Impact of gamma irradiation and osmotic dehydration on quality characteristics of guava (Psidium guajava) slices

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ABSTRACT

A multi-target (combination preservation) technique has been extensively applied to develop minimally processed and completely stabilized shelf stable food produces. A combination of irradiation and osmotic dehydration decrease the need for thermal treatments for enhancing the shelf life and microbial safety of cut fruits and vegetables. The present study aims at identifying combined effect of γ-irradiation pre-treatment and osmotic dehydration treatment on guava. The guavas packed in LDPE pouches were irradiated at 0.25 kGy, and 1.0 kGy dosages at the dose rate of 2.75 kGy/hr. The guava slices with and without irradiation were infused for osmotic dehydration process. Optimization of the process time (3, 6 and 9 hr) was also investigated. Further, stored guava slices were analyzed for their physico – chemical, antioxidant and microbial analysis. Mass transfer kinetics of guava slices osmotically dehydrated in sucrose solutions were significantly affected by irradiation dosage and sucrose concentration and treatment duration. The evaluation of hurdle approach on guava slices showed that, combination treated slices were significantly less susceptible to nutrient and colour changes during storage. The synergy between the irradiation and dehydration also resulted in adequate microbiological stability of the slices.

Key words: Guava, Gamma irradiation, Osmotic dehydration.

INTRODUCTION

Fruits and vegetables are potent sources of essential dietary nutrients such as vitamins, minerals and fibre. They are acclaimed universally as protective foods and increased consumption has been associated with reduced risk of coronary artery diseases, cerebro-vascular disease and muscular degenerative diseases. (Javaria et al., 2012).

India is the second largest fruit and vegetables producer in world with an annual production of 44 million metric tons. In India, post harvest losses of fruits and vegetables are estimated to be 25%. This is due to lack of proper retailing and inadequate storage capacity. Preserving food to extend its shelf-life, while ensuring its safety and quality is of primary concern. The development of the hurdle concept has lead to renewed interest in the use of more traditional preservation methods and the ways they can be combined with newer technologies (Ashok and Singh, 2012).

Synergies are more likely the individual hurdles targeting different functions within the cell, thus permitting gentler preservation treatment, with potentially less impact on the quality of the product (Leistner, 2000). Gamma irradiation has been proven to inhibit microbial growth, delay ripening and extend the shelf life of minimally processed fruits and vegetables (Prakash et al., 2000a). Osmotic dehydration is one of the potential preservation techniques for producing high quality products. This provides minimal thermal degradation of nutrients due to low temperature water removal process (Sodhi et al., 2006). The adaptation of osmotic dehydration as a best process hurdle can be ascribed to two aspects. It is a low temperature water removal process and hence, minimum loss of color and flavour retention is more when sugar syrup is used as an osmotic agent (Islam and Flink, 1982).

Guava is considered as common man’s fruit and called as the apple of the tropics (Adsule and Kadam, 1995). Guava fruit is an excellent source of nutrients and considered as a good source of antioxidant dietary fiber owing to its high content and extractable polyphenols (Jimenez et al., 2001).

A combination of irradiation and osmotic dehydration decrease the need for thermal treatments for enhancing the shelf life and microbial safety of cut fruits and vegetables. Hence, the current study aimed at identifying combined effect of γ-irradiation pre-treatment and osmotic dehydration treatment on guava slices and to examine the efficacy of combination treatments on the mass transfer kinetics, physico-chemical, antioxidant and microbial quality of guava slices.

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MATERIALS AND METHODS

Guavas were obtained from local market. To ensure homogeneity of sample, they were selected according to their quality attributes such as uniform degree of maturation based on skin color (greenish yellow) and total soluble solids content.

Gamma irradiation treatment: Irradiation treatment was carried out in a cobalt -60 chamber (Model: Gamma chamber 5000, BARC, Mumbai). The dose rate was 2.75 kGy/hr. The guavas were packed in LDPE pouches and irradiated separately at 0.25 kGy (I\textsubscript{A}) and 1.0 kGy (I\textsubscript{B}) dosages respectively. After radiation treatment, the guava samples were prepared for osmotic dehydration process. The gamma irradiated guavas were blot dried with absorbent tissue paper to remove external moisture. They were manually cut with a stainless steel knife into 0.25 cm thick circular slices.

Optimization of infusion media: Food grade sucrose solutions of 40\(^\circ\) Brix (A) and 60\(^\circ\) Brix (B) were prepared and food grade KMS (Potassium meta bisulphite) and citric acid were also added at 5\% level to the infusion media. Preliminary infusion process was conducted in 40\(^\circ\)B and 60\(^\circ\)B solution with three variant temperatures viz., 3 hrs, 6 hrs and 9 hrs at 30\(^\circ\)C. After the specified dehydration time, the samples were separated from the osmotic solution, rinsed with spray of plain water and dried on a filter paper. A preliminary sensory testing was performed by the selected panelists comprised of 10 members. They were asked to score the quality attributes such as appearance, texture, color, taste and overall acceptability using 9 point hedonic scale. Preliminary quantitative analysis was also carried out to determine the moisture content of the samples. After the analysis, 9 hours soaking time with 40\(^\circ\)B and 60\(^\circ\)B concentration were found best to obtain the fruit with desirable characteristics. Table 1 shows the different treatments given to the guava slices for storage.

Osmotic dehydration: The prepared guava slices were suspended in 40\(^\circ\)B and 60\(^\circ\)B infusion media at pre selected time (9 hours) and temperature (30\(^\circ\)C). The ratio of the fruits and infusion media was maintained as 1:8 in order to ensure complete immersion of samples. The solutions were stirred at an interval of 30 min to stimulate an ongoing osmotic process. Samples were withdrawn from osmotic solutions after the determined time (9 hrs), drained and dried with filter paper to remove adhering solution from the surface of the slices. The weight of the samples (i.e. slices) and volume of the osmotic solution were measured prior to immersion and after infusion. After osmotic dehydration, samples were packed in Ziploc (LDPE) pouches and stored in refrigerator at 12\(\pm 2\)\(^\circ\)C and periodically evaluated.

Mass transfer mechanisms

Per cent moisture loss (ML), per cent mass reduction (MR), and solid gain (SG) were calculated by the mass balance equations.

\[
% \text{ML} = \frac{\text{Initial moisture – moisture at time} \times 100}{\text{Initial moisture}}
\]

\[
% \text{MR} = \frac{\text{Initial mass – mass at time (T)} \times 100}{\text{Initial moisture}}
\]

SG (Solid gain) = moisture loss (%) – mass reduction (%)

The external color of the fruit slices were determined during storage by using Konika MINOLTA, CR – 10 colour reader as given by Hajare et al. (2006). The results were expressed in colour lightness (L\textsuperscript{*}), Chroma (C\textsuperscript{*}), a\textsuperscript{*} (greenness to redness) and b\textsuperscript{*} values(blueness to yellowness). Moisture was analyzed by method given by Berwal et al., (2004). Total soluble solids (\textsuperscript{°}Brix) were determined by using digital refractometer (ATAGO PR-1, Japan) according to AOAC methods (1995). The Titrable acidity and non-enzymatic browning of the samples were analyzed by using the method developed by Ranganna (1986) and Berwal et al., (2004); Vitamin C content by Ranganna, (1986); Total phenol content by Singleton and Rossi, (1965). The yeast and mold count of the fruit was determined by pour plate method using potato dextrose agar (PDA) as a media as described by Aneja (2001).

To investigate the significant differences amongst the average values of treatment, two way ANOVA was applied. In order to find out the significant difference between the samples, critical difference test was applied (Gupta, 1995).

RESULTS AND DISCUSSION

Maximum reduction in water content of guava slices was observed in GI\textsubscript{A} slices. Overall the infusion process for all the treatments resulted with nearly half the moisture content of fresh guavas (87\%) (Table2). Gamma irradiation treatment affected the rate of water removal and solute gain.

\begin{table}[h]
\centering
\begin{tabular}{|l|l|l|}
\hline
\textbf{Treatment no} & \textbf{Treatment code} & \textbf{Description of treatment} \\
\hline
1. & GC\textsubscript{A} & osmotically dehydrated at 40\(^\circ\) Brix concentration \\
2. & GI\textsubscript{A} & low dose (0.25 kGy) gamma irradiated, osmotically dehydrated at 40\(^\circ\) Brix concentration \\
3. & GI\textsubscript{A} & high dose (1.0kGy) gamma irradiated, osmotically dehydrated at 40\(^\circ\) Brix concentration \\
4. & GC\textsubscript{B} & osmotically dehydrated at 60\(^\circ\) Brix concentration \\
5. & GI\textsubscript{B} & low dose (0.25 kGy) gamma irradiated, osmotically dehydrated at 60\(^\circ\) Brix concentration \\
6. & GI\textsubscript{B} & high dose (1.0kGy) gamma irradiated, osmotically dehydrated at 60\(^\circ\) Brix concentration \\
\hline
\end{tabular}
\end{table}
irrespective of dosage. The above stated fact can be attributed to the effect of gamma irradiation as a pre-treatment. The reduction in the moisture of the infused fruits may also be attributed to large osmotic driving force difference between the cell sap of the guava fruit and surrounding hypertonic sucrose solution. An increase in osmotic sucrose solution concentration increased this gradient and in turn the driving force.

Rastogi (2005) concluded that gamma irradiation affected the cellwall structures leaving the cells more permeable for moisture and solute transfer. Singh and Pal (2009) indicated ionizing irradiation as a stress factor for fresh fruits. Severity of stress depends on dose level and maturity of the fruit. The increase in cell permeability due to increase in irradiation dose was reported by Hayashi et al., (1992). In the present study, a significant influence of irradiation dosage and sucrose concentration was observed on solute gain of guava slices. In GI_B sample, the solid gain was minimal which could be due to stress induced by gamma irradiation.

Mass transfer of control and gamma irradiated samples varied during the course of osmotic dehydration (Table2). There was a simultaneous increase in mass transfer as the radiation dose and concentration of sucrose solution increased. Guava slices immersed in 60%B solution showed higher mass transfer rates compared to those immersed in 40%B solution. The increase of mass transfer was due to the concentration difference between guava and osmotic solution which increased the rate of diffusion of solute and water exchange with osmotic solution. Lazavides et al., (1997) attributed the increased mass transfer of sugar molecules with increasing concentration to possible membrane swelling effect, which might increase the cell membrane permeability.

Jacob and Paliayath (2012) reported lower moisture content of the infused cherries and also gain in solids was relatively low in infused and oven dried cherries. In the present study, other factors affecting the rate of water removal and solid gain are the temperature of the osmotic solution, immersion time, level of agitation in the solution, the specific characteristics (size and shape) of the fruit and the solution to sample ratio. Several authors have described the role of these factors on the mass transfer kinetics during the osmotic dehydration of fruits and vegetables such as apples, bananas, carrots, tomatoes etc. (Dermonsolouglo et al., 2005).

**Fruit colour:** There was a significant difference among the treatments on the initial day of storage (Fig 1). This change could be correlated to gamma irradiation as well as osmotic dehydration treatment. It was observed that lightness (L) decreased with increase in the radiation dose and also the osmotic solution concentration. Thus, the highest decrease in L values was observed in GI_B samples. a* value increased with osmotic solution concentration. Moreover, gamma irradiation also would have contributed to the increase in the a* values. It was observed that, highest increase of a* value was found in 60%B solution than 40%B. By comparing irradiated and unirradiated infused samples, the a* values significantly increased with radiation treatment irrespective of dosage. The increase in the a* values could be attributed to the browning reactions that occur during drying and also concentration of the infusion media. Adam et al., (2000) has reported the change of color occurring during processing which could be attributed to the Maillard’s browning reaction. A similar trend with increase in a* value was found for microwave drying of kiwi fruit.

There was remarkable change upon storage on b* values of GI_B samples. There was minimal difference during storage on b* values for various treatments. The change in the b* value can be associated with less yellowness and more redness. It was reported in a study that air-dried carrot slices were found darker with less yellow and red hues as compared to microwave dried ones (Sumnu et al., 2009).

**Moisture:** The mean values of moisture in guava slices were found to be in the range of 32 to 46% respectively. The change was found to be statistically different (p<0.05) during initial period of storage (Table 3). It can be observed that, the treatments moisture contents ranged within the desirable levels of the Intermediate Moisture Foods (IMF) (30-45%) (Gullibert, 1988). It was also evident on 15th day of storage that there was an increase in moisture levels in both the doses of irradiation and low degree Brix concentration. However, GI_B retained the initial moisture content. During 30th and 45th day of storage, irrespective of Brix and dosage level there was over all increase in moisture content.

**Total soluble solids:** Experimental data (Table 4) revealed that the Brix increased during entire storage duration and found to be statistically significant at p<0.05. TSS was maximum in 40% Brix concentration of both irradiated and osmosed samples. TSS content increased maximum in GI_B sample from 7.3%Brix to 10%Brix (27% increase over initial TSS) after 15 days of storage. This increment followed the same trend throughout the storage period. Over all during entire storage period, all osmo-dried guava slices treated with gamma irradiation irrespective of sugar concentration.

<p>| Table 2: Effect of gamma irradiation and osmotic dehydration on mass transfer mechanisms of guava slices. |</p>
<table>
<thead>
<tr>
<th>Treatment</th>
<th>ML (%)</th>
<th>MR (%)</th>
<th>SG (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GI_A</td>
<td>46.4</td>
<td>25</td>
<td>21.4</td>
</tr>
<tr>
<td>GI_A</td>
<td>52</td>
<td>44</td>
<td>8</td>
</tr>
<tr>
<td>GI_A</td>
<td>62</td>
<td>47</td>
<td>15</td>
</tr>
<tr>
<td>GCB</td>
<td>47</td>
<td>10</td>
<td>37</td>
</tr>
<tr>
<td>GI_B</td>
<td>56</td>
<td>45</td>
<td>11</td>
</tr>
<tr>
<td>GI_B</td>
<td>58</td>
<td>55</td>
<td>3</td>
</tr>
</tbody>
</table>

By comparing irradiated and unirradiated infused samples, the a* values significantly increased with radiation treatment irrespective of dosage.
Table 3: Effect of gamma irradiation and osmotic dehydration on moisture (%) of guava slices.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>0 day</th>
<th>15th day</th>
<th>30th day</th>
<th>45th day</th>
</tr>
</thead>
<tbody>
<tr>
<td>GCA</td>
<td>46.6±0.1</td>
<td>47.2±0.2</td>
<td>53.0±0.1</td>
<td>70.0±0.1</td>
</tr>
<tr>
<td>GI1A</td>
<td>41.4±0.1</td>
<td>43.3±0.2</td>
<td>58.4±0.1</td>
<td>69.0±0.0</td>
</tr>
<tr>
<td>GI2A</td>
<td>32.7±0.0</td>
<td>48.3±0.1</td>
<td>63.0±0.0</td>
<td>67.0±0.1</td>
</tr>
<tr>
<td>GCB</td>
<td>40.0±0.0</td>
<td>28.3±0.1</td>
<td>48.1±0.1</td>
<td>53.1±0.1</td>
</tr>
<tr>
<td>GI1B</td>
<td>38.0±0.1</td>
<td>42.4±0.1</td>
<td>47.1±0.1</td>
<td>52.1±0.2</td>
</tr>
<tr>
<td>GI2B</td>
<td>36.1±0.1</td>
<td>36.0±0.1</td>
<td>42.0±0.1</td>
<td>56.7±1.1</td>
</tr>
</tbody>
</table>

Values are mean ± S.D, n=3.

Means within treatments in a column not having common superscripts are significantly different. (p<0.05)
Table 4: Effect of gamma irradiation and osmotic dehydration on total soluble solids (°Brix) of guava slices.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>0 day</th>
<th>15th day</th>
<th>30th day</th>
<th>45th day</th>
</tr>
</thead>
<tbody>
<tr>
<td>GCA</td>
<td>1.8±0.1</td>
<td>2.0±0.1</td>
<td>5.7±0.1</td>
<td>20.2±0.1</td>
</tr>
<tr>
<td>GI,A</td>
<td>10.2±0.2</td>
<td>12.9±0.0</td>
<td>16.5±0.0</td>
<td>22.8±0.1</td>
</tr>
<tr>
<td>GI,A</td>
<td>10.0±0.1</td>
<td>11.6±0.0</td>
<td>11.7±0.0</td>
<td>12.1±0.0</td>
</tr>
<tr>
<td>GCB</td>
<td>7.5±0.0</td>
<td>8.4±0.1</td>
<td>9.8±0.0</td>
<td>10.3±0.1</td>
</tr>
<tr>
<td>GI,B</td>
<td>3.7±0.1</td>
<td>10.0±0.1</td>
<td>19.7±0.1</td>
<td>20.5±0.1</td>
</tr>
<tr>
<td>GI,B</td>
<td>7.3±0.0</td>
<td>11.0±0.0</td>
<td>25.4±0.1</td>
<td>27.0±0.0</td>
</tr>
</tbody>
</table>

Values are mean ± S.D, n=3.
Means within treatments in a column not having common superscripts are significantly different. (p<0.05)

showed maximum increase in TSS in comparison with only osmosed slices. The difference in the TSS of the treatments could be due to sugar compositional changes resulted due to treatments. Similar study has been reported by Parker et al., (2010) during the development of papaya nectar using a combination of irradiation and mild heat treatment.

**Titrable acidity:** The percentage acidity of the samples ranged between 0.25% to 0.51% (Fig 2). There was significant interaction difference among the treatments and the storage period. Initial acidity value was highest in GI,B and lowest in GCA among the treatments. As the storage period progressed acidity values were invariably found to increase in all treatment combinations.

Among the treatments highest percentage increase in acidity value from 0.34-8.64% was recorded in irradiated guava slices of GI,B followed by GI,B sample. It was also observed that irradiation treatment significantly increased the acidity than un-irradiated controls. An increase in the acidity was reported by Paul et al., (2012) for osmotically pre-treated and vacuum dried pine apple cubes.

**Non-Enzymatic browning:** Table 5 shows the results of non-enzymatic browning (NEB) in guava slices during different storage periods. The color of the samples exhibited significant variation among the different treatments from initial to final storage period. The degree of browning was high in gamma irradiated and osmosed samples when compared to only osmosed samples.

Valdramidis (2010) stated that non-enzymatic browning may result from the condensation of a carbonyl group with amino acids, reaction of sugars and ascorbic acid oxidation resulting in formation of brown products. From the present study, it is clear that the increase in NEB values could be due to the reaction of sugars and ascorbic acid.

![Fig 2: Effect of gamma irradiation and osmotic dehydration on titrable acidity(%) of guava slices](image-url)
Table 5: Effect of gamma irradiation and osmotic dehydration on non enzymatic browning of guava slices.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Storage duration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0 day</td>
</tr>
<tr>
<td>GCA</td>
<td>0.09±0.02</td>
</tr>
<tr>
<td>GI, A</td>
<td>0.396±0.03</td>
</tr>
<tr>
<td>GI, A</td>
<td>0.803±0.02</td>
</tr>
<tr>
<td>GCB</td>
<td>0.086±0.04</td>
</tr>
<tr>
<td>GI, B</td>
<td>0.403±0.05</td>
</tr>
<tr>
<td>GI, B</td>
<td>0.626±0.06</td>
</tr>
</tbody>
</table>

Values are mean ± S.D, n=3.

Means within treatments in a column not having common superscripts are significantly different. (p<0.05)

These findings supports the work done by Mancilla et al., (2011), regarding non-enzymatic browning.

**Vitamin C:** Fig.3 indicates the value of ascorbic acid content at initial stage and at different storage intervals for different treatments. Initial values of ascorbic acid content ranged between 68.3±0.5 and 76.43±0.251 for GI, B and GCB. On zero day of the experiment, a sharp decrease in ascorbic acid content was observed in samples pre-treated with γ-irradiation, irrespective of dosage. In the initial period i.e. upto 15 days of storage, there was retention of vitamin C in all the samples, irrespective of treatments. However, high dose irradiation caused a significant loss in comparison with low dose treated fruit slices. A possible explanation for these differences could be stress induced enzyme activation during processing like oxidative reactions by enzymes such as, ascorbic acid oxidase, peroxidase found in fruits and non-enzymatic reactions.

In the present study, as the samples were blot dried after treatments, heat liable loss of vitamin C was avoided to some extent in the experiment. As a consequence, the degree of retention was high in the initial storage period. There was a gradual decrease in ascorbic acid content with the extension of storage period and this decrease was statistically significant at different storage intervals. Lowest value of ascorbic acid (62.5±1.4 mg/100gm) was recorded in GI, B sample after 30 days of storage. Whereas, highest value for ascorbic acid (69.9±0.4mg/100gm) after 30 days was recorded in GCB sample.

An additional decrease was observed during 45th day of storage in all treatments. Percentage decrease over initial value in vitamin C content of high dose irradiated guava slices irrespective of degree Brix concentration after 45 days where, 50.5% (from initial 70.46±0.20 mg/100 gm

**Fig 3:** Effect of gamma irradiation and osmotic dehydration on ascorbic acid content (mg/100g) of guava slices.
to final 34.86±0.15 mg/100 gm) for GI\textsubscript{1}A followed by low dose irradiated samples GI\textsubscript{1}B (72.63±0.30 to final 37.53±0.25 mg/100 gm).

Similar trend was observed by Patras et al., (2009) on their study on impact of high pressure processing on total antioxidant activity of strawberry and blackberry purees and stated that osmotic treatment might have caused significant loss in ascorbic acid content of samples ranging from 37.27\% to 52\%.

Progressive loss of ascorbic acid with storage duration might be due to increase in water activity (a\textsubscript{w}). The rate of oxidation of ascorbic acid in low moisture food systems was found to increase progressively with water activity and was thought to be associated with increased availability of water to act as a solvent for reactants and catalysts (Dennison and Kirk, 1978).

**Total phenolics:** As shown in fig 4, the contents of total phenolic compounds in the extracts were in the order GCA>G1\textsubscript{1}A>GCB>G1\textsubscript{2}B>G1\textsubscript{2}A. The total content of phenolics on 15\textsuperscript{th} day in the gamma irradiated samples ranged between 42.0±1.0 to 119.0±1 mg GAE/100 gm whereas, for the control samples, the contents ranged between 29.3±1.5 and 31.7±0.6 mg GAE/100 gm.

The increase in the phenolic content of the irradiated samples might be related to an increased extractability of some of the antioxidant compounds following irradiation treatment.

During storage, total phenolics degraded from a range of 29.3 mg GAE/100gm to 78.6 mg GAE/100gm after 15 days of storage indicating 62\% loss of phenolics in only osmotically dehydrated samples. Stojanovic and Silva (2007) stated that, different osmotic concentration treatments and ultra sound induced loss of phenolics by migration into the osmotic solution. Introduction of ultra sound may have accelerated formation of free radicals and increased the levels of polymerization of phenolics that resulted in 43.7\% loss of total phenolics.

**Yeast and mold count:** It was observed that the total plate count was below the detectable limits in all the treated samples till a storage period of 15 days. This might be due to the processing effects. Several reports stated the synergistic effects of gamma – irradiation with dehydration in rendering microbiological safety (Mayer et al., 1981). However, very low yeasts and mold counts were observed after a month of storage i.e., 6.47 and 6.301 log cfu/g in GI\textsubscript{1}A, GI\textsubscript{1}B, GI\textsubscript{2}B samples respectively. While GI\textsubscript{1}A, GI\textsubscript{1}B, GI\textsubscript{2}B samples did not exhibit detectable colonies. On 45\textsuperscript{th} day of storage very low counts were detected in GI\textsubscript{1}A, GI\textsubscript{1}B, GI\textsubscript{2}B whereas, GI\textsubscript{1}A, GI\textsubscript{1}B showed low yeast and mold counts. This might be attributed to low a\textsubscript{w} and synergistic effect of gamma-irradiation and osmotic dehydration.

Vibhakara et al., (2007) suggested combination of low dose irradiation with other hurdles such as acidification.

**FIG 4:** Effect of gamma irradiation and osmotic dehydration on Polyphenols content (mg/100g) of guava slices
and regulation of water activity for effective control over microbiological profiles of foods. Similar trend in the present study was observed in combination treated guava slices. The osmotic treatments influenced the total microbial count, but the impact of both the treatments increased the microbial resistance of sample to a great extent.

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