Enhancing antioxidant activity, microbial and sensory quality of mango (*Mangifera indica* L.) juice by γ -irradiation and its in vitro radioprotective potential

Kondapalli Naresh · Sadineni Varakumar ·
Prasad Shekhar Variyar · Arun Sharma ·
Obulam Vijaya Sarathi Reddy

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Abstract Gamma irradiation is an effective method currently being used for microbial decontamination and insect disinfestations of foods. In the present study, mango (*Mangifera indica* L.) juice was irradiated at doses of 0, 1.0, 3.0 and 5.0 kGy and microbial load, total polyphenols, flavonoids, ascorbic acid content, antioxidant activities, colour and sensory properties were evaluated immediately after irradiation and also during storage. Microbiological assay of the fresh and stored mango juice showed better quality after γ -irradiation. The total polyphenols and flavonoids were significantly ($p < 0.05$) increased while the ascorbic acid content decreased with the irradiation doses applied. As a result of γ -irradiation, a significant increment in gallic, syringic and chlorogenic acids and a significant reduction in ferulic and synapic acids were noted when analyzed by HPLC. In vitro antioxidant potentials were measured using DPPH, FRAP and NO scavenging assays; the results showed significant enhancement in the activities after irradiation, that correlated well with the increase in phenolic and flavonoid content. γ -irradiation improved the colour of mango juice without any adverse changes in the sensory qualities. Significant in vitro plasmid DNA protection was observed in the presence of mango juice against radiation induced damage, even at the dose of 5 kGy. This study confirmed the potential of γ -irradiation as a method for microbial decontamination and improving the quality of the mango juice without compromising on the sensory attributes.

Keywords Gamma irradiation · Mango juice · Microbial load · Antioxidant activity · Radioprotection · Sensory evaluation

Introduction

Fruits are important constituents of human diet and are rich sources of nutrients such as vitamin C, polyphenolic compounds, provitamin A carotenoids, and minerals. However, their high moisture content and the presence of macronutrients such as sugars make them vulnerable to spoilage by microorganisms and insects, thus limiting their shelf-life and marketability (Williams 1995). Lifestyle-related diseases such as cancer, coronary diseases and hypertension have increased recently. These diseases are closely related to the change in dietary habits like increased intake of animal protein or fats and a decreased intake of dietary fiber. As a result, various fruit and vegetable juices, as a functional food have gained popularity to reduce the incidence of these diseases (Song et al. 2006).

Among the tropical fruits, mango (*Mangifera indica* L.) is a commercially important fruit consumed worldwide because of its attractive colour, distinct taste and aroma. It is the 2nd largest tropical crop, with a global production beyond 27 million tonnes (Robles-Sanchez et al. 2009). Mango is an excellent source of β -carotene (provitamin A carotenoid), vitamin C and polyphenolic compounds with traces of vitamins E, K and B. These bioactive compounds are good antioxidants and their daily intake in the diet has been related to prevention of degenerative processes such as cardiovascular diseases and cancer (Liu 2003). Thus, consumption of mango could provide significant amounts of bioactive compounds possessing antioxidant activity in the human diet. As mango is a seasonal fruit, it is processed in to various forms

K. Naresh · S. Varakumar · O. V. S. Reddy (✉)
Department of Biochemistry, Sri Venkateswara University,
Tirupati 517 502, India
e-mail: ovsreddy@yahoo.com

P. S. Variyar · A. Sharma
Food Technology Division, Bhabha Atomic Research Centre
(BARC), Mumbai 400 085, India

like frozen and canned slices, puree, jam, squash, nectar, mango powder, mango toffee and wine (Varakumar et al. 2011).

The outbreaks of food-borne diseases from consumption of fresh fruit juices have indicated the necessity for pasteurization of these products (Parish 1997). During the last decade, with increase in demand for nutritious, fresh-like food products with good organoleptic quality and an adequate shelf-life, processing by non-thermal techniques have been the major research focus. Some of the investigated technologies are γ -irradiation, high hydrostatic pressure (HHP), pulsed electrical fields, and UV decontamination (Devlieghere et al. 2004). Exposure of foods to ionizing radiations such as γ -radiation has emerged as a potential alternate method of food preservation, obviating the use of chemical preservatives. The application of this cold process as a post-harvest treatment has yielded very satisfactory results in different aspects of food technology, such as disinfestation, sterilization, inhibition of sprouting and extension of storage life of fresh fruits and vegetables (Hussain et al. 2010). WHO (1981) has reported that γ -irradiation technology can be effectively used to improve safety and shelf-stability of food products. The effects of γ -irradiation on minimally processed fruit and vegetables have been studied from different aspects. For instance, γ -irradiation was used to extend the shelf life of fresh ginger (Mishra et al. 2004), carrot and kale juice (Song et al. 2006), sugarcane juice (Mishra et al. 2011), pomegranate (Alighourchi et al. 2008) and fresh kale juice (Kim et al. 2007). In addition, it was proved to have advantages like improving colour and antioxidant activities of various food stuffs (Jo et al. 2003; Kim et al. 2007; Lee et al. 2009).

While irradiation has been successfully demonstrated to extend shelf-life of mango fruit and its pulp (El-Samahy et al. 2000; Youssef et al. 2002), steaming of cans is still a routine process practiced in India. Radiation processing and preservation of mango juice has, however, has not so far been exploited (Ramteke et al. 1991). Hence, the present study was undertaken to assess the microbiological and sensory quality of mango juice treated by γ -irradiation. In addition, the effects of γ -irradiation on various antioxidant capacities of the mango juice were determined.

Materials and methods

Chemicals and phenolic standards

All chemicals and solvents used in this study were of analytical grade. 1,1-diphenyl-2-picrylhydrazyl (DPPH), 2,4,6-tripyridyl-S-triazine (TPTZ), N-(1-naphthyl) ethylenediamine dihydrochloride, acetic acid and acetonitrile (HPLC grade) were purchased from Sigma chemical Co., St. Louis, Mo., U.S.A.; 2,6-dichlorophenol indophenol, sodium nitroprusside

(SNP) and sulphanilamide were from Himedia, Mumbai, India; Folin and Ciocalteu phenol reagent, AlCl_3 , $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$, H_3PO_4 and other chemical solvents were obtained from SD-Fine chemicals (India); Purified plasmid DNA of pUC19 was procured from Bangalore Genei Pvt. Ltd., Bangalore, India. The water used in the analysis was obtained from a Milli-Q water purification system manufactured by Millipore (Bedford, MA). All solvents used as the mobile phase were previously filtered through 0.45- μm membranes (Millipore) and degassed prior to use.

The standard phenolic compounds; gallic acid, protocatechic acid, *p*-OH-benzoic acid, vanillic acid, syringic acid, ellagic acid, caffeic acid, *p*-coumaric acid, *m*-coumaric acid, ferulic acid, synapic acid, rutin and quercetin were purchased from Sigma-Aldrich (Steinheim, Germany) and (+)-catechin and chlorogenic acid were supplied from Fluka (Buchs, Switzerland). Stock solutions of all the phenolic standards were prepared in methanol.

Mango fruit processing

Mango fruits (Cv. *Baniginapalli*) of 2009–10 year crop were procured during the months of March–May from the local market, Tirupati, and then processed according to Varakumar et al. (2012). The samples were then stored at -20°C until use. Briefly, 50 fully ripened mangoes were selected randomly, peeled and stones were separated manually from the pulp. The pulp thus obtained was ground in a mixer. The homogenate was treated with pectinase (Bio-Tropicase, Biocon, India) enzyme to reduce the viscosity and facilitate juice extraction and then subsequently filtered through two layered cheese cloth. The juice obtained in this manner was centrifuged at 10,000g for 10 min at ambient temperature, to remove any suspended particulate matter that could affect the antioxidant and radioprotective assays by interfering with the spectrophotometric measurements, as well as the DNA gel electrophoresis, respectively (Saxena et al. 2011). The supernatant obtained was designated as clear juice, which was grouped in to four lots according to the dose of irradiation received 0 (control) 1, 3 and 5 kGy in 500 mL containers each.

Gamma-irradiation

Mango juice samples (100 mL) in tightly capped containers were irradiated to a dose of 1, 3 and 5 kGy separately at ambient temperature ($26 \pm 2^\circ\text{C}$) in a cobalt-60 irradiator (model GC-5000, Board of Radiation and Isotope Technology (BRIT), Mumbai; dose rate of 5.5 kGy/h) at Food Technology Division, Bhabha Atomic Research Centre (BARC), Mumbai, India. The calibration and absorbed dose rate of the irradiator were carried out using Fricke reference standard dosimeters (ASTM Standard, E 1026 2004). To confirm the actual absorbed dose in the juice samples, a set of alanine dosimeters

was used and absorbed dose was evaluated using EPR spectrometer (ASTM Standard, ISO/ASTM 51607:2004 E). A variation in absorbed dose with respect to the desired dose was observed within ± 2.5 %. Samples were rotated 360° continuously during the irradiation process to achieve uniform target doses while the non-irradiated control sample was placed outside the irradiation chamber to have the same environmental temperature effect with the irradiated sample. Immediately after irradiation, one set was used for analysis and considered henceforth as fresh mango juice (FMJ), while another set was analyzed after storage for 2 months at 4°C and considered as stored mango juice (SMJ).

Microbiological studies

Total microbial load was determined using the standard pour plate method. The control and irradiated juice samples (1 mL) were serially diluted in sterilized peptone water (0.1 %) and appropriate dilutions were poured on to the respective plates. Plate count agar was used for determination of total aerobic bacteria (TAB) and potato dextrose agar (PDA) for the determination of yeast and mold count (YMC). All the plates were incubated at 30°C for 4–6 days and microbial counts were expressed as CFU/mL. The presented data were the mean counts from three petri dishes for each diluted suspension. Three replicates were made for each irradiated sample.

Total polyphenolic content (TPC)

Total polyphenolic content (TPC) was determined by using Folin-Ciocalteu method of Singleton and Rossi (1965) and modified by Varakumar et al. (2011). Briefly 0.5 mL of appropriately diluted juice samples or standard solutions of gallic acid was pipetted into test tube, along with 5 mL of distilled water, 0.5 mL of Folin-Ciocalteu reagent, and the mixture was allowed to react for 3 min. One milliliter of 20 % Na_2CO_3 solution was added, mixed well and then left to stand for 1 h at room temperature (RT) for colour development. Absorbances against prepared reagent blank were measured at 750 nm using a spectrophotometer and results were expressed in mg of gallic acid equivalent per 100 mL (mg GAE/100 mL).

Extraction and characterization of polyphenolic compounds by HPLC

The juices (50 mL) were adjusted to pH 7.0 with 2 N NaOH and extracted with 50 mL ethyl acetate at 30°C by stirring for 5 min, using a casing vessel with a reflux condenser. The mixture was then centrifuged at 5,000 rpm for 5 min. The organic layer was transferred, and the extraction process was repeated twice with 50 mL ethyl acetate. The three organic layers were pooled, and evaporated to dryness at 35°C by

means of a helical gas flow (nitrogen) at 1.8 bar by vortexing action. The resulting residue was redissolved in 2 mL methanol.

Individual polyphenolic compounds were characterized and quantified by HPLC system (Model PU 980; JASCO International Co. Ltd., Tokyo, Japan), equipped with a C-18 reverse phase stainless steel column (250 mm $\times$ 4.6 mm, Thermo Hypersil-Keystone; Thermo Fisher Scientific Inc., Waltham, MA), which was kept at 25°C with a PDA detector as previously described by Schieber et al. (2000) with some modifications. The mobile phases were (A) 2 % (v/v) acetic acid in water and (B) 0.5 % acetic acid in water and acetonitrile (50:50, v/v). The detection was carried out at 280 and 320 nm at the flow rate of 1 mL/min. The gradient elution was as follows: 10–55 % B (50 min), 55–100 % B (10 min), 100–10 % B (5 min). The injection volume for all samples was 20 μL . Peaks were identified by comparing their retention times (RT) with that of authentic standards injected under analysis conditions.

Gallic acid, *p*-OH-benzoic acid, ellagic acid, *m*-coumaric acid and quercetin were dissolved in methanol (1 mg/mL), and dilute solutions (1:5) from these stock solutions were used to prepare calibration curves of standards. Three replicates of each sample were used for HPLC analyses. All samples and standards were injected in triplicate and mean $\pm$ S.D were used. Standard graphs were prepared by plotting peak area against concentration using above standards.

Total flavonoid content (TFC)

The total flavonoid content of juice samples were measured using colorimetric method described in Robles-Sanchez et al. (2009). Appropriately diluted juice sample (1 mL), was added to 4 mL of distilled water; followed by the addition 0.3 mL of 5 % NaNO_2 and the mixture was kept for 6 min at RT. Subsequently, 0.3 mL of 10 % methanol solution of AlCl_3 was added and the mixture was further incubated for 6 min. After 5 min, 2 mL 1 M NaOH was added and the total volume was made up to 10 mL with distilled water. The absorbance was measured at 510 nm after incubation for 10 min at RT against prepared reagent blank. The total flavonoid content was expressed in milligram rutin equivalent per mL (mg RE/mL).

Determination of ascorbic acid (vitamin C) content

Ascorbic acid content in the juice samples were determined by 2,6-dichlorophenolindophenol visual titration method according to AOAC (1984) with slight modifications. Briefly 3 mL of mango juice was extracted with 6 % metaphosphoric acid and the volume made up to 100 mL with 6 % metaphosphoric acid. An aliquot of 10 mL was then titrated against

standardized 2,6-dichlorophenol indophenol dye solution to a light pink colour, which persisted for 15 s. The result was expressed as mg ascorbic acid/100 mL.

Assay of antioxidant activities

DPPH (1,1-diphenyl-2-picrylhydrazyl) radical scavenging activity

The radical scavenging activity of the irradiated and control samples were determined by using DPPH according to the method described in Brand-Williams et al. (1995) and modified by Kumar et al. (2012). DPPH is a stable free radical having λ_{max} at 517 nm and the assay is based on the discolouration of the compound when reduced by a free radical scavenger. The stock reagent solution was prepared by dissolving 24 mg of DPPH in 100 mL methanol and stored at -20°C until use. The working solution was obtained by mixing 10 mL of stock solution with 45 mL methanol to obtain an absorbance value of 1.1 ± 0.02 at 517 nm, using a Spectrophotometer. Different volumes of mango juice (100, 300 and 500 μL) were allowed to react with DPPH solution (final volume 3 mL) and were shaken vigorously then allowed to stand for 30 min in the dark at RT. The absorbance of the resulting solution was then measured at 517 nm against methanol as a blank in a UV–vis Spectrophotometer. Radical scavenging activity (% inhibition) was calculated using the following equation:

DPPH free radical scavenging activity(%)

$$= [(A_{\text{control}} - A_{\text{sample}}) / A_{\text{control}}] \times 100$$

Where A = absorbance at 517 nm.

FRAP (ferric reducing/antioxidant power) assay

The FRAP assay was performed according to the method described in Benzie and Strain (1996) and modified by Kumar et al. (2012). Reductants in the sample reduce the Fe(III)/tripyridyltriazine complex, present in stoichiometric excess, to blue ferrous form with an increase in the absorbance at 593 nm. Absorbance readings were taken after 0.5 s and every 30 s thereafter during monitoring period for 5 min, and the readings at 4 min were used as the FRAP value (mM/g). Briefly, the working FRAP reagent was prepared by mixing 300 mM acetate buffer (pH 3.6), 10 mM 2,4,6-tripyridyl-s-triazine (TPTZ) in 40 mM HCl and 20 mM $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$ in 10:1:1 ratio prior to use and heated to 37°C in water bath for 10 min. Different volumes of mango juice (100, 300 and 500 μL)

were allowed to react with 3.0 mL of the FRAP reagent. The final volume of the reaction mixture was made up to 4.0 mL with distilled water. The increasing absorbance of the coloured product (ferrous tripyridyltriazine complex) was then recorded at 593 nm using UV-visible Spectrophotometer.

Nitric oxide (NO) scavenging assay

The procedure is based on the principle that, at physiological pH, sodium nitroprusside (SNP) in aqueous solution spontaneously generates nitric oxide which interacts with oxygen to produce nitrite ions that can be estimated using Griess reagent. Nitric oxide scavengers compete with oxygen, leading to reduced production of nitrite ions. The nitric oxide scavenging capacity was measured according to Sreejayan Rao (1997) based on the spontaneous generation of NO from the SNP buffered solution. The 2.0 mL of test mixture contained 10 mM SNP (1.5 mL) in buffered saline with appropriate volumes (100, 300 and 500 μL) of mango juice. After 150 min of incubation, 1.5 mL was withdrawn and diluted with 1.5 mL of Griess reagent [1.0 % sulphanilamide, 2.5 % H_3PO_4 and 0.1 % N-(1-naphthyl) ethylenediamine dihydrochloride]. The absorbance of the nitrite with sulphanilamide and subsequent coupling with N-(1 naphthyl) ethylenediamine dihydrochloride was measured at 546 nm in a UV–vis Spectrophotometer. The results were expressed as % NO scavenging capacity with respect to the negative control without mango juice.

NO scavenging capacity(%)

$$= [(Abs_{\text{control}} - Abs_{\text{sample}}) / (Abs_{\text{control}})] \times 100$$

Where Abs absorbance at 546 nm.

Colour measurement

Colour measurements were made with a Hunter colorimeter (LabScan XE, Hunter Associate Laboratories, Inc., Reston, VA). The sample was placed in a 1-cm path length optical glass cell in the total transmission mode, using illuminant C and 2° observer angles. Three values of chroma were evaluated: a^* , b^* and L^* . The value a^* characterizes the colour from red ($+a^*$) to the green ($-a^*$); the value b^* indicates the colour from yellow ($+b^*$) to the blue ($-b^*$). The value L^* determine the light ranging from white ($L=100$) to black ($L=0$). Chroma (C^*) and hue angle (h°) values were also evaluated and these parameters were associated with a^* and b^* values.

Sensory evaluation

The sensory acceptance of the irradiated and non-irradiated mango juice was carried out with 20 panelists, namely teaching faculty, research and master's students of our department. Panelists were instructed to evaluate each attribute using nine-point hedonic scale (1, dislike extremely; 2, dislike very much; 3, dislike moderately; 4, dislike slightly; 5, neither like nor dislike; 6, like slightly; 7, like moderately; 8, like very much; 9, like extremely). Five different parameters were used to grade the overall quality in terms of colour, flavor, smell, texture and overall acceptance. Test of acceptability of hedonic scale was used, since it is necessary to know consumer preference regarding the product, inferring the preference, in other words, the most favorite samples are the more accepted and vice versa. The scales were balanced, once they present equal number of positive and negative categories (1–9) (Varakumar et al. 2012). About 50 mL of each mango juice were served to each individual. A random three-digit code was used for the samples and water was provided to wash the oral cavity after tasting each treatment. Evaluations took place in the mornings between 9:00 and 10:00 AM and were conducted at room temperature (22–24 °C) under white light. The mean intensity scores of all the attributes were calculated and plotted.

In vitro protective effect of mango juice on DNA against damage induced by γ -irradiation

The in vitro radio protective effect of mango juice was evaluated using the method described earlier by Saxena et al. (2011). In brief, 15 μ L aliquot of clear juice was mixed with 15 μ L of pUC19 plasmid DNA (~400 ng) (Bangalore Genei, India) in a sterile 1.5 mL eppendorf tube. The samples were irradiated with different doses (1, 3, and 5 kGy) of γ -irradiation. The irradiated samples were mixed with 6X gel loading dye and the fragments were separated by electrophoresis and untreated plasmid DNA was used as a control.

Electrophoresis was carried out on 1 % agarose in 1X TAE buffer (2 M Tris, 1 M sodium acetate, 50 mM EDTA, and pH 8.0) at RT using a Genei (Bangalore Genei Pvt. Ltd., Bangalore, India) electrophoresis system. Subsequently the gel containing 20 μ L of ethidium bromide (10 mg/mL) was observed under U.V light, using a UV-transilluminator (Bangalore Genei Pvt. Ltd., India) and photographed.

Statistical analysis

All the experiments were carried out on three independent sample lots and the results were expressed as mean $\pm$ SD. Linear Correlations between various antioxidant parameters and phenolic content were calculated using the Pearson's correlation coefficient analysis by the SPSS statistical

software (version 12, SPSS Inc., USA). One-way analysis of variance (ANOVA) was done on all the data to confirm the variability of data and validity of results. Duncan's multiple range test (DMRT) was performed to determine the significant difference between treatments using SPSS 12.

Results and discussion

Microbial quality of mango juice

The effect of γ -irradiation on the microbial quality of FMJ and SMJ are shown in Table 1. During storage, significant ($P<0.05$) increase in microbial population was noted in the control samples when compared to the irradiated ones. Total bacterial counts were found to be significantly higher than the yeast and mold counts. However Significant ($P<0.05$) lower counts of TAB were observed in the radiation processed samples. The initial TAB counts in control FMJ and SMJ were $4.2\pm0.3\times10^4$ and $6.5\pm0.2\times10^5$ CFU/mL respectively. At an irradiation dose of 3.0 kGy, TAB counts were reduced to $2.6\pm0.2\times10^1$ and $1.1\pm0.8\times10^1$ CFU/mL in the two samples respectively. No bacterial population was, however, detected in both the fresh and stored samples subjected to an irradiation dose of 5.0 kGy. There was a significant ($P<0.05$) reduction in yeast and mold counts of both FMJ and SMJ by γ -irradiation and complete elimination was observed at irradiation doses above 3.0 kGy. Thus microbial population decreased as the irradiation dose increased in both FMJ and SMJ.

A decrease in microbial population resulting from the damaging effects of irradiation on cellular DNA has been reported. Cells that were damaged by irradiation were gradually inactivated, thus not adapting to the surrounding environment during storage (Byun et al. 2001). In the present study, the irreversible deleterious effects caused by γ -irradiation could be the reason for the drastic reduction in the bacterial counts. Similar phenomenon was also observed in heat-treated foods, where damaged cells were unable to repair and tend to die in an unfavorable environment. Kim et al. (2007) have earlier shown that a radiation dose of 3 to 5 kGy is adequate to prevent microbial growth in stored kale juice. Gamma-irradiation at doses up to 5 kGy also reduced the total aerobic bacteria, yeast and mold populations in ready-to-use tamarind juice without significantly influencing the colour and nutritional properties (Lee et al. 2009).

Total polyphenolic and total flavanoid contents (TPC and TFC)

Various polyphenolic compounds in fruits and vegetables have been reported to exhibit antioxidant activities because

Table 1 Effects of γ -irradiation on microbial load (CFU/mL) in mango juice

Type of microbial load	Mango juice	Irradiation dose (kGy)			
		0	1	3	5
Total aerobic bacteria	FMJ	$4.2 \pm 0.3 \times 10^{4d}$	$3.4 \pm 0.5 \times 10^{3c}$	$2.6 \pm 0.2 \times 10^{1b}$	ND ^a
	SMJ	$6.5 \pm 0.2 \times 10^{5d}$	$2.3 \pm 0.3 \times 10^{2c}$	$1.1 \pm 0.8 \times 10^{1b}$	ND ^a
Yeast and mold	FMJ	$1.4 \pm 0.9 \times 10^{2c}$	$1.2 \pm 0.4 \times 10^{1b}$	ND ^a	ND ^a
	SMJ	$2.1 \pm 0.3 \times 10^{2c}$	$<10^{1b}$	ND ^a	ND ^a

FMJ Fresh mango juice; SMJ Stored mango juice; ND No microbe detected on plates; Values are given as mean $\pm$ S.D ($n=3$); Values with different letters with in the same row differ significantly at $P<0.05$ according to Duncan's multiple range test (DMRT)

of the reactivity of the phenolic moiety, scavenging free radicals, via hydrogen donation or electron donation (Jayaprakasha and Patil 2007). In the present study, there was a significant ($P<0.05$) increase in the TPC of irradiated juice samples both in FMJ and SMJ (Table 2). A slight increase (2.2 %) in TPC was noted at 1 kGy that further increased by 6.8 and 12.3 % at 3 and 5 kGy in FMJ. During storage TPC significantly ($P<0.05$) increased to 8.8, 16.51 and 21.1 % with increase in irradiation dose (1, 3 and 5 kGy respectively). Harrison and Were (2007) found significant increase in TPC of irradiated almond skin extracts at a dose of 4 kGy and above and found that this increase could be attributed to their release from glycosidic precursors and the degradation of polymeric phenolic compounds to smaller units during γ -irradiation. The flavonols (quercetin, kaempferol and rhamnetin) are present mostly as O-glycosides, whereas mangiferin is a C-glycoside and occurs both in its non-esterified form or conjugated with gallic acid. The increase in TPC in irradiated samples could thus be accounted for the degradation of these conjugated phenolic compounds. Similar results were also reported in 'Triphala', in which degradation of high molecular weight complex polyphenolic compounds like tannins into simple phenolic compounds like phenolic acids facilitated the release of active ingredients, which contributed to the increased total

phenolic content (Kumari et al. 2009). In this study, a strong correlation has been demonstrated between increments in TPC and increments in antioxidant activities. The increase in TPC was also reported in soybeans and spices; irradiated soybean samples at dose of 0.5 to 5 kGy showed an increase in free (aglycone) phenolic content (Variyar et al. 2004). The present study is in agreement with the earlier reports on fresh vegetable juice (Song et al. 2006), and ready-to-use tamarind juice (Lee et al. 2009).

There was a significant ($P<0.05$) increase in TFC in SMJ in all the irradiated samples (Table 2). No significant differences in TFC of FMJ and SMJ samples were, however, noted at an irradiation dose of 1 kGy although the values increased significantly ($P<0.05$) at doses beyond 3 kGy. In the present study, there was a significant ($P<0.05$) increase in TFC with irradiation and also with storage. Our results were in agreement with the earlier studies of Mishra et al. (2011), who reported that the flavonoid content marginally increased during low temperature storage for 30 days in irradiated and control sugarcane juice samples. Hussein et al. (2011) also reported that two types of irradiated Malaysian honey exhibited a significantly ($P<0.05$) higher content of flavonoids than their non-irradiated counterparts.

Table 2 Effects of γ -irradiation on total polyphenolic, total flavanoid, and ascorbic acid content in mango juice

Parameters	Mango juice	Irradiation dose (kGy)			
		0	1	3	5
TPC (mg GAE/100 mL)	FMJ	54.22 ± 0.18^a	56.45 ± 0.15^b	62.34 ± 0.21^c	67.75 ± 0.19^d
	SMJ	51.04 ± 0.16^a	57.65 ± 0.17^b	65.26 ± 0.14^c	71.84 ± 0.22^d
TFC (mg RE/mL)	FMJ	4.32 ± 0.04^a	4.27 ± 0.02^a	4.75 ± 0.03^b	5.09 ± 0.02^c
	SMJ	4.36 ± 0.02^a	4.41 ± 0.03^a	5.48 ± 0.04^b	6.45 ± 0.01^c
Ascorbic acid (mg/100 mL)	FMJ	20.24 ± 0.05^d	12.57 ± 0.06^c	6.64 ± 0.04^b	5.92 ± 0.07^a
	SMJ	10.48 ± 0.08^d	6.29 ± 0.05^c	2.44 ± 0.03^b	1.21 ± 0.07^a

FMJ Fresh mango juice; SMJ Stored mango juice; TPC Total polyphenolic content; TFC Total flavanoid content; Values were mean $\pm$ S.D ($n=3$); Values not sharing a common superscript in a row differ significantly at $P<0.05$ according to Duncan's multiple range test (DMRT)

Effect of γ -irradiation on the content of individual polyphenolic compounds of mango juice

There were significant ($P<0.05$) differences noted in the concentration of polyphenolic compounds between non-irradiated and irradiated juice samples (Table 3). Even though significant differences were found in all the irradiated juice samples, the discussion here will be focused only on the dose effects at 5 kGy. The content of gallic, syringic, and chlorogenic acids increased by 3.2, 2.5 and 2.3 folds respectively, where as the contents of ferulic and synapic acids decreased by 4.5 and 2.7 folds respectively in irradiated juice samples. In a similar study, an increment in gallic acid and reduction in ferulic and synapic acids as a result of γ -irradiation was also reported by Variyar et al. (1998) in some of the Indian spices. However, no significant ($P<0.05$) changes in the amount of vanillic, *m*-coumaric acids, quercetin, and (+)-catechin in irradiated mango juice samples was observed. The amount of other polyphenolic compounds like protocatechuic acid, *P*-OH-benzoic acid, ellagic acid, caffeic acid, *p*-coumaric acid, and rutin was significantly ($P<0.05$) increased with increasing irradiation dose in the juice samples.

Reports suggest that the main phenolic compounds of mango pulp are gallic acid, mangiferin, quercetin glycosides and many identified and uncharacterized hydrolyzable tannins, called gallotannins (Schieber et al. 2000). In most mango varieties, free gallic acid, 3,4,5-trihydroxybenzoic acid, is the predominant compound present and has been shown to possess a high antioxidant capacity with numerous implications to overall human health (Shanrzan and Bitsch 1998). Gallic acid units possess three hydroxyl groups and an acid group

which allow the compound to link with another gallic acid to form an ester, digallic acid (Masibo and He 2008). Pinn et al. (1993) have reported a dose dependent decrease in tannin content of Brazilian beans upon γ -irradiation up to a dose of 20 kGy. Similar results were also observed by Karmazin et al. (1988) during decontamination of tannin containing drugs exposed to radiation doses up to 10 kGy. In the present study, increase in some of the phenolic compounds observed in γ -irradiated samples might be due to the degradation of hydrolyzable tannins present in the mango juice samples.

Ascorbic acid (vitamin C) content

The effects of γ -irradiation and storage on ascorbic acid content of mango juice samples are shown in Table 2. A significant ($P<0.05$) reduction in ascorbic acid was observed in all the irradiated samples with increase in radiation dose. The lowest content of ascorbic acid was found in the samples treated at 5 kGy.

There was nearly a 50 % reduction in ascorbic acid in the control samples during storage. Radiation processing resulted in a further decrease in ascorbic acid with a 70 and 94 % reduction in FMJ and SMJ respectively at dose of 5 kGy. Thus apart from its instability during storage, radiation processing was also found to further affect the stability of ascorbic acid in a dose dependent manner. This significant decrease could be due to the partial oxidation of ascorbic acid to dehydroascorbic acid (Song et al. 2007). Harder et al. (2009) have reported that irradiation at doses of 1.0 and 2.0 kGy induced a 50 % reduction in ascorbic acid content in nectar of kiwi fruit. Jo et al. (2012) also found a significant reduction in ascorbic acid content when exposed to dose of 3 and 5 kGy in

Table 3 Effects of γ -irradiation on polyphenolic compounds of mango juice

Phenolic compound ($\mu\text{g/mL}$)	RT (min)	Irradiation dose (kGy)			
		0	1	3	5
Gallic acid	5.01	175.94 $\pm$ 5.4 ^a	172.71 $\pm$ 8.0 ^a	380.54 $\pm$ 10.4 ^b	563.33 $\pm$ 11.9 ^c
Protocatechuic acid	7.57	77.02 $\pm$ 0.88 ^a	78.42 $\pm$ 1.12 ^a	80.37 $\pm$ 0.64 ^b	87.17 $\pm$ 0.73 ^c
<i>P</i> -OH-benzoic acid	11.68	19.81 $\pm$ 0.92 ^a	20.22 $\pm$ 1.34 ^a	29.61 $\pm$ 0.87 ^b	36.22 $\pm$ 1.04 ^c
Vanillic acid	13.42	13.83 $\pm$ 0.54 ^a	13.74 $\pm$ 0.68 ^a	13.96 $\pm$ 0.59 ^a	14.03 $\pm$ 0.43 ^a
Chlorogenic acid	15.34	20.07 $\pm$ 0.95 ^a	26.13 $\pm$ 1.23 ^b	32.54 $\pm$ 1.57 ^c	45.85 $\pm$ 1.09 ^d
Syringic acid	16.72	3.58 $\pm$ 0.19 ^a	6.72 $\pm$ 0.47 ^b	7.53 $\pm$ 0.44 ^c	8.89 $\pm$ 0.31 ^d
Caffeic acid	17.44	35.77 $\pm$ 1.07 ^a	46.96 $\pm$ 2.09 ^c	40.63 $\pm$ 1.09 ^b	39.22 $\pm$ 0.93 ^b
<i>p</i> -Coumaric acid	23.36	120.68 $\pm$ 6.6 ^a	131.02 $\pm$ 5.7 ^{ab}	142.27 $\pm$ 6.0 ^{bc}	151.81 $\pm$ 7.24 ^c
<i>m</i> -Coumaric acid	26.61	82.05 $\pm$ 5.14 ^a	81.24 $\pm$ 6.02 ^a	85.44 $\pm$ 4.98 ^a	88.38 $\pm$ 5.76 ^a
Ferulic acid	28.33	45.37 $\pm$ 1.29 ^d	22.81 $\pm$ 0.85 ^c	14.68 $\pm$ 0.73 ^b	10.42 $\pm$ 0.81 ^a
Synapic acid	29.78	37.84 $\pm$ 0.98 ^d	20.93 $\pm$ 1.02 ^c	16.60 $\pm$ 0.87 ^b	13.97 $\pm$ 0.66 ^a
Ellagic acid	31.91	8.94 $\pm$ 0.61 ^a	9.14 $\pm$ 0.76 ^a	10.17 $\pm$ 0.64 ^{ab}	11.04 $\pm$ 0.58 ^b
Rutin	34.55	15.02 $\pm$ 0.37 ^a	16.48 $\pm$ 0.46 ^b	17.09 $\pm$ 0.41 ^{bc}	18.36 $\pm$ 0.35 ^c
(+)-Catechin	37.24	16.07 $\pm$ 0.92 ^a	16.10 $\pm$ 1.03 ^a	16.35 $\pm$ 0.95 ^a	16.42 $\pm$ 0.83 ^a
Quercetin	51.86	13.43 $\pm$ 0.84 ^a	13.51 $\pm$ 0.79 ^a	13.56 $\pm$ 1.02 ^a	13.67 $\pm$ 0.91 ^a

RT Retention time; Values were mean $\pm$ S.D ($n=3$); Values with different letters with in the same row differ significantly at $P<0.05$ according to Duncan's multiple range test (DMRT)

Table 4 Effects of γ -irradiation on DPPH (%), FRAP (mM/g) and NO (%) scavenging activities of mango juice

Parameter	Dose (kGy)	Volume (μ L)					
		100		300		500	
		FMJ	SMJ	FMJ	SMJ	FMJ	SMJ
DPPH	0	61.49 $\pm$ 1.21 ^{ap}	63.79 $\pm$ 1.23 ^{ax}	78.84 $\pm$ 1.23 ^{aq}	80.61 $\pm$ 1.16 ^{ay}	85.41 $\pm$ 1.23 ^{ar}	87.51 $\pm$ 1.32 ^{az}
	1	63.72 $\pm$ 1.18 ^{bp}	66.68 $\pm$ 1.06 ^{bx}	82.26 $\pm$ 1.31 ^{bq}	84.32 $\pm$ 1.19 ^{by}	86.46 $\pm$ 1.18 ^{br}	91.48 $\pm$ 1.26 ^{bz}
	3	65.67 $\pm$ 0.98 ^{cp}	75.14 $\pm$ 1.15 ^{cx}	84.42 $\pm$ 1.17 ^{cq}	87.35 $\pm$ 1.32 ^{cy}	89.53 $\pm$ 1.29 ^{cr}	94.62 $\pm$ 1.34 ^{cz}
	5	67.66 $\pm$ 1.34 ^{dp}	81.39 $\pm$ 1.27 ^{dx}	86.55 $\pm$ 1.22 ^{dq}	94.81 $\pm$ 1.28 ^{dy}	91.51 $\pm$ 1.37 ^{dr}	96.81 $\pm$ 1.29 ^{dz}
FRAP	0	0.232 $\pm$ 0.02 ^{ap}	0.243 $\pm$ 0.05 ^{ax}	0.258 $\pm$ 0.03 ^{ap}	0.265 $\pm$ 0.07 ^{ax}	0.282 $\pm$ 0.03 ^{apq}	0.288 $\pm$ 0.06 ^{ax}
	1	0.256 $\pm$ 0.03 ^{ap}	0.279 $\pm$ 0.02 ^{ax}	0.317 $\pm$ 0.05 ^{abq}	0.385 $\pm$ 0.03 ^{by}	0.364 $\pm$ 0.06 ^{abq}	0.429 $\pm$ 0.04 ^{bz}
	3	0.274 $\pm$ 0.05 ^{ap}	0.295 $\pm$ 0.04 ^{abx}	0.332 $\pm$ 0.02 ^{bq}	0.424 $\pm$ 0.05 ^{by}	0.381 $\pm$ 0.04 ^{abq}	0.457 $\pm$ 0.05 ^{by}
	5	0.291 $\pm$ 0.06 ^{ap}	0.343 $\pm$ 0.03 ^{bx}	0.351 $\pm$ 0.03 ^{bq}	0.452 $\pm$ 0.04 ^{by}	0.397 $\pm$ 0.05 ^{bqr}	0.498 $\pm$ 0.07 ^{byz}
NO	0	62.16 $\pm$ 1.15 ^{ap}	65.24 $\pm$ 0.97 ^{ax}	69.52 $\pm$ 1.35 ^{aq}	70.75 $\pm$ 1.26 ^{ay}	78.17 $\pm$ 1.22 ^{ar}	80.23 $\pm$ 1.44 ^{az}
	1	65.46 $\pm$ 0.94 ^{bp}	67.45 $\pm$ 1.02 ^{bx}	72.72 $\pm$ 1.12 ^{bq}	73.56 $\pm$ 1.09 ^{by}	80.54 $\pm$ 1.45 ^{br}	83.54 $\pm$ 1.26 ^{bz}
	3	67.69 $\pm$ 1.04 ^{cp}	70.47 $\pm$ 1.22 ^{cx}	75.16 $\pm$ 1.26 ^{cq}	76.67 $\pm$ 1.34 ^{cy}	83.64 $\pm$ 1.33 ^{cr}	85.14 $\pm$ 1.38 ^{cz}
	5	70.54 $\pm$ 1.38 ^{dp}	78.19 $\pm$ 1.16 ^{dx}	78.27 $\pm$ 1.18 ^{dq}	85.27 $\pm$ 1.27 ^{dy}	85.79 $\pm$ 1.29 ^{dr}	95.56 $\pm$ 1.24 ^{dz}

FMJ Fresh mango juice; SMJ Stored mango juice; Values are given as mean $\pm$ S.D ($n=3$); a–d Column wise values with different superscripts of this type indicate significant difference ($P<0.05$); p–r Row wise FMJ values with different superscripts of this type indicate significant difference ($P<0.05$); x–z Row wise SMJ values with different superscripts of this type indicate significant difference ($P<0.05$) according to Duncan's multiple range test (DMRT)

fresh ashitaba and kale juices. At doses beyond 3 kGy, extensive degradation of ascorbic acid irrespective of the juice storage conditions was observed. Thus, in order to compensate the loss of ascorbic acid during irradiation or storage, exogenous supplementation may be helpful to maintain the normal levels.

In vitro antioxidant capacities

The antioxidant capacities of mango juice can be measured using various in vitro methods based on different principles since these methods are based on different mechanism of action. It was found that control (0 kGy) as well as γ -irradiated FMJ and SMJ samples were capable of scavenging

DPPH radicals in dose dependent manner and also with concentration of the juice (Table 4). The percent radical scavenging activity increased significantly with increase in irradiation dose as well as with the concentration tested. The highest scavenging activity was observed in irradiated SMJ samples at 5 kGy in all the concentrations. A significant ($P<0.05$) increase in activity with increase in dose and storage was also noted. In γ -irradiated FMJ samples, however, a significant ($P<0.05$) increase in the scavenging activity was observed only at doses of 3 and 5 kGy. It was earlier shown that mango wine contains carotenoids (Varakumar et al. 2011) and polyphenolic compounds (Kumar et al. 2012) possessing various in vitro antioxidant activities. As observed in this study, an increase in DPPH scavenging activity due to irradiation has

Table 5 Effects of γ -irradiation on Hunter colour parameters in mango juice

Hunter parameters	Mango juice	Irradiation dose (kGy)			
		0	1	3	5
L^* value	FMJ	53.19 $\pm$ 1.57 ^a	55.53 $\pm$ 1.65 ^a	63.34 $\pm$ 1.38 ^b	65.17 $\pm$ 1.86 ^b
	SMJ	66.51 $\pm$ 0.84 ^a	67.18 $\pm$ 1.72 ^a	70.95 $\pm$ 1.63 ^b	72.64 $\pm$ 1.45 ^b
a^* value	FMJ	5.79 $\pm$ 0.67 ^c	3.68 $\pm$ 0.73 ^b	1.04 $\pm$ 0.52 ^a	0.72 $\pm$ 0.21 ^a
	SMJ	2.84 $\pm$ 0.54 ^c	1.52 $\pm$ 0.47 ^b	0.98 $\pm$ 0.31 ^{ab}	0.32 $\pm$ 0.24 ^a
b^* value	FMJ	33.54 $\pm$ 1.25 ^d	29.66 $\pm$ 1.52 ^c	21.42 $\pm$ 1.08 ^b	15.84 $\pm$ 1.34 ^a
	SMJ	27.87 $\pm$ 1.32 ^c	25.73 $\pm$ 1.03 ^c	20.19 $\pm$ 1.72 ^b	16.68 $\pm$ 1.56 ^a
Chroma (C^*)	FMJ	34.05 $\pm$ 1.35 ^d	29.89 $\pm$ 1.60 ^c	21.45 $\pm$ 1.10 ^b	15.86 $\pm$ 1.36 ^a
	SMJ	28.02 $\pm$ 1.26 ^d	25.78 $\pm$ 1.06 ^c	21.44 $\pm$ 0.52 ^b	16.68 $\pm$ 1.57 ^a
Hue angle (h°)	FMJ	80.23 $\pm$ 0.75 ^a	82.97 $\pm$ 1.04 ^b	87.26 $\pm$ 1.26 ^c	87.43 $\pm$ 0.54 ^c
	SMJ	84.14 $\pm$ 1.37 ^a	86.65 $\pm$ 0.91 ^b	87.26 $\pm$ 0.65 ^{bc}	88.95 $\pm$ 0.73 ^c

FMJ Fresh mango juice; SMJ Stored mango juice; Chroma (C) = $[(a^*)^2 + (b^*)^2]^{1/2}$; Hue angle (h°) = $\arctan(b^*/a^*)$; Values were mean $\pm$ S.D ($n=3$); Values not sharing a common superscript letter differ significantly at $P<0.05$ according to DMRT

also been reported in carrot juice (Song et al. 2006), and ready-to-use tamarind juice (Lee et al. 2009). Jo et al. (2003) reported that green tea leaves extracts irradiated at 10 and 20 kGy significantly increased the scavenging ability of DPPH radicals. Variyar et al. (2004) reported a dose dependent increase in radical scavenging ability of extracts from γ -irradiated soybean exposed to doses between 0.5 and 5 kGy. In the present study, DPPH activities show a good correlation with TPC ($R^2=0.99276$ and 0.98786) for FMJ and SMJ respectively. With respect to TFC ($R^2=0.98859$), a good correlation was observed only for SMJ. It can be postulated that the increase in antioxidant activities following γ -irradiation could be due to the degradation of some high molecular weight polymeric phenolic compounds to simple phenols thus

enhancing their solubility in the test solvent resulting in greater interaction with the reagents. Hussein et al. (2011) reported increased antioxidant activities, resulting from higher polyphenol and flavonoid content in γ -irradiated honey samples.

The antioxidant capacities of γ -irradiated and control juice samples using FRAP assay is shown in Table 4. There was a significant ($P<0.05$) increase in the FRAP activity in all the γ -irradiated samples in a concentration dependent manner. A slight increase in FRAP activity was observed in FMJ while in SMJ samples, a significant increase was noted with increase in irradiation dose and concentration. FRAP activities were in good correlation with TPC ($R^2=0.9847$ and 0.9781), and TFC ($R^2=0.89808$ and 0.93552) for FMJ and SMJ respectively. Similar increase in activity has been reported in ready-to-use

Fig. 1 Effects of γ -irradiation on sensory notes of fresh (a) and stored (b) mango juice

tamarind juice (Lee et al. 2009) and peach fruits (Hussain et al. 2010) as a result of radiation treatment. The increase in total antioxidant activity could be as a result of high phenol accumulation by the radiation treatment as explained in earlier sections above. The polyphenolic compounds act as reducing agents, hydrogen donors and singlet oxygen quenchers and based on the antioxidant properties, it can be suggested that bioactive compounds present in mango juice have strong scavenging and ferric reducing power.

There was a significant ($P<0.05$) increase in NO scavenging activity with increase in dose in all the concentrations tested when compared to the control (Table 4). NO scavenging activity was slightly higher in SMJ than FMJ at all irradiation doses, indicating increased antioxidant activity during storage. Nitric oxide (NO) is a diffusible free radical that plays many roles as an effector molecule in various diverse biological systems (Hagerman et al. 1998). Hence the screening of various health foods in scavenging of NO radical is warranted. NO scavenging activities in the present study were in good correlation with TPC ($R^2=0.9847$ and 0.9781) and TFC ($R^2=0.90352$ and 0.97248) for FMJ and SMJ respectively. This could be because of the increase in TPC and flavanoid content during storage. A linear increase in the activity was observed with increase in the concentration of juice and the highest activity (95.5 %) was noted in SMJ (500 μ L) at 5 kGy. It has been reported that polyphenolic compounds have higher NO scavenging effects under low pH conditions (Mishra et al. 2011). Mango juice is rich in polyphenolic compounds and possesses a low pH and thus showed significant NO scavenging activity.

Hunter colour measurement

The effect of γ -irradiation and storage on the Hunter colour (L^* a^* b^*) values of mango juice samples is shown in Table 5. In this study, the Hunter colour L^* value (brightness) increased significantly ($P<0.05$) by γ -irradiation in both FMJ and SMJ in a dose dependent manner when compared to control samples. Previously, it was reported that carotenoids in cooking drips could be destructed by γ -irradiation resulting in a brighter colour (Choi et al. 2010). It was also reported that few carotenoids were broken down in mango wine (Varakumar et al. 2011) which could be the reason for increase in L^* value during storage. The Hunter colour a^* value (redness) and b^* value (yellowness) were found to be significantly decreased on irradiation in both FMJ and SMJ, which indicate mango juice revealed a bright colouration. During storage, brightness was significantly increased in all samples, but redness and yellowness decreased. The chroma (C^*) value was significantly ($P<0.05$) decreased in all juice samples during the storage period and also with the dose of irradiation, indicating that the juice colour became significantly less saturated with increasing of storage time. The hue angle (h°) of

both FMJ and SMJ was also significantly ($P<0.05$) increased by γ -irradiation when compared to control.

In the present study, there was a significant improvement in the colour of both the irradiated FMJ and SMJ, which was found to be more attractive than that of non-irradiated FMJ and SMJ. Our study is in accordance with the previous findings by Jo et al. (2003), Kim et al. (2006), and Lee et al. (2009) who showed a significant improvement in the colour in green tea, *Curcuma aromatica* extract and ready-to-use tamarind juice during radiation processing.

Sensory evaluation

The effect of γ -irradiation on the sensory notes with respect to colour, smell, flavor, texture and overall acceptability of FMJ and SMJ are shown in Fig. 1a and b. Panelists found that the overall sensory scores of the irradiated and control juice samples were not significantly different, immediately after irradiation. During storage the sensory quality of the control mango juice decreased while no significant changes in the sensory scores was noted in irradiated mango juice samples.

Sensory characteristics of any food item contribute significantly to its consumer acceptance or rejection. Thus sensory evaluation of food using panelists is routinely carried out by food scientists to help evaluate the acceptability of any new food product (Dzogbefia and Djokoto 2006). The 9-point hedonic test can yield both absolute and relative information about the test samples, reliability and validity in the assessment of several food items (Resurreccion 1998). Hence, this scale was used for characterization of sensory properties of irradiated and control samples. The most acceptable sensory qualities in the mango juice were found at 1 and 3 kGy dose (Fig. 1a and b). These results were in agreement with other previous studies (Harder et al. 2009; Lee et al. 2009; and Song et al. 2007), where no significant changes in the sensory

Fig. 2 Agarose gel electrophoresis showing radioprotection of pUC19 plasmid DNA by mango juice. Lane 1: non-irradiated (Control DNA); Lane 2–4: protection against DNA damage by mango juice at irradiation doses 1, 3 and 5 kGy respectively; Lane 5–7: degradation of DNA at 1, 3 and 5 kGy irradiation doses respectively

quality of irradiated kiwi nectar, ready-to-use tamarind juice, and fresh vegetable juices, when compared to the non-irradiated samples.

In vitro radioprotective effect of mango juice on plasmid DNA damage

In vitro radioprotective effect of mango juice against γ -irradiation induced DNA (pUC19 plasmid) damage was shown in Fig. 2. The non-irradiated plasmid DNA is highly super coiled (Fig. 2, lane 1). When exposed to different doses of γ -irradiation (1, 3 and 5 kGy), there was complete degradation of plasmid DNA (Fig. 2, lanes 5, 6, 7), whereas in presence of mango juice, the degradation was significantly prevented (Fig. 2, lanes 2, 3, 4), thus indicating radioprotective activity of mango juice.

Radiation treatment, as such can produce a variety of lesions in DNA resulting in both single or double strand breaks, alteration of bases, destruction of sugar moiety and cross-linking, and formation of dimers. The formation of open circular form of plasmid DNA from supercoiled plasmid DNA is an indication of single stranded breaks (SSBs), whereas the formation of linear form is indicative of double stranded breaks (DSBs) (Saxena et al. 2011). In the present study, mango juice offered protective action against radiation induced DNA damage. Similarly litchi juice was earlier shown to have a protective role against DNA damage (Saxena et al. 2011). Aqueous extracts of chili, black pepper, and turmeric (Sharma et al. 2000) have been reported to have similar protective effects. The protective action of mango juice could be due to the synergistic action of various bioactive compounds in mango juice.

Conclusions

The present study revealed that γ -irradiation could be an effective method for microbial decontamination, improving quality and for enhancing sensory attributes of mango juice. Irradiation doses used, resulted in increase in total polyphenolic and flavonoid content and antioxidant activities with a decrease in ascorbic acid content. The colour in both the FMJ and SMJ improved in the irradiated samples, which is essential for maintaining the quality during storage. Doses up to 3 kGy did not significantly influence the overall sensorial quality. Mango juice was found to be rich source of antioxidants and possessed strong in vitro radioprotective ability, even after exposure to doses of 5 kGy. Thus, this investigation suggests that irradiation treatment at 5 kGy is not only useful in ensuring the microbiological safety of the mango juice but also for enhancing its antioxidant activity and overall quality.

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