Post-Harvest Treatments of Radiation and Chemical on Organoleptic and Biochemical Properties of Mango (*Mangifera indica* L.) In Relation to Delay Ripening

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**Abstract:** The present study was carried out to investigate the effectiveness of chemical (0.2% and 0.3% citric acid and potassium sorbate) and radiation (0.5 and 1.0 KGY) at room and low temperature (4°C) in extending the post-harvest life in relation to delay ripening of mango (*Mangifera indica* L.) during storage to reduce the post-harvest losses which will have direct significant impact on local economy. During this study, Potassium sorbate (0.3%) and irradiated sample (0.5KGY and 1.0KGY) took 7 days to ripe fully at room temperature without any decay. At 4°C temperature, 0.3% potassium sorbate and 1.0 kGY treated samples took 28 days to fully ripe. Reduced rate of moisture and weight loss were found in irradiated sample (1.0 KGY) at both temperature comparing with the other treatments during the storage. A reversible result was attributed between Titratable acidity (TA) and pH. Increasing TSS and significant decline in ascorbic acid were found in all treatments under both temperatures during the storage. At room temperature, reduction in ascorbic acid was low in 1.0 kGY irradiated sample followed by 0.3% citric acid and 0.3% potassium sorbate treated samples from 0 day to 7th day. At 4°C temperature the lowest ascorbic acid loss 1.18 mg was attributed for 0.5 kGY radiation treated followed by 0.3% potassium sorbate (1.22mg) and 1.0 KGY irradiated sample (1.52mg). Total phenol content was increased in all treatments during preservation at both temperatures and the highest total phenol content was found in control sample compare to the other treatments. Total flavonoids content was increased with increasing storage period in all treatments at both temperatures. The present study revealed that postharvest treatment of 0.3% potassium sorbate and 1.0KGY radiation was most effective to delay ripening that resulted in extending shelf life of mango.

**Key words:** Mango (*Mangifera indica* L.) · Post-harvest · Irradiation · Ripening

**INTRODUCTION**

Mango (*Mangifera indica* L.) is one of the highly priced fruit in the tropics. In this context, mango is known as an appreciable fruit due to its pleasant aroma and flavor, whose nutritional value presents high calories and vitamin contents, among others [1, 2]. Many of the pharmacological properties attributed to mango might be due to the presence of phenolic acids. These phenolic compounds possess potent antioxidant activity that play an important role in human nutrition as preventative agents against several diseases caused by oxidative stress, protecting the body tissues against oxidative stress with their antioxidant, anti-mutagen, anti-inflammatory and anti-carcinogenic properties [3, 4]. Apart from the fruit, mango flesh also has been reported to have antilithiatic and free radical scavenging properties, which reduce lipid peroxidation and enhance antioxidant enzymes (superoxide dismutase and catalase) against isoproterenol [5]. It can also play an important role in balancing human diet by providing about 64-86 calories of energy per 100gram [6].

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The fruit is an emerging tropical export crop produced in about 90 countries [7]. The mango world market earns about 700 million dollars per year [8]. In terms of production by country in 2010-2011, India accounts for almost half of the world production (~16.34 million tons), followed by China (~4.35 million tons), Thailand (~2.55 million tons), Pakistan (1.78 million tons), Mexico (1.63 million tons), Indonesia (~1.31 million tons), Brazil (~1.19 million tons) and Bangladesh (~1.05 million tons) [9].

The high rate of respiration, moisture loss and susceptibility to microbial attack, especially when ripe, limit the shelf life of mango to less than 10 days under tropical ambient conditions [10]. This short shelf life aggravates postharvest losses and does not allow for efficient distribution and marketing [11].

In this regard, development of postharvest technology related to quality maintenance and extending the postharvest life are an important to consumer acceptability and marketing consideration along with export option [12, 13].

In Bangladesh, the fruit begin to ripen in May and the peak ripening months are June and July. From the end of July the yield of the fruit decreases and at August the mango season ends. Producers incur losses of the fruit at harvesting and distribution are due to short shelf life of the fruit. To minimize the losses, it is important to find methods of preserving the fruit or postharvest treatment which can be a way to delay the ripening.

The purpose of the present study was to find out the most suitable postharvest treatments for preservation of mango by using available resources. Potassium sorbate (0.2% and 0.3%), citric acid (0.2% and 0.3%), radiation (0.5 and 1.0 kGy) and temperature (room and 4°C) treatments were used in the proposed study. It is expected that the results of this research will assist in acquiring information about the effectiveness of temperature, chemical and radiation in extending the postharvest life to delay the ripening of mango under tropical room and controlled temperature.

MATERIALS AND METHODS

Mango Variety, Sampling and Treatments: Selected, freshly hand-harvested, uniformly sized, mature-green mango fruits (locally available wild type) were obtained from the orchard. All fruits were free from physical injury and other blemishes. Mangoes were initially washed with chlorinated water (125 ppm of active chlorine) for 5 minutes to prevent contamination. For chemical treatments, mangoes were dipped into 0.2% (citric acid and potassium sorbate) and 0.3% (citric acid and potassium sorbate) solution (w/v) for three minutes. Then water from the surface of mangoes was removed by using paper towel. For irradiation the mangoes were irradiated with two selected doses of gamma radiation which were 0.5 and 1.0 kGy with a 50kCi Co60 gamma source at dose rate of 6.4 kGy/hr located at Institute of Food and Radiation Biology, Atomic Energy Research Establishment, Savar, Dhaka. Mangoes without any treatments were treated as control. For each treatment one piece of sample was placed into low-density polyethylene pouches (150µ gauge) and sealed tightly. The sealed polythene bags were labeled by indicating the name of the product and both treated and untreated samples were stored at room temperature (25°C) and 4°C temperature for biochemical and microbiological analysis. For analysis fruit samples were cut and sampled according to the different chemical analyses. Mango slices were cut longitudinally to the mango pith (from stem end to blossom end) and the pericarp was removed from the slices. Each sample analyzed represents tissue from a single fruit. Each assay was sampled with three replications using one independent extraction per fruit.

Determination of Color Change And% of Decay: Storage life was measured at the completely ripened stage or at the limit of acceptability and was expressed in days. The fruit was considered ripened when their skin was completely yellow.

For each treatment, individual fruits were assessed for ripening during storage on the basis of change in skin color from green to fully yellow and softness, using an arbitrary scale of 1-6 (unripe to fully ripe). The Marking Scale was as below:

Scale for Marking: 6= Full Yellow, Moderately Soft; 5= 60-80% Yellow, Slightly Soft; 4= 30-60% Yellow, Slightly Soft; 3= Mature, Ripe, Firm; 2= Mature, Green; 1= Immature Green.

To assess the time taken for ripening color, changes from green to yellow along with the texture from farm to soft and the% of decay was assessed by visual inspection. A panel of five qualified person was established for this assessment. An introductory briefing was also conducted among the panelists describing the scoring system of the assessment.
Determination of Moisture Content: The moisture content of mango sample was determined by drying at an oven at 105°C for 5-6 hrs according to the standard method of AOAC (1975) [14].

Determination of Weight Loss: Weight loss was measured by calculating the difference between the initial and final weight of each replication. It was expressed as percent (%) using the following equation:

\[
\% \text{ of weight loss} = \frac{\text{Initial weight of the mango} - \text{Final weight of the mango}}{\text{Initial weight of the mango}} \times 100
\]

Determination of pH: The pH of the mango varieties were measured by digital pH meter (type H1 98106; HANNA) at ambient temperature using juice extracted directly from pulp.

Determination of Titratable Acidity (TA): Titratable acidity was determined by dissolving a known amount of mango pulp in distilled water and then titrated against 0.1N sodium hydroxide (NaOH) using phenolphthalein as an indicator [15]. The results were calculated as percent of citric acid.

Determination of Total Soluble Solid (TSS): Total Soluble Solids (TSS) content was determined using an Abbe refractometer (TAGO 9099, Japan); pulp samples were homogenized in a blender. By placing a drop of thoroughly mixed sample on its prism, a direct refractometer reading was taken by the method described by Rababah [16].

Determination of Ascorbic acid (Vitamin-C): Ascorbic acid was determined by 2,6-dichloroindophenol titrimetric method [17]. Briefly, sample (2g) was homogenized with 3% metaphosphoric acid (25ml) and was filtered through filter paper (Whatman 1, 7.0cm). Then an aliquot (5ml) of filtrate was titrated with the 2,6-dichloroindophenol dye (standardized by the metaphosphoric acid) to a pink endpoint. Results were expressed on a fresh weight basis as mg ascorbic acid equivalent/100gm. The estimation of ascorbic acid (vitamin-C) content of mango fruits was carried out by the titration result of the sample extract with 2,6- Dichlorophenol-Indophenol (Dye) [17].

Determination of Total Phenolic Compounds: Phenolic compounds in mango samples were estimated by a modified spectrophotometric Folin–Ciocalteu method [18]. Briefly, 200 µL of mango extract were mixed with 1 mL Folin and Ciocalteu’s phenol reagent. After 3 min, 1 mL of 10% Na₂CO₃ solution was added to the mixture and adjusted to 10 mL with distilled water. The reaction was kept in the dark for 90 min, after which the absorbance was read at 725 nm by a T 80 UV/VIS spectrophotometer (Chromotek GmbH, Germany). Gallic acid was used to calculate the standard curve (20, 40, 60, 80 and 100 µg/mL). Estimation of the phenolic compounds was carried out in triplicate. The results were expressed as micrograms (µg) of gallic acid equivalents (GAEs) per gram (g) mango.

Determination of Total Flavonoids: Total flavonoid content (TF) of each Mango sample was determined according to the colorimetric assay developed by Zhishen and others [19]. Mango extract (200 µL) was mixed with 4 mL of distilled water. At baseline, 0.3 mL of NaNO₂ (5%, w/v) was added. After 5 min, 0.3 mL AlCl₃ (10% w/v) was added, followed by the addition of 2 mL of NaOH (1 M) 6 min later. Immediately after that, the volume was increased to 10 mL by the addition of 2.4 mL distilled water. The mixture was vigorously shaken to ensure adequate mixing and the absorbance was read at 510 nm. A calibration curve was prepared using a standard solution of Querchetin (20, 40, 60, 80 and 100 µg/mL). The results were also expressed as micrograms (µg) of Querchetin equivalents (QE) per gram (g) mango.

Statistical Analysis: All determinations were obtained from triplicate measurements and results were expressed as mean ± standard deviation. Data were analyzed by the SPSS.16.0 (Statistical Package for Social Sciences) software. Statistical significance was declared at p < 0.05.

RESULT AND DISCUSSION

Color Change and Decay: Color changes in mangoes are primarily associated with several biochemical changes; both degradation and synthesis of various classes of molecules including carotenoids in fruit [20]. The scores for color changes attained in different treatments at room and 4°C refrigerated temperature have been represented at Figure-1 and Figure-2, respectively. Control sample was fully ripened on 5th day at room temperature. Whereas, citric acid (0.2% and 0.3%) and 0.2% potassium sorbate treated sample was ripened on 6th day. The most delayed ripening result was observed with 0.3% potassium sorbate and irradiated (0.5Kgy and 1.0Kgy) sample which took 7 days to fully ripe (Fig-1). No decay was observed in this
period in all treatments. At 4°C temperature, the most delayed ripening was found at 0.3% Potassium sorbate and 1.0 kGy irradiation treatment which was 28th day (Fig-2) whereas the control sample was ripened on the 21st day and the citric acid (0.2% and 0.3%), 0.2% potassium sorbate and 0.5 kGy irradiated samples were found to be fully ripened on the 25th day. On day 28, no decay was observed in all samples except 10% decay was found only in control sample. In the present study, 0.3% potassium sorbate and 1.0 K Gy irradiation were the most effective for delaying ripening of mango at both room and 4°C temperature in compare to the other treatments.

**Moisture and Weight Loss:** Changes of moisture in different treatments at both room and 4°C temperature are shown in the Figure-3 and Figure-4, respectively.

At room temperature, between day-0 and day-7 the significantly lowest increase in moisture was found 1.65% and 1.85% for radiation treated samples (1.0kGy and 0.5kGy, respectively) followed by 2.65% and 2.89% which citric acid and potassium sorbate (0.3%) treated samples, respectively. Significantly the highest increase in moisture was found due to the control and 0.2% citric acid treatments which were 3.15% for both. At 4°C temperature, between day-0 and day-28 the lowest
The increase in moisture content of the fruits pulp during ripening could be attributed to loss of moisture from peel to the pulp. During ripening, carbohydrates are hydrolysed into sugars increased osmotic transfer of moisture from peel to pulp [10]. The observed increase in moisture content of the mango pulp was therefore expected during the ripening and the lowest moisture was considered as the indication of delaying ripening. In the present study, 1.0 kGy radiation and 0.3% potassium sorbate were the most effective for delaying ripening of mango at both room and 4°C temperature in compare to the other treatments.

The percentage (%) of weight loss of mango during storage at room and 4°C temperature are shown in Figure-5 (Changes in different days) and Figure-6 (Changes in different treatments). For both temperatures, Figure-5 showed that the mean of the percentage of weight loss was fall down initially with preservation days then it gradually increased with days. Similar findings were also reported by Orathai and others [21]. The rate at which water is lost depends on the water pressure gradient between the fruit tissue and the surrounding atmosphere and the storage temperature [22]. At the same time the lowest weight loss was found for potassium sorbate (0.2% and 0.3%) and radiation (0.5kGy and 1.0kGy) treated samples (Figure-6). In case of percentage of weight loss, potassium sorbate (0.2% and 0.3%) and irradiation (1.0 kGy and 0.5 kGy) were the most effective for delaying ripening of mango at both room and 4°C temperature in compare to the other treatments.

**Titratable Acidity (TA) and pH:** Titratable acidity (TA) gives a measure of the amount of acid present in a fruit and citric acid is known to be the major acid in mango [23, 24]. In the present study, TA was decreased with increasing the storage period in all treatments at both temperatures. A significantly reduced rate of TA was found with 0.3% potassium sorbate at room temperature. In case of 4°C temperature, significantly reduced TA was found by 0.2% citric acid treated sample. At room temperature, there were no significant differences between 0.2% citric acid and 0.5kGy radiation along with 0.3% citric acid and 0.2% potassium sorbate treated samples but control was highly significant than all other treatments (Table-1). On the contrary, at 4°C temperature, the changes of TA were not significantly different in control, radiation (0.5kGy and 1.0kGy) and 0.3% potassium sorbate treated samples. Thus temperature had a significant effect on TA. The decline in acidity could be due to susceptibility of citric acid to oxidative destruction as impacted by the ripening environment [25]. The decline in acidity during ripening is a consequence of starch hydrolysis leading to an increase in total sugars and a reduction in acidity [26]. Variation in acidity among different treatments may be attributed to the extent of degradation of citric acid as a function of the activity of citric acid glyoxylase during ripening [6, 27]. Similarly, a decrease in titratable acidity of mango fruits during ripening has been reported [28].
### Table 1: Effect of different treatments on pH, TA and TSS at room and 4°C temperature

<table>
<thead>
<tr>
<th>Parameters</th>
<th>4°C temperature</th>
<th>Room Temperature</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Day-0</td>
<td>Day-1</td>
<td>Day-3</td>
</tr>
<tr>
<td>Control</td>
<td>3.33</td>
<td>3.32</td>
<td>3.36</td>
</tr>
<tr>
<td>0.2% Citric Acid</td>
<td>3.12</td>
<td>3.12</td>
<td>3.28</td>
</tr>
<tr>
<td>0.3% Citric Acid</td>
<td>3.24</td>
<td>3.24</td>
<td>3.22</td>
</tr>
<tr>
<td>0.2% Potassium Sorbate</td>
<td>3.25</td>
<td>3.25</td>
<td>3.29</td>
</tr>
<tr>
<td>0.3% Potassium Sorbate</td>
<td>3.21</td>
<td>3.21</td>
<td>3.19</td>
</tr>
<tr>
<td>0.5KGy Radiation</td>
<td>3.37</td>
<td>3.39</td>
<td>3.24</td>
</tr>
<tr>
<td>LSD (5%) n=3, n=21</td>
<td>0.05</td>
<td>0.12</td>
<td></td>
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</table>

Titratable Acidity  

<table>
<thead>
<tr>
<th>Parameters</th>
<th>4°C temperature</th>
<th>Room Temperature</th>
<th>TA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Day-0</td>
<td>Day-1</td>
<td>Day-3</td>
</tr>
<tr>
<td>Control</td>
<td>3.49</td>
<td>3.49</td>
<td>3.38</td>
</tr>
<tr>
<td>0.2% Citric Acid</td>
<td>3.28</td>
<td>3.26</td>
<td>3.23</td>
</tr>
<tr>
<td>0.3% Citric Acid</td>
<td>3.32</td>
<td>3.29</td>
<td>3.22</td>
</tr>
<tr>
<td>0.2% Potassium Sorbate</td>
<td>3.18</td>
<td>3.16</td>
<td>3.11</td>
</tr>
<tr>
<td>0.3% Potassium Sorbate</td>
<td>3.31</td>
<td>3.23</td>
<td>3.17</td>
</tr>
<tr>
<td>0.5KGy Radiation</td>
<td>3.26</td>
<td>3.22</td>
<td>3.2</td>
</tr>
<tr>
<td>LSD (5%) n=3, n=21</td>
<td>0.05</td>
<td>0.13</td>
<td></td>
</tr>
</tbody>
</table>

Total Soluble Solids (TSS): Total soluble solids (TSS) content is an indicator of good quality of fruits [32]. In the present study TSS value was increased significantly during the storage period in all treatments with both temperatures and storage period had also a significant effect on TSS. Highest TSS% was found in control sample which was 14.86 and 16.16 at room and 4°C temperature, respectively (Table-1). Present study showed that TSS was increased with the decreasing of TA during ripening of mango. Comparatively higher amount of TSS was found in refrigerated temperature at fully ripened mango than room temperature. So temperature had a significant effect on TSS. Increasing TSS during fruit ripening was attributed to the increasing activity of enzymes responsible about the hydrolysis of starch to soluble sugars [22]. Generally, taste and particularly sweetness of the fruits depend on the percentage of TSS content [33].

Ascorbic Acid (Vitamin-C): A significant decline in ascorbic acid (AA) was found in all treatments under both temperatures during storage (Table 2). Storage period has also significant effect on AA. Ascorbic acid is one of the effective nutrient stability index during fruit storage operations and has been generally seen that if it is well retained, the other nutrients are also well retained [34, 35]. Our results depict that AA was much higher in citric acid.
Table 2: Effect of different treatments on Total Polyphenol, Flavonoid and Vit-C at room and 4°C temperature

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Room Temperature</th>
<th>4°C temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Polyphenol</td>
<td>Flavonoid</td>
</tr>
<tr>
<td>Control</td>
<td>373.08-373.18</td>
<td>89.24-91.37</td>
</tr>
<tr>
<td>0.2% Citric Acid</td>
<td>367.31-367.37</td>
<td>89.87-90.26</td>
</tr>
<tr>
<td>0.3% Citric Acid</td>
<td>363.46-363.56</td>
<td>87.97-91.56</td>
</tr>
<tr>
<td>0.2% Potassium Sorbate</td>
<td>363.46-363.56</td>
<td>88.61-91.56</td>
</tr>
<tr>
<td>0.3% Potassium Sorbate</td>
<td>353.85-354.54</td>
<td>87.34-90.26</td>
</tr>
<tr>
<td>0.5KGy Radiation</td>
<td>350-350.14</td>
<td>86.08-92.21</td>
</tr>
<tr>
<td>1.0KGy Radiation</td>
<td>365.38-367.31</td>
<td>89.87-90.26</td>
</tr>
<tr>
<td>LSD (5%) n=3. n=21</td>
<td>0.68</td>
<td>0.26</td>
</tr>
</tbody>
</table>

(0.2 and 0.3%), potassium sorbate (0.2 and 0.3%) and radiation (0.5 and 1.0 kGy) treated mango during storage as compared to the control under both temperature. These results agree with those reported by Ayranci and Tunc who stated that “ascorbic acid loss rate was much lower in stored apricots treated with citric acid as compared to control fruits” [36]. González-Aguilar and others (2007) have reported the negative effect of UV-C irradiation on AA in mango “Tommy Atkins” fruits when compared with control fruits which disagree with our findings [37]. Decline in AA is attributable to susceptibility of ascorbic acid to oxidative destruction during ripening [25]. Similarly, much lower values of AA were found in green preclimacteric wild mangoes relative to ripe fruits [20].

**Polyphenol and Flavonoid:** The action of phenolic compounds in foods has been drawn a lot of attention because of their biological activity in cancer and heart diseases prevention [38]. Table-2 shown that the total phenols were significantly different (P < 0.001) between treatments with the mean levels throughout the storage period at room temperature. Storage period had no significant effect on total phenols content. At 4°C temperature, storage period had a significant effect (P < 0.001) on total phenols content in all treatments that increased during storage (Table-2). Significantly lower total phenol content was found in citric acid (0.2 and 0.3%), potassium sorbate (0.2 and 0.3%) and radiation (0.5 and 1.0 kGy) treated samples compared to control at both temperature. A Significantly highest amount of flavonoid was found by 0.5 and 1.0 kGy radiation treated samples at room temperature compare to the other treatments. At 4°C temperature 0.2% citric acid and 1.0 kGy showed the highest total flavonoids content among other treatments (Table-2).

Irradiation induces the accumulation of phenolic compounds and flavonoids in plants as a defense mechanism against irradiation, also the increase in TP and TF can be attributed to the phenylalanine ammonialyase activity, which is one of the key enzymes in the synthesis of phenolic compounds in plant tissues [39, 40]. Increase in phenolic compounds of irradiated plant produce has also been attributed to depolymerization and dissolution of cell wall polysaccharides, which facilitated higher extractability [41]. The variation of phenolics in fruits...
depends on many factors, it is known that the different stages in the process of fruits development. e.g., in red pepper, it increases during the ripening stage due to maximum deposition of anthocyanin and flavonoids [42].

CONCLUSION

Postharvest treatments of 0.3% potassium sorbate and 1.0 kGy radiation were found to be the most effective treatments among all other treatments on biochemical and organoleptic properties of mango in relation to delay ripening without any external decay of fruits. In this investigation, mango loses its weight, titratable acidity (TA) and ascorbic acid (Vitamin-C) whereas, an increasing value is obtained for pH, moisture in pulp, total soluble solids (TSS), total polyphenols (TP) and total flavonoids (TF) during preservation.

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