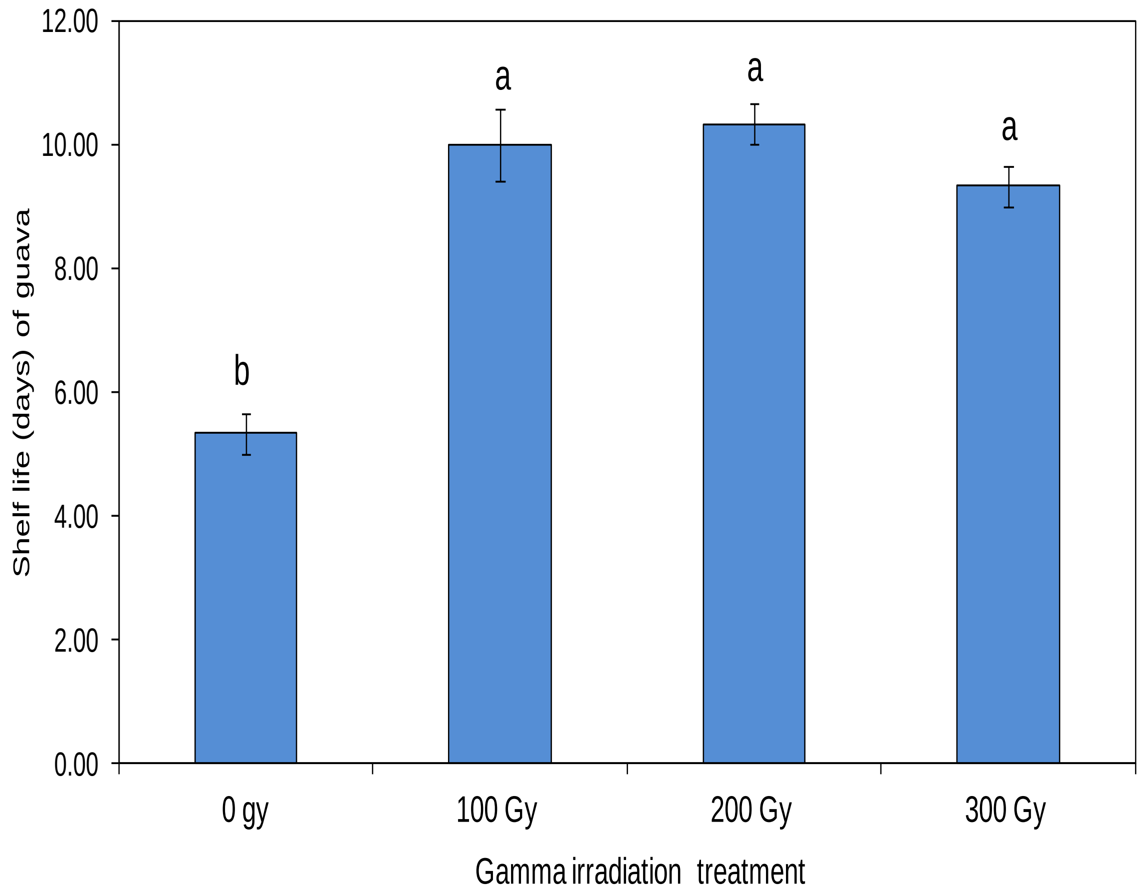

Fig.2 Effect of gamma irradiation on Ascorbic acid (mg100 g^{-1}) of guava. Treatment values followed by the same letter are not significantly different (P≤0.05)

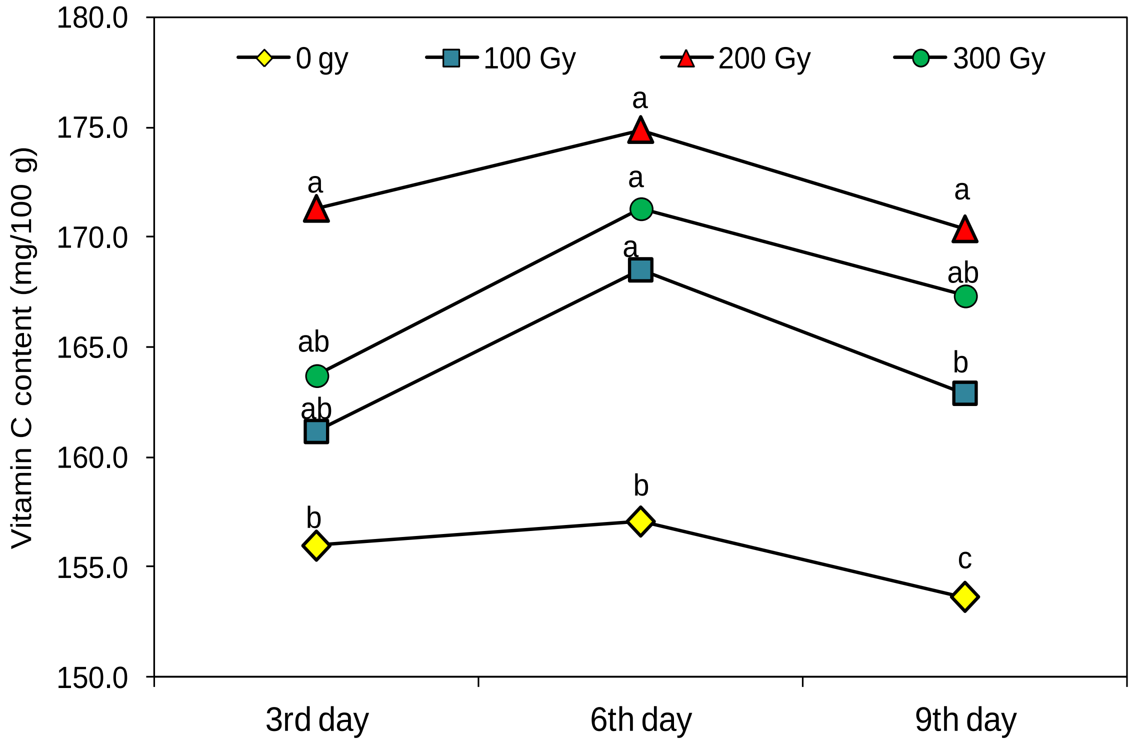

Fig.3 Rader diagram showing the effect of gamma irradiation on the sensory parameters of guava

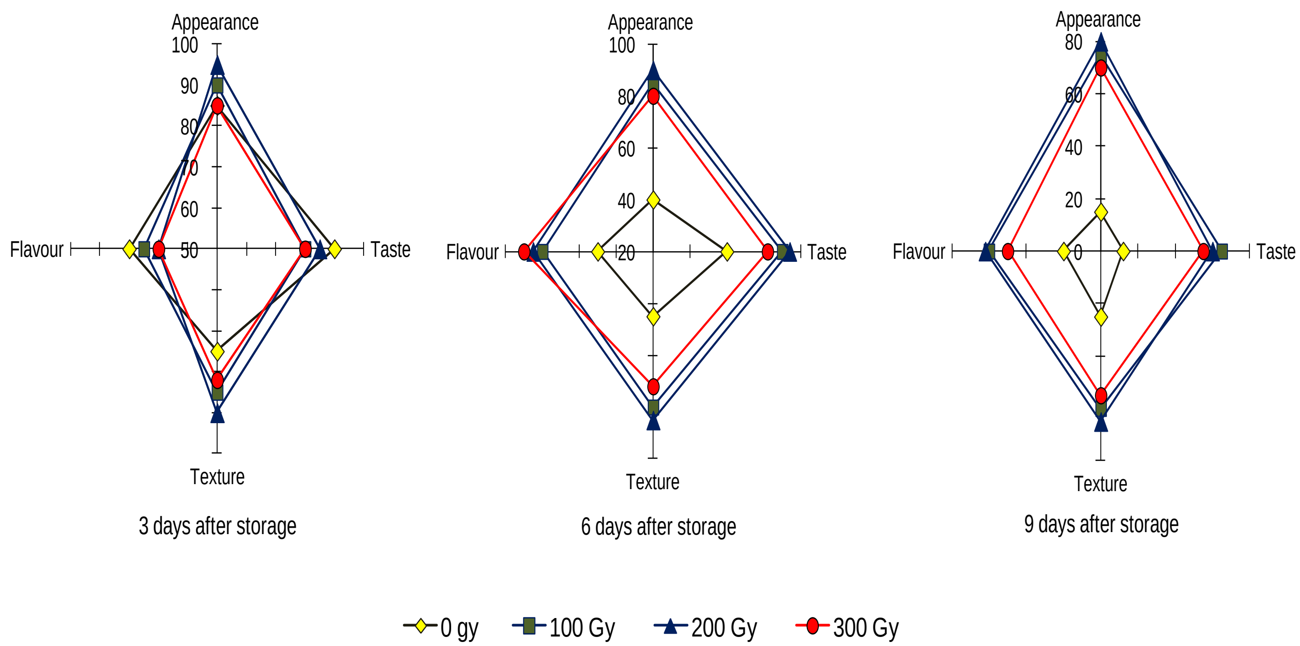

Fig.4 Comparison between irradiated (200 Gy gamma) and non-irradiated guava at different days of storage

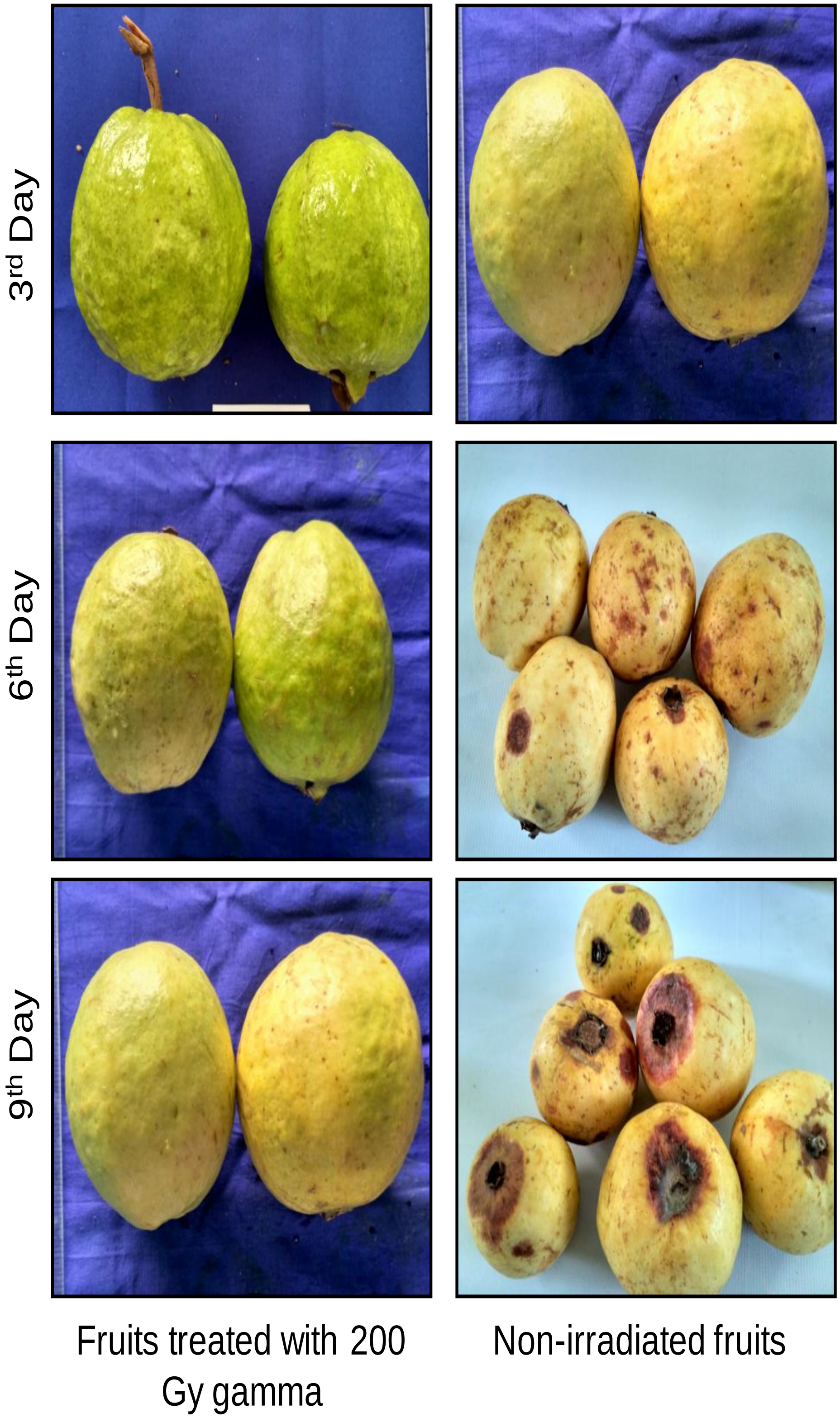

Table.1 Effect of gamma irradiation on Physiological Loss of Weight (%) and Unmarketable fruit % of guava

Treatment	Physiological Loss of Weight (%)			Unmarketable fruit %		
	3rd day	6th day	9th day	3rd day	6th day	9th day
Non –irradiated (0 Gy)	5.23 ± 0.55[a]	9.73 ± 0.39[a]	12.90 ± 0.20[a]	27.00 ± 1.15[a]	60.00 ± 2.88[a]	84.45 ± 3.28[a]
100 Gy gamma irradiation	3.45 ± 0.13[b]	5.14 ± 0.13[b]	9.45 ± 0.13[b]	0.00*	11.96 ± 0.98[b]	28.15 ± 1.37[bc]
200 Gy gamma irradiation	3.11 ± 0.06[b]	5.02 ± 0.07[b]	9.25 ± 0.02[b]	0.00*	11.35 ± 0.44[b]	25.83 ± 2.25[c]
300 Gy gamma irradiation	3.93 ± 0.03[b]	5.58 ± 0.07[b]	9.65 ± 0.08[b]	3.67± 0.88[b]	13.33 ± 1.66[b]	33.70 ± 0.96[b]

Values are mean ±standard error (n=5).Treatment values followed by the same letter are not significantly different ($P \leq 0.05$); *any unmarketable has not observed on the day of observation.

Table.2 Effect of gamma irradiation on fruit firmness (kg cm^{-2}) and days required to reach break down point of crispiness of guava

Treatment	Fruit firmness (kg cm^{-2})			Days to reach break down point of crispiness
	3rd day	6th day	9th day	
Non –irradiated (0 Gy)	6.67 ± 0.10[c]	4.63 ± 0.29[b]	3.95 ± 0.07[b]	3.33 ± 0.33[b]
100 Gy gamma irradiation	7.66 ± 0.12[ab]	6.47 ± 0.38[a]	5.10 ± 0.15[a]	5.33± 0.33[a]
200 Gy gamma irradiation	8.13 ± 0. 18[a]	6.83 ± 0.20[a]	5.13 ± 0.07[a]	5.67± 0.33[a]
300 Gy gamma irradiation	7.47 ± 0.21[b]	6.10 ± 0.26[a]	5.03 ± 0.06[a]	5.00 ±0.57[a]

Values are mean ±standard error (n=5).Treatment values followed by the same letter are not significantly different ($P \leq 0.05$)

Table.3 Effect of gamma irradiation on TSS (° Brix) and Titratable acidity % of guava

Treatment	TSS (°Brix)			Titratable acidity %		
	3rd day	6th day	9th day	3rd day	6th day	9th day
Non –irradiated (0 Gy)	8.56 ± 0.04 ^{a}	9.20 ± 0.02 ^{a}	9.01± 0.04 ^{a}	0.60 ± 0.02 ^{b}	0.43 ± 0.02 ^{b}	0.39 ± 0.02 ^{b}
100 Gy gamma irradiation	8.41 ± 0.06 ^{ab}	8.95 ± 0.02 ^{b}	8.73 ± 0.04 ^{b}	0.68 ± 0.01 ^{a}	0.50 ± 0.01 ^{ab}	0.42 ± 0.03 ^{ab}
200 Gy gamma irradiation	8.35 ± 0.02 ^{b}	9.07 ± 0.08 ^{ab}	8.80 ± 0.11 ^{ab}	0.72 ± 0.03 ^{a}	0.55 ± 0.03 ^{a}	0.48 ± 0.01 ^{a}
300 Gy gamma irradiation	8.45 ± 0.08 ^{ab}	9.15 ± 0.02 ^{a}	8.85 ± 0.02 ^{ab}	0.71± 0.02 ^{a}	0.53 ± 0.02 ^{a}	0.50 ± 0.03 ^{a}

Values are mean ±standard error (n=5).Treatment values followed by the same letter are not significantly different ($P \leq 0.05$)

Table.4 Effect of gamma irradiation on Total sugar % and Reducing sugar % of guava

Treatment	Total sugar %			Reducing sugar %		
	3rd day	6th day	9th day	3rd day	6th day	9th day
Non –irradiated (0 Gy)	8.44 ± 0.03 ^{b}	8.79 ± 0.03 ^{c}	8.59 ± 0.02 ^{c}	3.63 ± 0.04 ^{c}	3.81 ± 0.04 ^{c}	3.67 ± 0.01 ^{a}
100 Gy gamma irradiation	8.57 ± 0.04 ^{ab}	9.00 ± 0.05 ^{b}	8.69 ± 0.03 ^{bc}	3.79 ± 0.02 ^{b}	3.98 ± 0.04 ^{b}	3.69 ± 0.18 ^{a}
200 Gy gamma irradiation	8.66 ± 0.07 ^{a}	9.25 ± 0.03 ^{a}	8.89 ± 0.03 ^{a}	4.10 ± 0.02 ^{a}	4.33 ± 0.04 ^{a}	4.04 ± 0.26 ^{a}
300 Gy gamma irradiation	8.57 ± 0.04 ^{ab}	9.10 ± 0.05 ^{b}	8.75 ± 0.05 ^{b}	3.83 ± 0.04 ^{b}	4.05 ± 0.02 ^{b}	3.73 ± 0.02 ^{a}

Values are mean ±standard error (n=5).Treatment values followed by the same letter are not significantly different ($P \leq 0.05$)

Irrespective of treatments, with the progress of storage period a declining trend was observed in titratable acidity of guava (Table 3). Throughout the storage period, fruits treated with 200 Gy gamma radiations recorded significantly higher titratable acidity (%) than non-irradiated fruits, but different irradiation treatments (100, 200 and 300 Gy) are statistically at par with each other. Reduction in acidity over time may be attributed to the conversion of organic acids into sugar and utilization of organic acids during respiration as acid forms the necessary respiratory substrate for the catabolic process in fruits (Chouksey *et al.*, 2013). Similar types of findings on this trait also reported by Hossain *et al.*, (2014) and Baghel *et al.*, (2005).

Ionizing radiation treatment significantly improved ascorbic acid content of guava over non-irradiated fruits at ambient storage conditions (Fig. 2). Irradiation with 200 Gy gamma radiations recorded significantly higher vitamin C content (170.38 mg 100 g^{-1}) throughout the storage period. The increase in vitamin C content in earlier stages of storage may be due to the increasing rate of phenols whereas during storage (after 8 days), the increase may be due to conversion of L–ascorbic acid into dehydroascorbic acid (Singh and Pal, 2009). Similar results have also observed by Mahajan *et al.*, (2005) in kinnow.

Data presented in Table 4 was revealed that irrespective of irradiation treatment, the both total and reducing sugar content of guava increased upto 6^{th} day of storage but a certain decline in both the sugar content in advanced storage days was also observed. Amongst the applied doses of gamma radiation, the maximum sugar content (total sugar 9.25% and reducing sugar 4.33%) at ambient storage condition was obtained from the fruits treated with 200 Gy while non-irradiated fruits recorded the minimum value for both the sugar content throughout the storage period (upto 9^{th} day of storage). The increase in total sugars may be attributed to radiation induced degradation of higher polysaccharides (starches and pectin substances) into simple sugars (mono-saccharides) (Hussain *et al.*, 2008a). Retention of total sugar in irradiated fruits up to 9^{th} day of storage may be due to the ability of gamma radiation to delay the ripening process by alteration in physiological metabolism (Chouksey *et al.*, 2013). Sugars are used for biochemical and physiological metabolism by ripe guavas as a result climacteric peak is also observed between seven to nine days of storage. Baghel *et al.*, (2005) and Sharma and Rastogi (2016) also find similar results in guava and strawberry, respectively.

Sensory parameters of guava during storage period were improved by gamma irradiation treatments (Fig. 3). From the radar diagrams it was clearly understood that gamma irradiation has positive impact on physical (Fig. 4) and sensory appearance of guava, thus throughout the storage period fruits got irradiation treatment received maximum sensory score by the judges panel. Throughout the storage period the maximum scores of sensory parameters like appearance, flavour, texture, taste was observed from the fruits treated with 200 Gy gamma radiation followed by 100 Gy, whereas non-irradiated fruits received the least score by the panel members. At the early days of storage (upto 3^{rd} day), panel members failed to find any significant differences of sensory parameters amongst treatments. But, at later time (6^{th} day onwards) a significant difference was observed between non-irradiated and irradiated fruits. Flavour of fruits increased with gradual ripening of fruits and attained its peak at 6^{th} day of storage and decreased thereafter (9^{th} day of storage). The flavour increased due to enhancement in the chemical attributes of fruits like increase in sugars and TSS/acid ratio where, it decreased at later days of storage due to degradation of the complex organic molecules. Our observation on sensory parameters corroborate with the findings of Dhaka *et al.*, (2001) in mango fruits and Pandey and Joshua (2010) in guava.

Gamma irradiation significantly improved most of the physical and bio-chemical parameters of the off-season guava like shelf life, unmarketable fruit percent, weight loss, TSS, Sugar content etc. and even in all the sensory observed parameters stored at ambient storage condition. All applied three low doses of gamma irradiation more or less equally effective to improve fruit storage and quality attributes. However, gamma irradiation doses of 200 and 100 Gy were most effective to extend the shelf-life of guava. Thus summarizing the findings of present study, it can be suggested that gamma irradiation doses of 200 Gy may be effectively used for shelf life extension and for minimizing postharvest decay and weight loss of guava in ambient storage condition.

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