Influence of gamma irradiation and benzyl adenine on keeping quality of custard apple fruits during storage

Swati Chouksey · Alpana Singh ·
Rajendra Singh Thakur · Reena Deshmukh

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Abstract The custard apple (*Annona squamosa*) fruits were procured from local market, irradiated with radiation doses 0, 0.25, 0.50, 0.75, 1.00, 1.25, 1.50, 1.75 kGy and then treated with benzyl adenine (50 and 100 part per million) and stored at ambient temperature (25 ± 5 °C, Relative Humidity $90 \pm 2\%$) for 12 days. The treated fruits were evaluated for sensory (viz; flavour, texture, internal and external colour) and chemical constituents (viz; Total Soluble Solids, titrable acidity, ascorbic acid, free soluble sugar, reducing sugar, non reducing sugar, carbohydrate) during storage. The study concluded that radiation dose of 1.5 kilo Gray along with 50 ppm benzyl adenine enhanced in shelf-life of custard apple fruits by 6 days at ambient temperature with good pulp texture, flavour, colour and nutritional quality as compared to control.

Keywords Gamma radiation · Antioxidant · Custard apple · *Annona squamosa* · Benzyl adenine · Sensory quality · Chemical constituents

Introduction

Custard apple (*Annona squamosa*) also known as sugar apple, Sharifa or Sitaphal belongs to family, Annonaceae and genus Annona. In India it is cultivated mainly under rainfed condition and covers more than 42,000 hectare area. Custard apple is very popular in Deccan Plateau and is grown

commercially on smaller scale in Andhra Pradesh, Bihar, Madhya Pradesh, Maharashtra, Uttar Pradesh, Tamilnadu, Assam, Karnataka and Orissa (Ghosh et al. 2001).

Custard apple is a very delicious fruit and valued for flavour and texture of their pulp. The pulp is widely used in high tech processing units for preparation of ice creams and other products. It is an excellent source of vitamins, carbohydrates and minerals. The post harvest development like maturation and senescence changes continue even after harvesting. Fresh fruits cannot be stored for more than 2 days at ambient temperature. To check such problem, an appropriate technology is needed by processors and farmers. The purpose of irradiation is to eradicate the cross contamination and ensure microbial safety in addition to delay the processes of ripening. The potential scope of irradiation technology to minimize post harvest losses was studied by Thomas et al. (1995), Al-Bachir-M (1998) for grapes, Gautam et al. (1998), Roy et al. (2000) for button mushroom, Aina et al. (1999) for plantain fruit, McLauchlan et al. (1990) for mangoes, Kamat (2005) for perishable foods.

It is well known that the use of benzyl adenine an antioxidant (a Cytokinin) acts as an antisenescence and arrest the metabolic break down deterioration caused by various biochemical activities in the fruits (Bhardwaj et al. 2005). The effect of post harvest treatment with benzyl adenine on quality of fruits was evaluated by Jiang and Fu (1998) for lichi, Jayachandran et al. (2003) for guava, Nagar et al. (2004) for lime, Bhardwaj et al. (2005) for mandarin cv Nagpur Santra. However, the custard apple has received little attention for such studies. Hence the present investigation was undertaken to study effect of gamma radiation in combination with antioxidant in enhancing the shelf life and other quality aspects of custard apple fruits.

S. Chouksey · A. Singh · R. S. Thakur (✉) · R. Deshmukh
Department of Food Science and Technology,
Jawaharlal Nehru Krishi Vishwa Vidyalaya,
Jabalpur 4820004, India
e-mail: rajput_rajendra83@yahoo.co.in

Materials and methods

The semi-matured fruits were selected on the account of fully developed fruit size and eyes of custard apple. However, the colour of the fruit was still green with hard texture. Uniform sized custard apple fruits were procured from local market and irradiated using cobalt 60 source of γ radiation in radiation chamber with and without combination of benzyl adenine. The fruits were irradiated with radiation doses 0, 0.25, 0.50, 0.75, 1.00, 1.25, 1.50 and 1.75 kGy (R_1 to R_8) and then treated by benzyl adenine (50 and 100 ppm) by quick dip method for 1 min [T_1 - Radiation, T_2 - Radiation+50 ppm Benzyl adenine, T_3 - Radiation+100 ppm Benzyl adenine] and stored at ambient temperature ($25\pm 5^\circ\text{C}$ RH $90\pm 2\%$) for 12 days.

For determination of chemical parameters two fruits were selected randomly and their pulp was taken for estimation. All the experiments were carried out in triplicate and mean values have been reported. The fruits were evaluated for TSS by using hand refractometer of $0\text{--}32^\circ$ Brix range (AOAC 1995), titrable acidity (AOAC 1970), ascorbic acid (Ranganna 1979), carbohydrate (Hassid and Abraham 1957), free soluble sugar (Dubois et al. 1951), reducing sugar (Broune and Zerban 1952). Non reducing sugar of custard apple fruits was calculated by subtracting reducing sugar from free soluble sugar.

Fruits stored under different treatments were sensorily evaluated after 0/3/6/9/12 day of storage by a panel of 15 trained judges drawn from the university staff and students using 9 point hedonic scale (Amerine et al. 1965). External colour of fruit, pulp texture, flavour and colour were considered as deciding factors. The external colour of fruits was noted as per visual observation as dark green, light green, yellowish green, blackish green, yellowish green with few black spots, black and internal colour as cream, creamy white, dull cream, brownish cream. A factorial experimental design with Completely Randomized Design (Critical Difference at 5% level) was adopted for statistical analysis of data related to storage studies by following the procedure as described by Panse and Sukhatme (1985).

Results and discussion

Chemical parameters

Mean value of different chemical parameters obtained from statistical analysis under different treatments, storage days and radiation doses are presented in Table 1. All these treatments significantly affected the chemical parameters of custard apple fruits. Maximum TSS was observed in treatment T_2 (26.19^0 Brix) and was significantly superior to treatment T_3 with minimum TSS content (25.50^0 Brix). It

was gradually increased up to 9th day then decreased on further storage. The TSS content of fruits was also increased with increase in radiation doses up to 1 kGy and then decreased with higher doses of radiation (Table 2). These results are in contrast with the findings of Garcia et al. (1990) and Yanez et al. (1990). This increase in TSS of fruits might be due to delay in ripening and senescence. The initial increase in TSS was due to the enzymatic conversion of higher polysaccharides into simple sugars during ripening (Paull et al. 1984; Chan and Kwok 1975) or due to the radiation induced hydrolysis of pectic substances (El Assi et al. 1997; Howard et al. 1995), whereas the subsequent decrease was associated with the oxidative break down of sugars as a result of respiration. These results were in line with those of Hussain et al. (2008), Hussain et al. (2007), Puziah and Yousof (1996), Dhemre and Waskar (2003), Waskar and Khedkar (1999), Sarkale et al. (2003), Reddy and Haripriya (2002), Kannan and Thirumaran (2003), Nagpal and Dashara (2004), Mahajan et al. (2005), EI- Monem et al. (2003).

The decrease in TSS at the advanced stage of storage might be due to continuous utilization of sugars in respiration process. It is also attributed to metabolic breakdown and senescence of the fruit as a result of moisture loss during storage. Earlier Ram Chandra and Chandra (1995), Kaur and Kanwar (2004), Nagar et al. (2004), Tanwar et al. (2004), Kamble and Chavan (2005) also reported similar observation during storage.

Irrespective of treatments there was a linear declining trend in acidity (%) with the progress of storage period (Tables 1 & 2). Decrease in acidity might be attributed to the conversion of acid into sugar and utilization of organic acids during respiration as acid forms the necessary respiratory substrate for the catabolic process in fruits. Similar findings were reported by Jiang and Fu (1998) Hussain et al. (2008), Hussain et al. (2007), and various scientists mentioned earlier in this paper. Whereas findings of Puziah and Yousof (1996) are in contrast with these results. Titrable acidity percentage of fruits was decreased up to radiation dose of 1 kGy and then increases up to 1.75 kGy. The decrease in acidity under low dose of gamma radiation might be due to rapid utilization of organic acid as respiratory substrate and as carbon skeleton for synthesis of new compound during ripening or delay ripening might have been responsible for minimizing the titrable acidity which was also confirmed by Baghel et al. (2005), Yanez et al. (1990) and Thomas et al. (1995). Also accumulation of sugars due to polysaccharide break down during ripening contributes to the decrease of acidity as a result of increase in TSS/acid ratio (Stanley 1991; Batten 1989; Paull et al. 1984; Chan and Kwok 1974).

Highest ascorbic acid was noted in treatment T_1 (51.21 mg/100 g) and lowest value (46.16 mg/100 g) was

Table 1 Mean values of different chemical parameters obtained from statistical analysis under different treatments, storage days and radiation doses

Radiation treatment							
Treatments	TSS (⁰ Brix)	T.A. (%)	A.A. (mg/100 g)	F.S.S. (%)	R.S. (%)	N.R.S. (%)	CARBO. (%)
T ₁	26.06	0.06	51.21	20.24	13.59	4.58	23.01
T ₂	26.19	0.11	46.16	22.32	17.62	4.12	26.26
T ₃	25.50	0.09	48.03	23.70	19.34	3.08	23.56
SEM ±	0.100	0.012	0.844	0.471	0.424	0.257	0.314
C.D. at 5%	0.281	0.036	2.393	1.334	1.202	0.729	0.889
T1- Radiation, T2- Radiation+50 ppm Benzyl adenine, T3- Radiation+100 ppm Benzyl adenine, <i>n</i> =3							
Radiation doses (kGy)							
Radiation doses (kGy)	TSS (⁰ Brix)	T.A. (%)	A.A. (mg/100 g)	F.S.S. (%)	R.S. (%)	N.R.S. (%)	CARBO. (%)
R ₁	25.00	0.16	38.40	15.60	12.87	1.65	19.00
R ₂	25.08	0.08	69.66	19.04	15.05	2.15	20.77
R ₃	25.42	0.06	61.23	20.01	16.43	2.42	21.60
R ₄	26.17	0.05	52.84	21.71	17.40	2.98	23.31
R ₅	27.25	0.05	49.17	23.33	18.19	3.86	24.36
R ₆	26.42	0.08	42.76	27.73	20.06	5.38	26.48
R ₇	26.00	0.09	39.36	25.48	18.42	6.67	28.36
R ₈	26.00	0.12	34.31	23.79	16.39	6.30	30.30
SEM ±	0.165	0.021	1.379	0.769	0.693	0.420	0.512
C.D. at 5%	0.460	0.059	3.908	2.178	1.193	1.190	1.451
R ₁ =0.00, R ₂ =0.25, R ₃ =0.50, R ₄ =0.75, R ₅ =1.00, R ₆ =1.25, R ₇ =1.50, R ₈ =1.75, <i>n</i> =3							
Storage days							
Storage days	TSS (⁰ Brix)	T.A. (%)	A.A. (mg/100 g)	F.S.S. (%)	R.S. (%)	N.R.S. (%)	CARBO. (%)
0		0.19	80.55	12.12	3.00	3.00	20.13
3	19.08	0.10	54.28	19.55	16.24	3.30	26.73
6	27.29	0.06	47.41	25.89	20.29	5.60	30.81
9	29.25	0.05	37.38	32.76	29.84	2.91	24.04
12	28.04	0.04	22.71	20.12	14.88	4.81	19.67
SEM ±	0.117	0.016	1.091	0.608	0.548	0.332	0.405
C.D. at 5%	0.325	0.047	3.089	1.722	1.552	0.941	1.147
TSS- Total Soluble Solids, TA- Titrable Acidity, AA- Ascorbic Acids, FSS- Free Soluble Sugar, RS- Reducing Sugar, NRS- Non Reducing Sugar, CARBO- carbohydrate, <i>n</i> =3							

exhibited by T₂ as reported in Table 1. The data pertaining to a scorbic acid represented that vitamin C content of custard apple fruits decreased with progress in storage (Tables 1 & 2). This may be due to the fact that gamma radiation in combination with benzyl adenine jointly helped in reducing the rate of respiration and ripening which normally results in dissipation of ascorbic acid during storage. Similar results are reported by RamChandra and Chandra (1995), Bhadra and Sen (1999) and Mahajan et al. (2005) while the present results are in contrast with the studies conducted by Puziah and Yousof (1996), Kannan and Thirumaran (2003).

The fruits treated with low dose of radiation exhibited increased amount of ascorbic acid but it decreased gradually with increase in radiation doses. The decreasing trend of vitamin C under higher doses of gamma radiation might have happened due to rapid conversion of ascorbic acid into

de-hydro ascorbic acid in presence of enzyme ascorbinase in over ripe fruits. These results were confirmed by Garcia et al. (1990), Thomas et al. (1995) and Baghel et al. (2005).

Maximum free soluble and reducing sugar (%) was recorded in treatment T₃ while non reducing sugar was maximum in T₁. A gradual increase in free soluble and reducing sugar percent was noted up to radiation dose of 1.25 kGy and 9th day than it decreased on further storage of fruits (Tables 1 & 3). Retention of total sugar up to 9th day might be due to the ability of gamma radiation and benzyl adenine to slow down the ripening process. This resulted into delay in ripening, physiological aging and alteration in metabolism which ultimately resulted in higher retention of sugars in stored fruits. The results are in accordance with Baghel et al. (2005), Bhardwaj et al. (2005) and Kamble and Chavan (2005). While in case of non reducing sugar, trend of gradual increase was observed

Table 2 Effect of different treatments on TSS ($^{\circ}$ Brix), Titration Acidity (%) and Ascorbic Acid (mg/100 g) of custard apple fruits during storage ($25\pm 5^{\circ}\text{C}$ RH $90\pm 2\%$)

Radiation doses	Treatments											
	Radiation (T_1)						Radiation + 50 ppm benzyl adenine (T_2)					
	Storage days						Radiation + 100 ppm benzyl adenine (T_3)					
	0	3	6	9	12		0	3	6	9	12	
Total soluble solid ($^{\circ}$ Brix)												
R_1	–	19	28	29	24	–	–	17	24	28	28	27
R_2	–	21	25	29	23	–	–	20	25	30	29	28
R_3	–	21	28	31	28	–	–	20	27	27	27	26
R_4	–	22	28	30	29	–	–	21	27	29	28	27
R_5	–	22	30	30	28	–	–	22	24	31	24	27
R_6	–	18	29	29	31	–	–	18	26	31	29	32
R_7	–	17	27	29	30	–	–	20	27	31	30	28
R_8	–	15	26	28	30	–	–	21	27	30	30	30
Titration Acidity (%)												
R_1	0.13	0.15	0.10	0.06	0.06	0.46	0.06	0.21	0.08	0.06	0.06	0.03
R_2	0.13	0.08	0.06	0.06	0.06	0.11	0.06	0.10	0.08	0.06	0.06	0.06
R_3	0.10	0.06	0.06	0.06	0.03	0.11	0.06	0.08	0.06	0.06	0.05	0.03
R_4	0.08	0.06	0.06	0.03	0.03	0.11	0.06	0.06	0.06	0.06	0.03	0.03
R_5	0.05	0.05	0.03	0.03	0.03	0.10	0.06	0.06	0.05	0.06	0.03	0.03
R_6	0.06	0.06	0.03	0.03	0.03	0.20	0.08	0.11	0.06	0.08	0.03	0.03
R_7	0.08	0.60	0.06	0.03	0.03	0.21	0.06	0.33	0.06	0.06	0.03	0.05
R_8	0.13	0.60	0.06	0.03	0.03	0.72	0.03	0.28	0.08	0.03	0.06	0.03
Ascorbic Acid (mg/100 g)												
R_1	72.8	42.2	40.5	43.2	13.3	58.0	37.1	43.4	39.2	42.7	37.5	14.9
R_2	128.8	75.6	61.6	43.1	39.0	102.9	51.8	70.2	56.3	137.0	68.1	45.0
R_3	105.0	73.0	59.9	43.1	34.0	83.3	45.0	65.8	55.8	112.0	65.3	28.0
R_4	98.0	61.6	44.1	39.7	28.0	74.2	41.3	63.5	54.5	77.9	57.6	17.5
R_5	95.2	58.5	43.4	38.5	26.6	72.1	37.0	61.0	54.5	74.6	49.5	16.6
R_6	85.4	49.0	43.1	36.4	16.1	71.4	28.7	42.5	43.5	72.3	40.5	16.3
R_7	70.0	45.5	42.0	30.1	16.0	43.5	28.0	42.1	32.5	65.8	40.6	15.9
R_8	70.0	43.7	39.9	36.4	15.7	42.0	20.3	38.5	28.4	47.8	39.2	15.2

 $R_1=0.00$, $R_2=0.25$, $R_3=0.50$, $R_4=0.75$, $R_5=1.00$, $R_6=1.25$, $R_7=1.50$, $R_8=1.75$ (kGy), $n=3$

Table 3 Effect of different treatments on Free Soluble Sugar, Reducing Sugar, Non Reducing Sugar and Carbohydrate (%) of custard apple fruits during storage ($25\pm5^{\circ}\text{C}$ RH $90\pm2\%$)

Radiation doses	Treatments														
	Radiation (T ₁)					Radiation + 50 ppm benzyl adenine (T ₂)					Radiation + 100 ppm benzyl adenine (T ₃)				
	Storage days														
0	3	6	9	12	0	3	6	9	12	0	3	6	9	12	
Free Soluble Sugar															
R ₁	9.2	9.7	10.1	20.8	12.6	7.9	16.5	23.7	28.4	14.4	5.6	17.2	18.9	28.4	9.9
R ₂	9.2	11.8	14.4	28.4	13.5	9.2	16.9	24.6	37.6	14.6	6.2	18.4	25.1	33.6	11.6
R ₃	10.1	12.8	15.6	28.4	15.1	9.4	18.1	25.6	37.9	15.1	7.91	20.8	33.1	34.1	15.6
R ₄	10.6	18.1	24.6	28.4	16.1	9.2	20.8	26.5	37.9	15.6	12.6	21.0	33.1	34.8	15.6
R ₅	11.7	19.4	25.6	28.9	18.0	11.9	24.9	28.3	37.9	17.0	13.7	24.0	33.6	37.0	17.5
R ₆	23.7	24.6	28.4	37.9	28.4	20.2	23.2	28.4	27.5	28.4	17.6	24.8	37.9	37.9	26.5
R ₇	18.9	21.0	23.2	28.4	22.2	8.6	18.4	24.6	33.1	33.1	18.4	28.3	37.9	37.9	27.5
R ₈	18.6	18.8	18.9	33.6	28.4	7.6	16.1	24.6	37.9	29.4	11.9	22.8	33.6	28.4	25.6
Reducing Sugar															
R ₁	1.2	7.0	3.1	19.7	11.5	1.1	15.4	22.5	27.1	13.4	1.0	16.1	17.5	27.2	8.6
R ₂	1.2	9.1	7.2	27.2	11.7	1.2	15.7	17.9	36.3	13.5	1.0	17.3	23.5	32.3	10.0
R ₃	2.0	9.4	8.3	26.8	13.7	1.7	16.7	18.8	36.2	13.6	1.2	19.4	31.3	32.7	14.0
R ₄	2.5	14.5	16.9	27.0	14.8	2.3	18.9	19.7	36.2	14.0	1.4	19.2	31.2	33.1	8.70
R ₅	2.2	14.7	17.9	27.0	10.4	5.2	22.7	20.7	35.3	15.4	1.6	22.0	31.6	35.2	10.37
R ₆	3.9	18.7	19.0	32.8	20.4	6.9	19.3	19.0	25.5	21.1	2.8	21.5	35.7	34.6	19.2
R ₇	3.9	15.5	14.9	25.6	11.8	6.6	15.9	15.3	24.9	22.8	9.6	20.0	35.6	35.4	18.0
R ₈	2.8	11.6	10.7	23.4	20.2	5.2	13.7	16.2	27.7	21.5	2.8	14.5	31.5	25.9	17.5
Non Reducing Sugar															
R ₁	1.2	2.6	7.0	1.1	1.1	1.1	1.1	1.1	1.3	1.0	1.0	1.0	1.4	1.1	1.3
R ₂	1.2	2.7	7.1	1.2	1.7	1.2	1.2	6.7	1.3	1.1	1.0	1.1	1.5	1.3	1.6
R ₃	2.0	3.3	7.3	1.6	1.4	1.7	1.4	6.7	1.6	1.5	1.2	1.3	1.8	1.4	1.6
R ₄	2.5	3.6	7.6	1.3	1.3	2.3	1.8	6.8	1.6	1.5	1.4	1.8	1.9	1.6	6.9
R ₅	2.2	4.7	7.7	1.8	7.5	5.2	2.1	7.6	2.6	1.5	1.6	1.9	2.0	1.7	7.1
R ₆	3.9	5.8	9.4	5.0	8.0	6.9	3.9	9.3	2.0	7.3	2.8	3.3	2.2	3.3	7.2
R ₇	3.9	5.5	8.2	2.7	10.	6.6	2.4	9.3	8.2	10.3	9.6	8.2	2.3	2.5	9.4
R ₈	2.8	7.1	8.2	10.2	8.1	5.2	2.3	8.4	10.2	7.8	2.8	8.2	2.1	2.5	8.0
Carbohydrate															
R ₁	15.0	17.6	22.7	19.2	17.0	19.1	22.0	25.6	16.6	15.4	18.0	21.9	20.5	18.8	14.7
R ₂	15.5	24.3	25.0	21.2	17.6	19.4	23.9	26.6	19.7	15.6	18.2	22.8	23.3	21.8	15.9
R ₃	16.4	24.7	26.3	21.6	20.1	19.8	25.6	27.2	20.9	15.6	19.4	23.2	24.2	22.3	16.1
R ₄	16.7	25.3	27.9	23.6	20.3	21.9	28.9	31.2	21.5	18.6	19.5	24.2	27.1	25.3	16.9
R ₅	16.8	26.4	26.3	24.2	20.7	22.1	30.6	34.9	23.0	21.6	20.3	25.8	29.4	25.9	19.9
R ₆	18.1	26.5	29.4	24.3	21.0	24.7	30.0	47.9	26.2	21.6	21.6	27.7	30.9	26.0	23.5
R ₇	18.4	30.9	33.6	26.8	21.3	25.6	31.1	49.5	28.9	23.5	22.4	29.1	31.3	28.4	24.1
R ₈	21.9	31.4	34.3	28.8	22.2	27.3	36.6	50.4	32.0	25.9	27.0	29.9	32.8	28.6	24.7
R ₁ =0.00, R ₂ =0.25, R ₃ =0.50, R ₄ =0.75, R ₅ =1.00, R ₆ =1.25, R ₇ =1.50, R ₈ =1.75(kGy), n=3															

$R_1=0.00$, $R_2=0.25$, $R_3=0.50$, $R_4=0.75$, $R_5=1.00$, $R_6=1.25$, $R_7=1.50$, $R_8=1.75(\text{kGy})$, $n=3$

up to 6th day and 1.50 kGy radiation dose and then decreasing trend was noted up to end of storage.

Maximum carbohydrate content was observed in treatment T2 (26.26%) which was followed by T3 and it was minimum

in T1 (23.01). A gradual increase in carbohydrate was noted up to 6th day then it decreased with further storage. The trend of increase in carbohydrate content was observed with increase in radiation doses (Tables 1 & 3). The increase in

Table 4 Effect of different treatments on sensory characteristics of custard apple fruits during storage ($25\pm 5^{\circ}\text{C}$ RH $90\pm 2\%$)

Radiation doses	Treatments														
	Radiation (T ₁)					Radiation + 50 ppm benzyl adenine (T ₂)					Radiation + 100 ppm benzyl adenine (T ₃)				
	Storage days														
	0	3	6	9	12	0	3	6	9	12	0	3	6	9	12
Flavour															
R ₁	4.0	8.0	7.0	6.0	4.0	4.0	8.0	7.8	6.0	4.0	4.0	8.0	7.0	6.0	4.0
R ₂	4.0	5.0	7.2	8.5	6.9	4.0	5.0	7.2	8.8	6.4	4.0	5.0	7.2	7.5	6.0
R ₃	4.0	5.0	7.3	8.5	6.8	4.0	5.0	7.3	8.7	6.5	4.0	5.0	7.3	7.6	6.2
R ₄	4.0	5.0	7.4	8.4	6.7	4.0	5.0	7.4	8.7	6.4	4.0	5.0	7.4	8.0	6.4
R ₅	4.0	5.0	7.5	8.4	6.7	4.0	5.0	7.5	8.6	6.5	4.0	5.0	7.5	8.0	6.4
R ₆	4.0	5.0	7.4	8.3	6.6	4.0	5.0	7.4	8.6	6.6	4.0	5.0	7.4	8.1	6.3
R ₇	4.0	5.0	7.4	8.3	6.5	4.0	5.0	7.4	8.5	6.6	4.0	5.0	7.4	8.1	6.3
R ₈	4.0	5.0	7.3	8.2	6.5	4.0	5.0	7.3	8.5	6.5	4.0	5.0	7.3	8.1	6.3
Texture															
R ₁	–	8.0	7.0	6.0	4.0	–	8.0	7.0	6.0	4.0	–	8.0	7.0	6.0	5.0
R ₂	–	5.0	7.0	7.0	7.6	–	5.0	7.0	7.5	6.0	–	5.0	7.0	7.5	5.0
R ₃	–	5.0	7.0	7.8	7.6	–	5.0	7.0	8.0	7.6	–	5.0	7.0	7.5	6.0
R ₄	–	5.0	7.0	8.0	7.0	–	5.0	7.0	8.0	7.5	–	5.0	7.0	8.0	7.8
R ₅	–	5.0	7.0	7.8	7.5	–	5.0	7.0	8.8	7.6	–	5.0	7.0	8.0	7.8
R ₆	–	5.0	7.0	8.0	7.0	–	5.0	7.0	7.8	7.5	–	5.0	7.0	7.9	6.8
R ₇	–	5.0	7.0	8.0	7.7	–	5.0	7.0	8.0	7.7	–	5.0	7.0	8.0	6.9
R ₈	–	5.0	7.0	8.0	6.0	–	5.0	7.0	8.0	8.0	–	5.0	7.0	8.0	7.8
Internal Colour															
R ₁	–	CW	C	DC	BC	–	CW	C	DC	BC	–	CW	C	DC	BC
R ₂	–	–	CW	DC	BC	–	–	CW	C	DC	–	–	CW	C	DC
R ₃	–	–	CW	DC	BC	–	–	CW	C	DC	–	–	CW	C	DC
R ₄	–	–	CW	C	DC	–	–	CW	CW	DC	–	–	CW	CW	BC
R ₅	–	–	CW	C	DC	–	–	CW	C	DC	–	–	CW	CW	BC
R ₆	–	–	CW	C	DC	–	–	CW	CW	C	–	–	CW	DC	DC
R ₇	–	–	CW	C	DC	–	–	CW	CW	C	–	–	CW	CW	DC
R ₈	–	–	CW	C	DC	–	–	CW	CW	C	–	–	CW	CW	C
External Colour															
R ₁	DG	YG	BG	B	B	DG	YG	BG	B	B	DG	YG	BG	B	B
R ₂	DG	LG	YG	YGB	B	DG	LG	YG	YG	BG	DG	LG	YG	YGB	B
R ₃	DG	LG	YG	YGB	B	DG	LG	YGB	BG	B	DG	LG	YG	YGB	B
R ₄	DG	LG	YG	YGB	B	DG	LG	YGB	BG	B	DG	LG	YGB	BG	B
R ₅	DG	LG	YG	YGB	B	DG	LG	YGB	BG	B	DG	LG	YGB	BG	B
R ₆	DG	LG	YG	YGB	B	DG	LG	YGB	BG	B	DG	LG	YG	BG	B
R ₇	DG	LG	YG	YGB	B	DG	LG	YGB	BG	B	DG	LG	YG	BG	B
R ₈	DG	LG	YGB	BG	B	DG	LG	YGB	BG	B	DG	LG	YG	BG	B
DG - Dark Green, LG - Light Green, YG - Yellowish Green, YGB - Yellowish Green with few black spots, BG - Blackish Green, B – Black, CW - Creamish White, C – Cream, DC - Dull Cream, BC - Brownish Cream.															
R ₁ =0.00, R ₂ =0.25, R ₃ =0.50, R ₄ =0.75, R ₅ =1.00, R ₆ =1.25, R ₇ =1.50, R ₈ =1.75(kGy), n=3															

DG - Dark Green, LG - Light Green, YG - Yellowish Green, YGB - Yellowish Green with few black spots, BG - Blackish Green, B - Black, CW - Creamish White, C - Cream, DC - Dull Cream, BC - Brownish Cream.

$R_1=0.00$, $R_2=0.25$, $R_3=0.50$, $R_4=0.75$, $R_5=1.00$, $R_6=1.25$, $R_7=1.50$, $R_8=1.75(\text{kGy})$, $n=3$

carbohydrate content of fruits might be due to hydrolytic changes during ripening. Further conversion of polysaccharides into monosaccharide may be the reason of

declining trend of carbohydrate with advancement in storage period. The result is supported by the findings of Roy et al. (2000).

Sensory characteristics

Flavour

Initial doses of radiation did not affect the fruit flavour adversely but at higher doses fruit flavour changed slightly and showed low score (Table 4). These results were in collaboration with the findings of Moy et al. (1971), Nagvi and Moy (1985), Mohoney and Goldstein (1987) and Sarkale et al. (2003).

Texture

Maximum score for texture (8.80) was noticed on 9th day of storage under 1.50 kGy radiation doses in T₂ treatment. It may be due to delay in ripening and senescence, slower metabolic activities as well as slower biochemical changes throughout the storage period under this treatment while under control it was deteriorated rapidly under all treatments. Quite good and acceptable texture of fruits was noticed on higher doses of radiation with prolonged storage. Firmness was good enough under lower doses as fruit firmness is one of the most crucial factors for determining the post harvest quality of fruits. Softening of fruits caused either by breakdown of insoluble protopectin into soluble pectin or by cellular disintegration leading to increased membrane permeability. These finding are supported by Brij Bhushan et al. (1998), Liu et al. (1989), Paull (1996) Damyanti et al. (1992), Zhao et al. (1996), Arthur and Wiendl (1999), Gautam et al. (1998) and Aina et al. (1999).

External colour

Irradiated fruits maintained original yellowish green colour up to 6th day of storage and yellowish green with few black spots were observed on 9th day of storage with 0.25–1.50 kGy dose in T₂ treatment. This may be due to retardation of senescence process, slower metabolic activities, enzymatic reaction and slow degradation of chlorophyll as well as uniform colour development of the fruits under this treatment. The fruits treated with higher doses of gamma radiation showed less acceptability with yellowish green colour with few black spots on 6th day followed by blackish green colour on 9th day under advance stage of storage. This is perhaps due to irradiation injury of higher doses of gamma radiation which causes destruction of colour pigments and tissue damage tended to early deterioration of external colour of fruits. Similar findings were also reported by Rashid and Farooki (1984), Pablo et al. (1971), Mahoney et al. (1985), Gautam et al. (1998), Aina et al. (1999) and Jiang and Fu (1998).

Internal colour

Original creamy white colour retained up to 6th day in T₂ treatment and up to 9th day in T₁ and T₃ treatment while under control it was retained only 3rd day of storage. Quite good and acceptable cream colour was maintained in fruits up to 12th day at higher doses of radiation in all treatment. It might be due to retardation of senescence process, slower metabolic activities as well as enzymatic reactions tended to slower deterioration of internal colour. These results are in accordance of Rashid and Farooki (1984), Pablo et al. (1971), Mahoney et al. (1985), Gautam et al. (1998), Aina et al. (1999), Jiang and Fu (1998).

It is concluded that 1.50 kGy dose of gamma radiation alongwith 50 ppm benzyl adenine maintained the quality of custard apple fruit by 6 days at ambient temperature without any objectionable changes in pulp texture, flavour, colour as well as nutritional quality as compared to control. This promises to provide advantage to producers for product development.

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