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ISSN: 0974-4908
Res. Environ. Life Sci.
9(5) 575-580(2016)

Shelf life extension and post harvest quality of mango fruits (*Mangifera indica* L.) cv. Dashehari as affected by gamma radiation and packaging material

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(Received: July 29, 2015; Revised received: March 09, 2016; Accepted: March 11, 2016)

Abstract: This experiment was conducted to find out the effect of gamma radiation and packaging material on shelf life and post harvest quality of mango fruits cv. Dashehari. During both the years mango fruits were irradiated with 0.0 Gy (G_1), 100 Gy (G_2), 200 Gy (G_3), 300 Gy (G_4) and 1 kGy (G_5) gamma radiation and packed in different packaging material viz. bamboo basket (P_1), plastic basket (P_2), CFBB (P_3) and perforated polythene bags (P_4) and stored under ambient conditions (24.5-33^{0}C with 61-84.5% RH). The data on physiological loss in weight, retention/shelf life of fruits and different chemical composition viz. TSS, acidity, ascorbic acid (vitamin-C), reducing, non-reducing and total sugar was recorded at 4, 8 and 12 DAS. The results of this study showed that mango fruits treated with 200 Gy gamma radiation and packed in corrugated fibre board boxes significantly influenced the physico-chemical properties with minimal changes in chemical content during storage. Lowest physiological loss in weight (5.23%, 7.27% and 10.27%) was observed with G_3P_4 interaction after 4, 8 and 12 days of storage, while, the shelf life of fruits could be extended upto 8 days with 100% retention of fruits without adversely affecting the fruit quality in terms of skin and flesh colour and texture under G_3P_3.

Key words: Gamma irradiation, Mango, Shelf life, Packaging material, Physiological loss in weight

Introduction

Mango commonly called as "King of fruit" is considered as fruit of excellence and thus has prominent position among commercial fruits grown in India. Mango being a climacteric and highly perishable fruit possesses a very short shelf life and reach to respiration peak of ripening process on 3rd or 4th day after harvesting at ambient temperature (Narayana *et al.*, 1996). This short period seriously limits the long distance commercial transport of this fruit. The ripening process of mango fruit involves a series of biochemical reactions, resulting into increased respiration, ethylene production, change in structural polysaccharides causing softening, degradation of chlorophyll, developing pigments by carotenoids biosynthesis, thus leading to ripening of fruit with softening of texture to acceptable quality (Herianus *et al.*, 2003). In fact, post-harvest decay of fruits and vegetables triggered by inappropriate storage conditions, pathogenic attacks, mechanical injuries during transportation and environmental stresses are serious problems causing substantial losses of fresh produce every year (Zhang *et al.*, 2011). To reduce post-harvest losses and extend shelf life of fresh produce, different post-harvest management techniques such as low temperature storage (Wiley, 1994) control atmosphere packaging (Holcroft and Kader, 1999; Wszelaki and Mitcham, 2003) and surface treatment with synthetic chemicals (Geransayeh *et al.*, 2012) have been widely practiced. However, in many reports it has been documented that these methods may not be able to control certain pathogenic fungi and bacteria in the prevailing storage conditions (Berrang *et al.*, 1989; Sumner and Peters, 1997). Furthermore, there is an increasing demand from consumers to use pesticides free alternative methods to control post-harvest decay of fruits and vegetables (Lichter *et al.*, 2006).

Gamma irradiation has been successfully used as an alternative treatment for microbial disinfection (Hallman, 2008) and longevity of shelf life of fresh produce (Prakash *et al.*, 2000). Exposure of fresh fruit to ionizing radiation has been seen in control of post harvest diseases and extension of shelf life by slowdown the rate of metabolism of the produce as well as production of ethylene which helps in delay ripening and senescence. Unlike other preservation techniques that often tend to produce unacceptable changes in the quality of food, radiation processing does not bring about serious organoleptic changes, as it is a cold process. According to WHO, any food irradiated upto a maximum dose of 10 kGy is safe for human consumption. Packaging technologies are important to fulfill the requirements of a longer shelf life of perishable fruits and to reduce the inclusion of additives. Packaging of harvested fruits is to assemble the produce in convenient units to protect them from deterioration during their handling and transportation from the farm gate to consumer's house. Adequate and proper packaging protects the produce from mechanical damage, physiological and pathological deterioration.

Hence, there is a need to study the combined effect of different doses of gamma radiation and variety of packaging materials in mango so that it can maintain its quality during storage till it reaches to consumer. Keeping the above points in view, the present investigation was undertaken to evaluate the optimum dose of gamma radiation and effective packaging material for enhancing the shelf life and improving quality of mango fruits with the objectives: 1) To find out the effect of different doses of gamma radiation on delayed ripening and prolonged storability of mango fruits. 2) To find out the effect of gamma radiation on physico-chemical composition of mango fruits. 3) To see the efficacy of packaging material on shelf life and physico-chemical composition of irradiated fruits of mango. 4) To find out the combined effect of different doses of gamma radiation and packaging material on storability and physico-chemical composition of mango fruits.

Materials and Methods

The fresh, good looking and uniform size mango fruits were procured from the Fruit Research Station, Imalia, Department of Horticulture, JNKVV, Jabalpur. The fruits were washed and graded by density gradation method to select fruits having uniform maturity and only water sinker fruits were used for storage studies. The fruits were irradiated 0.0 Gy (G_1), 100 Gy (G_2), 200 Gy (G_3), 300 Gy (G_4) and 1 kGy (G_5) of gamma radiation at Gamma Radiation Chamber, Department of Soil Science and Agriculture Chemistry, JNKVV, Jabalpur on 14th June 2010 and 16th June 2011. Ten fruits of mango were taken for each treatment in each replication. After irradiation of fruits with different doses of gamma radiation, fruits were packed in different packaging material viz. bamboo basket (P_1), plastic basket (P_2), Corrugated Fibre Board Boxes (P_3) and perforated polythene bags (P_4) as per treatments and stored under ambient temperature (24.5-33^{0}C with 61-84.5% RH). The experiment was conducted to see the effect of gamma radiation and packaging material on shelf life and physico-chemical composition of mango fruits in Factorial Complete Randomized Design with three replications.

The physiological loss in weight and physico-chemical composition viz. retention of mango fruits, TSS, acidity, ascorbic acid (vitamin-C), reducing, non-reducing and total sugar was recorded at 4, 8 and 12 days of storage (DAS). Physiological Weight loss was calculated by the following formula as described by Akhtar *et al*. (2010). Physiological Weight loss (%) = [(*a*-*b*)/*a*] x 100, where *a* and *b* represent initial and final fruit weights, respectively. The TSS of fruit was measured with the help of hand refractometer. Vitamin C was estimated by the visual titration method using 2, 6, di-chlorophenol indophenol dye (Gyorgy and Pearson 1967). Reducing, non reducing and total sugars were determined from the detailed procedures as described in Lane-Eynon method (Ranganna 1986).The acidity was determined as per the method of AOAC, 1995 (Official methods of analysis, Association of analytical chemists, Washington D.C., USA).

Results and Discussion

Physiological loss in weight: The physiological loss in weight of mango fruits increased as the storage period progressed irrespective of the gamma radiation imposed and packaging material used. (Table-1). As far as different doses of gamma radiation is concerned, the lowest physiological loss in weight after 4, 8 and 12 days of storage was observed when mango fruits were irradiated with 200 Gy of gamma radiation which was found significantly superior to the remaining doses *i.e.* control, 100 Gy, 300 Gy and 1 kGy, whereas, maximum physiological loss in weight i.e. 7.30% and 10.51% after 4 and 8 days of storage was observed under control as reported by Majeed *et al.* (2014) in strawberry fruits but after 12 days, the maximum weight loss (16.81%) was observed under highest dose (1 kGy) of gamma radiation. The minimum weight loss in 200 Gy gamma radiation (G_3) might be due to anti-senescence property of low dose gamma radiation like slow storage break down associated with slow respiratory rate, transpiration rate and binding of ethylene biosynthesis. The increase in weight loss under higher doses (>200 Gy) of gamma radiation might be due to radiation injury which caused increased respiratory rate and ethylene production. Among the packaging materials used, mango fruits packed in perforated polythene bags (P_4) maintained significantly lower physiological

Table-1: Effect of gamma radiation and packaging material on physiological loss in weight and retention/shelf life of mango fruits (Pooled analysis of both years)

Treatments	Physiological loss in weight (%) Days After Storage			Retention/shelf life of mango fruits (%) Days After Storage		
	4	8	12	4	8	12
Gamma Radiation (G)						
G_1	7.30	10.51	15.27	87.29	34.83	0.00
G_2	6.03	8.05	11.38	100.00	87.25	50.70
G_3	5.76	7.71	10.74	100.00	100.00	61.22
G_4	6.40	9.02	16.20	95.12	66.97	0.00
G_5	7.02	10.03	16.81	89.92	52.17	0.00
CD at 5%	0.03	0.02	0.04	-	-	-
Packaging material (P)						
P_1	6.73	9.26	14.25	96.97	71.98	23.20
P_2	6.90	9.56	14.53	96.35	67.34	20.62
P_3	6.50	8.91	13.94	97.46	77.23	28.66
P_4	5.87	8.54	13.59	87.07	58.41	17.05
CD at 5%	0.03	0.02	0.04	-	-	-
Interaction (G x P)						
G_1P_1	7.63	10.73	15.48	91.64	39.30	0.00
G_1P_2	7.75	11.12	15.78	90.37	32.37	0.00
G_1P_3	7.26	10.35	15.09	92.16	44.18	0.00
G_1P_4	6.54	9.84	14.71	74.98	23.46	0.00
G_2P_1	6.22	8.24	11.55	100.00	90.36	52.03
G_2P_2	6.38	8.49	11.89	100.00	83.46	48.74
G_2P_3	6.03	7.93	11.19	100.00	95.70	64.20
G_2P_4	5.48	7.54	10.87	100.00	79.46	37.82
G_3P_1	5.97	7.82	10.91	100.00	98.07	63.98
G_3P_2	6.10	8.22	11.15	100.00	96.48	54.34
G_3P_3	5.74	7.51	10.64	100.00	100.00	79.12
G_3P_4	5.23	7.27	10.27	100.00	93.14	47.43
G_4P_1	6.55	9.21	16.33	99.08	72.62	0.00
G_4P_2	6.75	9.47	16.61	98.98	67.60	0.00
G_4P_3	6.43	8.90	16.11	99.25	76.57	0.00
G_4P_4	5.88	8.51	15.73	83.15	51.09	0.00
G_5P_1	7.29	10.28	16.96	94.15	57.62	0.00
G_5P_2	7.52	10.48	17.22	92.41	53.26	0.00
G_5P_3	7.02	9.85	16.69	95.88	59.72	0.00
G_5P_4	6.24	9.52	16.38	77.22	38.06	0.00
CD at 5%	0.06	0.05	0.09	-	-	-

G_1: 0.0 Gy; G_2: 100 Gy; G_3: 200 Gy; G_4: 300 Gy; G_5: 1 kGy; P_1 : Bamboo Basket; P_2 : Plastic Basket; P_3 : CFBB; P_4 : Perforated polythene Bags; DAS : Days After Storage

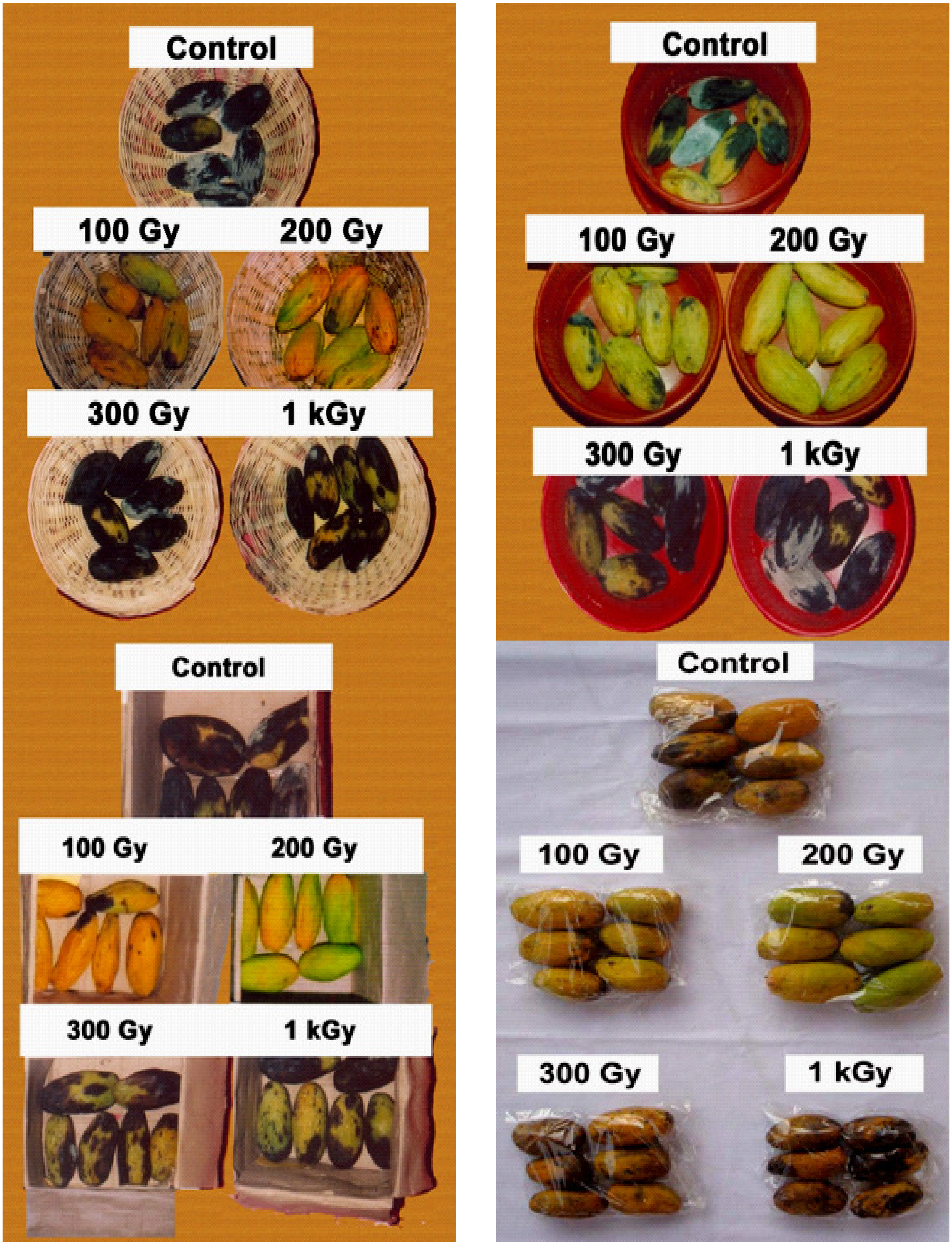

Fig. 1: Physical condition of gamma irradiated mango fruits stored in different packaging material after 12 days of storage

Table 2: Effect of gamma radiation and packaging material on total soluble solids, vitamin-C, acidity, reducing sugar, non-reducing sugar and total sugar content of mango fruits (Pooled analysis of both years)

Treat-ments	Total Soluble Solids (%)			Vitamin-C (mg/100 g pulp)			Acidity (%)			Reducing Sugar			Non-reducing Sugar (%)			Total Sugar (%)		
	DAS			DAS			DAS			DAS			DAS			DAS		
	4	8	12	4	8	12	4	8	12	4	8	12	4	8	12	4	8	12
Gamma Radiation (G)											G_1	15.4	16	14.5	16.85	15.17	13.01	0.16
G_1	0.16	0.14	5.3	5.6	4.3	13.9	14.3	12.6	19.2	19.9	16.9							
G_2	15.2	16.4	15.7	16.03	16.29	14.25	0.19	0.15	0.13	5	6	5.1	13.7	14.6	13.7	18.7	20.6	18.8
G_3	15.1	16.5	15.9	15.79	16.71	14.59	0.2	0.14	0.12	4.9	6.2	5.4	13.5	14.9	13.9	18.4	21	19.3
G_4	15.5	16.1	14.6	16.58	14.93	12.59	0.17	0.16	0.15	5.5	5.6	4.1	14	14.2	12.2	19.5	19.7	16.3
G_5	15.6	15.9	14.2	16.72	14.75	12.36	0.15	0.16	0.15	5.6	5.3	3.9	14.2	13.8	11.8	19.7	19	15.7
CD at 5%	0.11	0.11	0.1	0.04	0.04	0.03	0.01	0.01	0.009	0.11	0.11	0.12	0.1	0.11	0.11	0.17	0.18	0.2
Packaging material (P)											P_1	15.4	16.2	15.1	16.44	15.69	13.45	0.17
0.15	0.13	5.3	5.8	4.7	13.9	14.4	12.9	19.2	20.1	17.6								
P_2	15.3	16.1	14.9	16.25	15.43	13.25	0.17	0.16	0.14	5.2	5.7	4.6	13.9	14.4	12.9	19.1	20.1	17.5
P_3	15.5	16.4	15.3	16.82	16	13.7	0.16	0.14	0.13	5.4	5.9	4.9	14	14.5	13	19.3	20.4	17.9
P_4	15.2	16	14.6	16.06	15.16	13.03	0.19	0.16	0.14	5.1	5.5	4	13.7	14.1	12.6	18.8	19.6	16.6
CD at 5%	0.1	0.1	0.09	0.04	0.03	0.02	0.01	0.01	0.01	0.09	0.09	0.1	0.09	0.1	0.1	0.15	0.16	0.18
Interaction (G x P)										G_1P_1	15.4	16.1	14.5	16.91	15.3	13.07	0.16	0.15
0.14	5.4	5.6	4.4	14	14.3	12.7	19.4	19.9	17.1									
G_1P_2	15.3	15.9	14.4	16.76	15.05	12.9	0.16	0.16	0.14	5.3	5.6	4.3	13.9	14.3	12.7	19.2	19.9	17
G_1P_3	15.5	16.2	14.7	17.28	15.64	13.28	0.15	0.15	0.13	5.4	5.8	4.7	14	14.4	12.8	19.4	20.2	17.5
G_1P_4	15.2	15.8	14.2	16.43	14.67	12.77	0.18	0.16	0.14	5.1	5.4	3.8	13.8	14	12.2	18.9	19.4	16
G_2P_1	15.2	16.4	15.8	16.01	16.32	14.33	0.18	0.14	0.12	5.1	6.1	5.2	13.7	14.7	13.7	18.8	20.8	18.9
G_2P_2	15.2	16.3	15.6	15.89	16.19	14.18	0.19	0.15	0.13	5	6	5.2	13.7	14.6	13.7	18.7	20.6	18.9
G_2P_3	15.3	16.6	16	16.46	16.67	14.52	0.17	0.14	0.12	5.1	6.1	5.4	13.8	14.8	13.8	18.9	20.9	19.2
G_2P_4	15.1	16.1	15.3	15.76	15.96	13.95	0.2	0.15	0.13	4.8	5.7	4.5	13.6	14.4	13.5	18.4	20.1	18
G_3P_1	15.2	16.5	16	15.77	16.76	14.71	0.19	0.13	0.11	4.9	6.2	5.5	13.5	14.9	13.9	18.4	21.1	19.4
G_3P_2	15.1	16.5	15.8	15.66	16.65	14.48	0.2	0.14	0.12	4.9	6.2	5.5	13.5	14.9	13.9	18.4	21.1	19.4
G_3P_3	15.2	16.8	16.2	16.2	17.09	14.93	0.18	0.13	0.11	5	6.3	5.7	13.6	15	14.1	18.6	21.3	19.8
G_3P_4	15	16.3	15.5	15.52	16.35	14.22	0.21	0.15	0.12	4.8	5.9	4.9	13.4	14.6	13.7	18.2	20.5	18.6
G_4P_1	15.5	16.2	14.7	16.65	15.1	12.63	0.17	0.16	0.15	5.5	5.6	4.2	14.1	14.2	12.3	19.6	19.8	16.5
G_4P_2	15.4	16.1	14.5	16.43	14.73	12.46	0.17	0.17	0.15	5.4	5.5	4.2	14	14.2	12.2	19.4	19.7	16.4
G_4P_3	15.6	16.3	14.9	17.01	15.37	12.99	0.16	0.15	0.14	5.6	5.7	4.4	14.1	14.4	12.4	19.7	20.1	16.8
G_4P_4	15.3	15.9	14.2	16.24	14.52	12.28	0.19	0.17	0.15	5.3	5.4	3.6	13.9	13.8	11.8	19.2	19.2	15.4
G_5P_1	15.7	15.9	14.3	16.84	14.96	12.49	0.14	0.16	0.15	5.6	5.3	4.1	14.2	13.8	11.9	19.8	19.1	16
G_5P_2	15.6	15.8	14	16.53	14.51	12.25	0.15	0.17	0.15	5.5	5.2	4	14.2	13.8	11.8	19.7	19	15.8
G_5P_3	15.7	16	14.5	17.16	15.22	12.76	0.13	0.15	0.15	5.7	5.4	4.2	14.3	13.9	11.9	20	19.3	16.1
G_5P_4	15.5	15.7	13.8	16.35	14.3	11.93	0.16	0.17	0.16	5.4	5.1	3.4	14	13.5	11.6	19.4	18.6	15
CD at 5%	0.22	0.23	0.21	0.09	0.08	0.06	0.02	0.02	0.019	0.22	0.22	0.24	0.2	0.22	0.23	0.34	0.37	0.41

G_1: 0.0 Gy; G_2: 100 Gy; G_3: 200 Gy; G_4: 300 Gy; G_5: 1 kGy; P_1 : Bamboo Basket; P_2 : Plastic Basket; P_3 : CFBB; P_4 : Perforated polythene Bags; DAS : Days After Storage

loss in weight during storage period as compared to the other packing materials. The minimum physiological loss in weight of fruits packed in perforated polythene bags might be due to wrapping with polyethylene film which acted as a barrier between inner and outer environment of the fruit. These results get support with the conclusion of Ramin and Khoshbakhat (2008) who reported that packing acid lime fruits with micro-perforated polythene bags reduced weight loss as compared with no polyethylene bags.

The results obtained due to interaction effect of gamma radiation and packaging material indicated that the treatment combination G_3P_4 noticed lowest physiological loss in weight while highest weight loss (7.75% and 11.12%) was observed under the treatment combination G_1P_2 after 4 and 8 days of storage but at 12th day, it was maximum (17.22%) under the treatment combination G_5P_2. Minimum weight loss in the treatment combination G_3P_4 might be due to reduced transpiration rate, respiration activity and reduced microbial growth due to the influence of gamma radiation and perforated poly film used in the treatments.

Retention / Shelf life of mango fruits: As regard different doses of gamma radiation, the shelf life of 100% fruits was retained till 8th day under 200 Gy gamma radiation followed by 100 Gy gamma radiation (87.25%) without affecting fruit quality as evidenced by physico–chemical composition, colour, aroma and taste of the fruits, while only 34.83% marketable fruits were retained under control upto 8 days of storage. Maximum retention of marketable fruits under this dose might be owing to slow degradation of chlorophyll and decreased enzymatic activities which are responsible for delay in ripening. This result conform the findings of Zaman *et al.* (2007)

in banana fruits. Singh and Pal (2009) also reported that ionizing radiation suppressed the respiration and ethylene production and retarded the process of guava fruit ripening during storage, thereby increasing the post harvest life by 3-4 days with the use of 0.2 kGy radiation dose. On the other hand, none of the marketable fruits were retained under control as well as higher doses *i.e.* 300 Gy and 1 kGy gamma radiation after 12 days of storage.

Amongst the different packaging material used, mango fruits packed in CFBB obtained maximum marketable fruits and increase the shelf life of 97.46% and 77.23% mango fruits after 4 and 8 days of storage, whereas, only 17.05% marketable fruits were retained till 12th day when mango fruits were packed in perforated polythene bags. These results are supported by studies carried out by Alabadan *et al.* (2008). In case of fruits packed in CFBB, production of ethylene which is responsible for triggering ripening process were reduced due to ventilation which might have delayed the ripening of mango fruits. Anwar *et al.* (2008) and Sharma and Singh (2010) also found better shelf life with CFBB. Interaction effect of both treatments indicated that maximum (100%) shelf life of fruits after 8 days of storage were retained in G_3P_3 treatment combination, whereas, only 23.46% marketable fruits was obtained under G_1P_4 treatment combination. More retention of marketable fruits under G_3P_3 treatment combination might be due to the combined effect of gamma radiation and CFBB because low dose irradiation slowed down the rate of metabolism, decrease respiration rate and ethylene production and CFBB reduce decay loss and mechanical injury during handling and transportation.

Total Soluble Solids (TSS): The initial value of TSS consistently increased upto 8 days of storage in all the treatments and treatment combinations but it declined with further storage (Table-2). Amongst the fruits irradiated with gamma radiation, maximum TSS (16.5%) was noted after 8 days of storage under 200 Gy of gamma radiation and it was found significantly superior to control as well as 300 Gy and 1 kGy of gamma radiation but it did not differ significantly over 100 Gy gamma radiation. The results are in line with the results of Zhang *et al.* (2014). The maximum value of TSS under 200 Gy gamma radiation during storage might be due to alternation in cell wall structure and breakdown of complex carbohydrates into simple sugars due to the application of gamma radiation.

Among the different packaging material, TSS content of mango fruits were increased from 15.5% to 16.4% upto 8 days of storage and thereafter decrease upto 15.3% after 12 days of storage in the mango fruits packed in CFBB. Mango fruits packed in perforated polythene bags obtained lowest TSS value in each storage period. This finding are in close conformity with the finding of Sharma and Singh (2010) who reported that total soluble solids content of apple increased up to 30 days, which declined afterwards under different packaging containers. The interaction effect of gamma radiation and packaging material also increased the TSS values of mango fruits as the storage period was advanced upto 8 days and afterwards it declined with further storage upto 12 days. They also interacted significantly with each other and maximum TSS (16.8% and 16.2%) was observed under G_3P_3 treatment combination after 8 and 12 days of storage.

Vitamin-C (Ascorbic acid): Irradiation processing of mango fruits with 100 Gy and 200 Gy gamma radiation significantly increase the vitamin-C content of the fruits but it was decreased under higher doses as well as non irradiated or control fruits upto 8 days of storage. Maximum vitamin-C content (16.71 and 14.59 mg/100 g pulp) of fruits was noted under 200 Gy gamma radiation followed by 100 Gy gamma radiation (16.29 and 14.25 mg/100 g pulp), whereas, minimum vitamin-C (14.75 and 12.36 mg/100 g pulp) was obtained under 1 kGy gamma radiation after 8 and 12 days of storage. These results are in accordance with the findings of Mohamed and Mahmoud (2010) and Rashid *et al.* (2015). The probable reason for decreasing trend of vitamin-C under higher doses of gamma radiation as well as non irradiated fruits was due to rapid conversion of L-ascorbic acid into dehydro ascorbic acid in the presence of enzymes ascorbinase in over ripe fruits of mango. This result confirm the findings of Singh and Pal (2009) who reported that irradiation doses higher than 0.25 kGy decreased the vitamin-C content of guava fruits. Regarding the different packaging material, the maximum retention of vitamin-C was recorded in mango fruits packed in CFBB, while it was minimum in mango fruits packed in perforated polythene bags during all storage period. Similar results were also obtained by Alabadan *et al.* (2008). The maximum retention of vitamin-C in the CFBB might be due to less oxidative reduction of ascorbic acid in the presence of molecular oxygen by ascorbic acid oxidase. As regard interaction effect of gamma radiation and packaging material, treatment combination G_3P_3 had significantly superior over the rest of the treatment combinations and obtained maximum (17.09 and 14.93 mg/100 g pulp) vitamin-C content after 8 and 12 days of storage.

Acidity: The acidity of the fruits is an important character to determine its quality and acceptability. Very high or very low values of the acidity are not recommended for good fruits. The titratable acidity content of mango fruits decreased gradually with the advancement of storage period irrespective of the treatments. As regard gamma radiation, lowest acidity (0.14% and 0.12%) after 8 and 12 days of storage was recorded in 200 Gy gamma radiation which was at par with 100 Gy gamma radiation but significantly superior to control as well as higher doses (>200 Gy) of gamma radiation. The decrease in acidity on prolonged storage under 200 Gy gamma radiations might be due to rapid utilization of organic acid in respiration at senescence stage of fruits or delay in ripening resulted in minimizing the titratable acidity.

Regarding different packaging material, minimum acidity (0.16%, 0.14% and 0.13%) was obtained in the mango fruits packed in CFBB (P_3) during each storage period. These results are in accordance with the findings of Srinivasa *et al.* (2002) who found that titratable acidity values of Alphonso mango packed in carton showed a decreasing trend when store at ambient temperature. While highest acidity (0.19%, 0.16% and 0.14%) was recorded in mango fruits packed in perforated polythene bags which may be due to reduction of O_2 supply to the fruit surface which inhibited respiration rate. As regards interaction effect of gamma radiation and packaging material, lowest acidity (0.13% and 0.11%) was obtained by the G_3P_3 treatment combination after 8 and 12 days of storage, whereas, it was maximum (0.17% and 0.16%) under G_5P_4 in the same storage period.

Total Sugar: Total sugar of the fruit is considered as one of the basic criteria to evaluate the fruit ripening. Mango fruits irradiated with 200 Gy gamma radiation significantly increased the total sugar content of fruits upto 8 days of storage and obtained highest (21.0%) total sugar content as compared to other samples irradiated with gamma radiation (Table-2). On the other hand, mango fruits irradiated with highest dose (1 kGy) of gamma radiation obtained minimum (19.0% and 15.7%) total sugar content during 8 and 12 days of storage. The above mentioned results came in agreement with those of Mahmoud *et al.* (2010). The initial rise in total sugar content of mango fruits under 200 Gy gamma radiation might be due to more conversion of starch into sugar, while decreasing trend of total sugar under higher dose of gamma radiation was perhaps due to consumption of more sugar in respiration in over ripening of fruits during storage. Similar findings were also reported by Mitchell *et al.* (1992).

Different packaging material used for packing of mango fruits, the value of total sugar was increased first (upto 8 days of storage) and with the progress of storage time from 8th to 12th days, it was decreased. However, during each storage period, maximum (19.3%, 20.4% and 17.9%) total sugar was retained in the mango fruits packed in CFBB (P_3), while it was minimum (18.8%, 19.6% and 16.6%) in the mango fruits packed in perforated polythene bags (P_4). This result confirms the findings of Hailu *et al.* (2012). The reason for higher total sugar content in CFBB might be accumulation of ethylene which rise the fruits internal temperature and ultimately accelerated the ripening metabolism resulting in more total sugar content. Similar results were also obtained under the interaction of gamma radiation and packaging material and treatment combination G_3P_3 maintained higher (21.3% and 19.8%) total sugar content followed by G_3P_1 and G_3P_2 treatment combination after 8 and 12 days of storage, while the minimum (18.6% and 15.0%) total sugar was observed under G_5P_4 treatment combination.

References

Akhtar, A., Abbasi, N.A. and Hussain, A.: Effect of calcium chloride treatments on quality characteristics of loquat fruit during storage. *Pak. J. Bot.,* **42**: 181-188 (2010).

Alabadan, B.A., Sunmonu, M.O. and Sunmonu, T.O.: Effect of packaging materials on some nutritional qualities of fruit and vegetables stored in a passive evaporative cooler. *As. J. Food Ag-Ind.*, **1**: 184-196 (2008).

Anwar, R., Malik, A.U., Amin, M., Jabbar, A. and Saleem, B.A.: Packaging material and ripening methods affect mango fruit quality. *Int. J. Agri. Biol.,* **10**: 35-41 (2008).

A.O.A.C.: Association of Official Analytical Chemists. Official Methods of Analysis, Washington DC 16th edn. (1995).

Berrang, M.E., Brackett, R. E. and Beuchat, L.R.: Growth of Listeria monocytogeneson fresh vegetables stored under controlled atmosphere. *J. Food Prot*., **52**: 702-705 (1989).

Geransayeh, M., Mostofi, Y. and Abdossi, V.: Effect of ozonated water on storage life and postharvest quality of Iranian table grape (cv. Bidaneh Qarmez). *J. Agric. Sci.,* **4**: 31-38 (2012).

Gyorgy, P. and Pearson, W.N.: The Vitamins. 2nd ed., Academic Press, New York, p. 32 (1967).

Hallman, G.J.: Potential increase in fruit fly (Dipteratephritidae) interceptions using ionizing irradiation phytosanitary treatments. *J. Economic Entomol.*, **101**: 716-719 (2008).

Hailu, M., Workneh, T. S. and Belew, D.: Effect of packaging materials on the quality of banana cultivars. African J. Agril. Res., **7**: 1226-1237 (2012).

Herianus, J.D., Singh, L.Z. and Tan, S.C.: Aroma volatiles production during fruit ripening of Kensington Pride mango. *Postharvest Biol. Technol*., **27**: 323-336 (2003).

Holcroft, D.M. and Kader, A.A.: Controlled atmosphere induced changes in pH and organic acid metabolism may affect color of stored strawberry fruit. *Post harvest Biol. Technol*., **17**: 19–32 (1999).

Lichter, A., Gabler, F.M. and Smilanick, J.L.: Control of spoilage in table grapes. *Stewart Postharvest Rev*. **6**: 1-10 (2006).

Mahmoud, G.A., El-Tobgy, K.M.K. and Abo-El-Seoud, M.A.: Biocides application for increasing storage periods and maintaining quality and chemical constituents of banana fruits. *Archives Phytopathology Plant Prot.*, **43**: 910-921 (2010).

Majeed, A., Muhammad, Z., Majid, A., Shah, A.H. and Hussain, M.: Impact of low doses of gamma irradiation on shelf life and chemical quality of strawberry (*Fragaria xananassa*) cv. Corona. *J. Animal Plant Sci.*, **24**: 1531-1536 (2014).

Mitchell, G.E., McLauchlan, R.L., Isaacs, A.R., Williams, D.J. and Nottingham, S.M.: Effect of low dose irradiation on composition of tropical fruits and vegetables. *J. Food Composition Analysis*, **5**: 291-311 (1992).

Mohamed, Gamal A. and Mahmoud, Gihan A.: Effect of gamma radiation on microbial load and chemical constituents of banana fruits stored under different temperatures. Res. *J. Agri. Biol. Sci.,* **6** : 431-442 (2010).

Narayana, C.K., Pal, R.K. and Roy, S.K.: Effect of pre-storage treatments and temperature regimes on shelf-life and respiratory behaviour of ripe Baneshan mango. *J. Food Sci. Tech*., **33**: 79-82 (1996).

Prakash, A., Inthajak, P., Huibregtse, H., Caporaso, F. and Foley, D.M.: Effect of low dose gamma irradiation and conventional treatments on shelf life and quality characteristics of diced celery. *J. Food Sci*., **65**: 1070-1075 (2000).

Ramin, A.A. and Khoshbakhat, D.: Effects of micro-perforated polyethylene bags and temperatures on the storage quality of acid lime fruits. *American-Eurasian J. Agric. Environ. Sci.,* **3**: 590-594 (2008).

Ranganna, S.: Handbook of analysis and quality control for fruit and vegetable products. 2nd ed . Tata Mc Graw Hill Publishing Company Ltd., New Delhi, p 12 (1986).

Rashid, M.H.A., Grout, B.W.W., Continella, A. and Mahmud, T.M.M.: Low dose gamma irradiation following hot water immersion of papaya (*Carica papaya* linn.) fruits provides additional control of postharvest fungal infection to extend shelf life. *Radiation Physics Chem.,*110: 77–81 (2015).

Sharma, R.R. and Singh, Dinesh: Effect of different packaging materials on shelf-life and quality of apple during storage. *Indian J. Hort.* **67**: 94-101 (2010).

Singh, S.P. and Pal, R.K.: Ionizing radiation treatment to improve post harvest life and maintain quality of fresh guava fruit. *Radiation Physics Chem.,* **78**: 135-140 (2009).

Srinivasa, P.C., Baskaran, R., Ramesh, M.N., Prashanth, K.V.H. and Tharanathan, R.N.: Storage studies of mango packed using biodegradable chitosan film. *Eur. Food Res. Tech*., **215**: 504–508 (2002).

Sumner, S.S. and Peters, D.L.: Microbiology of vegetables. In: Smith, D.S., Cash, J.N., Nip, W.K. and Hui, Y.H. (eds.). Processing vegetables science and technology. Technomic publishing Co, Inc. Lancaster, Pa. p 87-106 (1997).

Wiley, R.C.: Minimally processed refrigerated fruits and vegetables. Chapman and Hall, New York. p 368 (1994).

Wszelaki, A.L. and Mitcham, E.J.: Effect of combinations of hot water dips, biological control and controlled atmospheres for control of gray mold on harvested strawberries. *Post harvest Biol. Technol*., **27**: 255-264 (2003).

Zaman, W., Paul, D., Alam, K., Ibrahim, M. and Hassan, Parvez: Shelf life extension of banana (*Musa sapientum*) by gamma radiation. *J. Bio. Sci*., **15**: 47-53 (2007).

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

Zhang, Ke, Deng, Yueye, Haohao Fu, Weng, Qunfang: Effects of Co-60 gamma-irradiation and refrigerated storage on the quality of Shatang mandarin. *Food Sci. Human Wellness*, **3**: 9–15 (2014).