The Effectiveness of Calcium Citrate for Improving the Quality and Extending the Shelf-Life of Winter Guava Fruits during Ambient Storage

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ABSTRACT

High profits can be achieved by using safe natural compounds to keep the quality of fresh fruit during storage, increase their suitability in the market, as well as generate chances for export to remote markets. Therefore, this experiment was conducted in 2021 & 2022 seasons to evaluate the efficacy of Calcium citrate in enhancing quality and prolonging shelf-life of winter guava. Fruits were harvested at maturity stage (yellowish-green), and dipped in different concentrations of calcium citrate solution at 0.5, 1 and 1.5%, in addition to control treatment (water only) for 5 minutes. Thereafter, the soaked fruits were stored under ambient conditions at 20±1°C and 70 ±5% RH for a duration of 15 days. The obtained results revealed that weight loss and decay of guava fruit were notably reduced by the use of calcium citrate compared to control. Also, fruit soaked in calcium citrate at 0.5, 1 and 1.5% maintained their desirable physical and chemical quality when stored under ambient conditions. Specifically, using calcium citrate at 1.5% proved to be exceptionally effective in reducing weight loss, decay and delayed the decline in acidity, vitamin C, SSC% and SSC/acid ratio of winter guava fruits. Consequently, this treatment demonstrated superior findings such as extending the shelf life of guava fruit and preserving their post-harvest quality.

Keywords: firmness, loss, decay, storage

INTRODUCTION

Guava (Psidium guajava L.), trees tolerate adverse environmental conditions and grow well in different soil types. So, it has widespread cultivation in many areas and it has gained high commercial importance in Egypt (Khalil et al., 2015 and Arafat et al., 2020). Guava fruit is rich in nutrient content, boasting significant amounts of vitamin “C”, pectin and minerals like calcium, phosphorus and iron (Vijaya et al., 2020). Usually, guava fruit is eaten fresh, but it has very good potential processing such guava jelly and extracted juice (Yousaf et al., 2021). Under Egyptian conditions, guava tree flower in mid-April and the principal yield appears in markets in summer. However, this yield is low in price, quality and has a very short marketability as the fruits are exposed to high heat and direct solar radiation, which causes browning, rot and short shelf life (El-Baz et al., 2011 and Atawia et al., 2017). Therefore, farmers using some agriculture practices to obtained winter crop, by prevent partially of irrigation for four months, and in this case the crop is given in January and February (El-Shobaky 2007 & Amin and Saafan 2016). The importance of winter guava is due to the fact that most of the production is exported abroad, so there is need to some postharvest application for keeping overall quality and extension shelf life.

Calcium compounds are used for achieving this purpose since, numerous studies have shown the major role of postharvest calcium application in maintaining overall quality and extending the shelf life of guava fruit under storage conditions. (Deepthi et al., 2016, Mahitha et al., 2018, Alba-Jimenez et al., 2018, Bhooriya et al., 2018, Sonkar et al., 2019 and Kaur et al., 2019). In this line, Fekry (2018) revealed that post-harvest calcium treatments improved the calcium content in the cell wall, slowed down fruit aging, kept fruit stability, and the quality of winter guava fruits appeared high. In addition, Nasima et al. (2019) reported that postharvest application of 1 and 2% CaCl₂ & Ca(NO₃)₂ were the best treatments for enhancing fruit quality and prolonging the shelf life of winter guava fruits.

Calcium citrate is considered a safe coating for improving fruit quality, prevents the growth and activity of bacteria and fungi in fruits. It also stimulates the improvement of disease resistance in fruits (Troyo and Acedo Jr 2019). El-Bana and Ennab (2023) revealed that, mandarin fruits dipped in 0.5% calcium citrate had the lowest activities of β-galactosidase, pectin methylesterase, polygalacturonase enzymes. Additionally, the fruits maintained significantly higher fruit firmness during storage 4±1°C for 45 days. This finding is confirmed with the study conducted by Yang et al. (2019), which demonstrated that peach fruits dipped in 10 ppm citric acid were significantly reduced rot and maintaining overall quality under storage at 20 ± 0.5°C with 85 ± 95 % RH for 15 days, Alali et al. (2023) cleared that immersing peach fruit in 0, 1, 2, 3 mM citric acid resulted in improved characteristics such as firmness, titratable acid ascorbic acid content. Furthermore, this treatment reduced weight loss and decay, while extending the storage life under cold storage.

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It is important to note that this study highlight the potential benefits of using postharvest treatments with calcium citrate for improving quality and extending shelf-life winter guava fruits stored at room temperature

MATERIALS AND METHODS

Two experiment was conducted on fruits collected from 14-year-old common guava trees in an exclusive farm at El-Bocelli village, Rashied, El-Bohaira governorate, Egypt. The trees were cultivated with a spacing of 5 × 5m in clay soil under drip irrigation system. In this farm, guava trees were subjected to water stress to induce fruit production during the winter season. Irrigation was withheld for four months after harvest, starting from August until the end of July. Full irrigation went out in August, resulting in fruit production in January and February. Harvesting took place on February 12th and 7th in 2021 and 2022 at maturity stage, when and fruit peel was exhibited a yellowish-green as described by Yusof et al. (1988). Immediately after harvest, the fruits were directly brought to laboratory. Uniform, medium-sized fruits without any damage were selected for the experiment. Fruits were categorized into four groups and immersing in aqueous solutions of calcium citrate at concentrations of 0.5, 1 and 1.5% in addition to control (water only) for 5 minutes. A total of 144 kg of fruits were placed in carton boxes, each box containing 3kg of guava fruits, each treatment consists of 12 boxes represent 36 kg. Subsequently, the fruits were placed in an open environment within laboratory. The treatments were arranged in completely randomized block design with three replicates. Evaluations and measurements were conducted at 5 days intervals during storage under ambient conditions for 15 days at 20 ± 1°C and 70 ± 5%. The weight loss of the fruits was calculated by dividing the weight lost in grams by the initial weight and expressed as a percentage. Decay was determined by examining visible signs of fungal growth or rotting, and the results were expressed as percentages. The fruit firmness was examined using a pressure tester and expressed as Newton. The soluble solid content (SSC) of guava fruit during storage was measured using hand refractometer, titratable acidity was determined through titration method (AOAC, 1990), and SSC/acid ratio was estimated. The vitamin C content of guava was determined using 2,6-dichlorophenol indophenol according to Rangana (1977).

The data collected during the experiment under went to statistical analysis using SAS software and the significance of differences between means was determined using LSD at p ≤ 0.05 following the method described by Snedecor and Cochran (1990).

The changes in weight loss of guava fruits dipped in calcium citrate at 05, 1 and 1.5%, and stored under ambient conditions (20±1°C with 70±5 % RH) for 15 days as shown in Figure 1. The findings showed that the weight loss increased as the storage period advanced. Additionally, guava fruits immersed in calcium citrate at 0.5, 1 and 1.5% had the lowest weight loss compared to control ones. These findings confirmed with Goutam et al. (2010) and Sonkar et al. (2019) on guavas. Moreover, calcium citrate at concentration of 1.5% exhibited a more pronounced impact in decreasing loss of weight as comparison with their low concentrations. These findings are in accordance with Kaur et al., (2019), who reported that the loss of guava fruits weight was significantly reduced using calcium nitrate at 2%. Also, Bhooiya et al., (2019) reported that the calcium nitrate at 1% and calcium chloride 2% as individual postharvest treatments caused an increase in firmness and reduction in loss of guava fruits weight under storage at room temperature for 12 days.

Fig. 1. Effect of different calcium citrate concentrations on fruit weight loss (%) of winter guava fruits during ambient storage.

Decay %:

It is obvious from data in Table 1 that winter guava fruits dipped in calcium citrate at concentrations of 0.5, 1, 1.5% showed no signs of decayed fruit throughout storage time under ambient conditions, unlike the untreated fruits. However, decay in the control group was observed from the beginning of the storage period and increased over time. These findings are in accordance with the study conducted by Vani et al., (2020), where they concluded that post-harvest treatment of calcium salts like CaCl₂, CaSO₄, Ca (NO₃)₂ each at 1 and 2% reduced in fruit decay during storage. Similarly, Azam et al. (2021) concluded that a 4% calcium nitrate treatment significantly reduced fruit weight losses and decay during ambient storage at 25±3°C for 12 days.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Stored at room temperature 20±1°C with 70±5 % RH</th>
<th>0</th>
<th>5</th>
<th>10</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>2.79 ± 0.041</td>
<td>5.75 ± 0.086</td>
<td>8.89 ± 0.195</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calcium citrate 0.5</td>
<td>0.00 ± 0.00</td>
<td>0.00 ± 0.00</td>
<td>0.00 ± 0.00</td>
<td>0.00 ± 0.00</td>
<td></td>
</tr>
<tr>
<td>Calcium citrate 1%</td>
<td>0.00 ± 0.00</td>
<td>0.00 ± 0.00</td>
<td>0.00 ± 0.00</td>
<td>0.00 ± 0.00</td>
<td></td>
</tr>
<tr>
<td>Calcium citrate 1.5%</td>
<td>0.00 ± 0.00</td>
<td>0.00 ± 0.00</td>
<td>0.00 ± 0.00</td>
<td>0.00 ± 0.00</td>
<td></td>
</tr>
<tr>
<td>LSD (p≤5%)</td>
<td>0.10</td>
<td>0.08</td>
<td>0.06</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Mean value ± standard error, mean values within column have the same letters are not significant according to LSD at p ≤ 5

RESULTS AND DISCUSSION

Weight loss %:

Data collected during the experiment under went to statistical analysis using SAS software and the significance of differences between means was determined using LSD at p ≤ 0.05 following the method described by Snedecor and Cochran (1990).

The data collected during the experiment under went to statistical analysis using SAS software and the significance of differences between means was determined using LSD at p ≤ 0.05 following the method described by Snedecor and Cochran (1990).
In generally, the application of calcium citrate at 0.5, 1, 1.5% gave the best results in reducing decayed fruits under storage conditions. This result may be attributed to the induction of antioxidant enzyme activity, which enhances resistance against fungal attack in treated fruits (Abd El-Moneim et al., 2015). Also, calcium citrate reduced the respiration rate and ethylene production, enzymatic browning and softening and weight losses, which reflected in minimum decayed fruits (Troyo and Acedo Jr, 2019; Yang et al., 2019 and Alali et al., 2023). Moreover, calcium compounds significantly reduced fruit decay by thickening the middle lamellae of fruit cells with higher accumulation of calcium pectate than that in untreated ones. In addition, the increase in guava fruit firmness was directly proportional to the concentration of calcium citrate. In this respect, the highest firmness was found in fruit dipped in calcium citrate at 1.5%, while the lowest firmness was observed in the control. Similar findings have been reported by Rajput et al. (2008), Goutam et al., (2010) and Javed, (2015). In this respect, Mohamed and Abd El-Khalek (2018) found that an increase in firmness of winter guava fruits dipped in calcium chloride at 2-4% under storage at 8±1°C for 21 days. Also, Riaz et al., (2020) found that orange fruits immersed in 1, 1.5 and 2% calcium chloride and calcium lactate, showed an increase in fruit firmness during storage for 35 days as compared with those immersed in distilled water (control). So, it’s clear that post-harvest treatments of calcium citrate increase fruit firmness, and these results can be attributed to the role of calcium in stabilizing the cellular membrane (Abrol et al., 2017 and Alba-Jimenez et al., 2018). Calcium helps in the formation of calcium pectate, which accumulates in cell wall, thus increasing fruit rigidity (Aghdam et al., 2012). Moreover, calcium regulates the activity of enzymes that cause softening (Gill, 2018). Therefore, it can be concluded that there is a positive correlation between calcium application and fruit firmness, and this increase was much pronounced in treatment of calcium citrate 1.5% as compared with the other treatments. These findings are supported by Mahitha et al. (2018) and Ennab et al. (2020).

**Fruit firmness (Newton)**

With regard to the effect on fruit firmness, data in Table 2 demonstrate that, using different concentrations of calcium citrate treatments significantly enhanced fruit firmness compared to the control. However, fruit firmness decreased as the storage period progressed. In addition, the increase in guava fruit firmness was directly proportional to the concentration of calcium citrate. In this respect, the highest firmness was found in fruit dipped in calcium citrate at 1.5%, while the lowest firmness was observed in the control. Similar findings have been reported by Rajput et al. (2008), Goutam et al., (2010) and Javed, (2015). In this respect, Mohamed and Abd El-Khalek (2018) found that an increase in firmness of winter guava fruits dipped in calcium chloride at 2-4% under storage at 8±1°C for 21 days. Also, Riaz et al., (2020) found that orange fruits immersed in 1, 1.5 and 2% calcium chloride and calcium lactate, showed an increase in fruit firmness during storage for 35 days as compared with those immersed in distilled water (control). So, it’s clear that post-harvest treatments of calcium citrate increase fruit firmness, and these results can be attributed to the role of calcium in stabilizing the cellular membrane (Abrol et al., 2017 and Alba-Jimenez et al., 2018). Calcium helps in the formation of calcium pectate, which accumulates in cell wall, thus increasing fruit rigidity (Aghdam et al., 2012). Moreover, calcium regulates the activity of enzymes that cause softening (Gill, 2018). Therefore, it can be concluded that there is a positive correlation between calcium application and fruit firmness, and this increase was much pronounced in treatment of calcium citrate 1.5% as compared with the other treatments. These findings are supported by Mahitha et al. (2018) and Ennab et al. (2020).

**Table 2. Effect of different calcium citrate concentrations on fruit firmness (Newton) of winter guava fruits during ambient storage (average of the two seasons).**

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Stored at room temperature 20±1°C with 70±5% RH</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Control</td>
<td>7.29 ± 0.103</td>
</tr>
<tr>
<td>Calcium citrate 0.5</td>
<td>7.29 ± 0.103</td>
</tr>
<tr>
<td>Calcium citrate 1%</td>
<td>7.29 ± 0.103</td>
</tr>
<tr>
<td>Calcium citrate 1.5%</td>
<td>7.29 ± 0.103</td>
</tr>
<tr>
<td>LSD (p≤ 5%)</td>
<td>ns</td>
</tr>
</tbody>
</table>

Mean value ± stander error, mean values within column have the same letters are not significant according to LSD at p≤ 5%.

**Soluble solids content (SSC):**

Concerning the effect on fruit soluble solids content (SSC), the data in Figure 2 illustrated that SSC% in winter guava fruits significantly decreased with increasing storage period. Also, fruits treated with the different concentrations of calcium citrate exhibited lower soluble solid content than that of untreated ones. In addition, fruit dipped in 1.5% calcium citrate had the lowest SSC%, whereas fruit immersing in water only had the high soluble solids content (Figure 2). These findings are confirmed with the observations made by Bhoooriya et al., (2018), who noted that the minimum TSS% was found in fruits soaked in 1% Ca(NO₃)₂ and the maximum TSS% was detected in guava fruits dipped in water during storage. Also, Tabasum et al. (2019) reported that guava fruits soaked in CaCl₂ had a lower soluble solid content as compared to the control. In this respect, Kaur et al., (2019) indicated that, guava fruits soaked in 1% Ca(NO₃)₂ and 2% CaCl₂ had lower TSS% compared to the control under ambient storage conditions. The decrease in SSC% during storage can be attributed to a reduction in respiration rate, metabolic activity (Tokala and Mahajan, 2018 & Alba-Jimenez et al., 2018).

**Titratable acidity**

As for the effect on titratable acidity, data in Figure 3 illustrates that titratable acidity values increased up to 5 days and then declined with increasing storage period. Moreover, all calcium citrate concentrations caused an increase in fruit acidity as compared with control. In addition, the maximum values of acidity% were found in fruit immersion in 1.5% calcium citrate, while the lowest content was observed on fruit immersing in water only. Such findings are in agreements with those reported by...
Javed (2015), who used calcium chloride and calcium lactate at 2% as postharvest application on guava fruit, resulting in increased fruit acidity during storage. In this line, Bhooriya et al. (2018) revealed that the highest values of acidity were found in guava fruit dipped in 1% calcium nitrate compared with fruit dipped in 1% calcium chloride and in distilled water. The increase in titratable acidity observed in fruits dipped in different calcium citrate concentrations may be due to the lower activities of enzymes involved in respiration such as carboxylase and dehydrogenase. The increase in titratable acidity in fruit dipped in different concentrations of calcium citrate, as comparison with control, may be associated with a delayed senescence process. This explanation was conformed with the findings of El-Bana and Ennab (2023).

![Fig. 3. Effect of different calcium citrate concentrations on fruit acidity (%) of winter guava fruits during ambient storage (average of the two seasons).](image)

**SSC/acid ratio:**

The results in Figure 4 revealed that, SSC/acid ratio at harvest date was higher than that on the other samples dates during storage, thereafter up to 5 days SSC/acid ratio was increased with increasing storage period. Also, fruit treated with distilled water had higher values of SSC/acid ratio than those treated with all concentrations of calcium citrate. It seemed that post-harvest application of Ca-citrate reduced SSC/acid ratio during storage at ambient conditions. In this line, Fekry (2018) showed that calcium gluconate at 2% decreased SSC/acid ratio values in guava fruits during storage. Also, El-Dengawy et al., (2019) cleared that calcium chloride at 2% reduced total soluble solids/acid ratio of peach under storage. In this line, Ennab et al., (2020) revealed that application of 2 % CaCl$_2$ showed the lowest SSC/acid ratio of apricot under cold storage. The SSC/acid ratio is the most important parameter in evaluating fruit quality, it determines fruit flavor harmony and consumer acceptability (Abrol et al., 2017).

![Fig. 4. Effect of different calcium citrate concentrations on fruit SSC/acid ratio of winter guava fruits during ambient storage (average of the two seasons).](image)

**Table 3. Effect of different calcium citrate concentrations on fruit ascorbic acid mg/100g fresh weight of winter guava fruits during ambient storage (average of the two seasons).**

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Stored at room temperature 20±1°C with 70±5% RH</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Control</td>
<td>74.41 ± 0.832</td>
</tr>
<tr>
<td>Calcium citrate 0.5</td>
<td>74.41 ± 0.832</td>
</tr>
<tr>
<td>Calcium citrate 1%</td>
<td>74.41 ± 0.832</td>
</tr>
<tr>
<td>Calcium citrate 1.5%</td>
<td>74.41 ± 0.832</td>
</tr>
<tr>
<td>LSD (p≤5%)</td>
<td>ns</td>
</tr>
</tbody>
</table>

Mean value ± standard error, mean values within column have the same letters are not significant according to LSD. at p≤5%.

**CONCLUSION**

The immersion of guava fruits in 0.5, 1 and 1.5% calcium citrate solutions has proven to be effective in reducing weight loss, decay and maintaining fruit stability and juice chemical quality during storage at room temperature 20±1°C. Therefore, it is clear that the use of 1.5% calcium citrate extend the shelf life and maintaining fruit quality of winter guava.

**REFERENCES**


Yang, C.; T. Chen; B. Shen; S. Sun; H. Song; D. Chen and W. Xi (2019). Citric acid treatment reduces decay and maintains the postharvest quality of peach (Prunus persica L.) fruit Food Sci Nutr., 7:3635 – 3643.


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