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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 Ca-citrate to 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 and1.5% 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.

Kaywords: 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% $CaCl_2$ & $Ca(NO_3)_2$ 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 acidy 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 was then carried 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 $p \leq 0.05$ following the method described by Snedecor and Cochran (1990).

RESULTS AND DISCUSSION

Weight loss %:

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, Bhooriya *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.

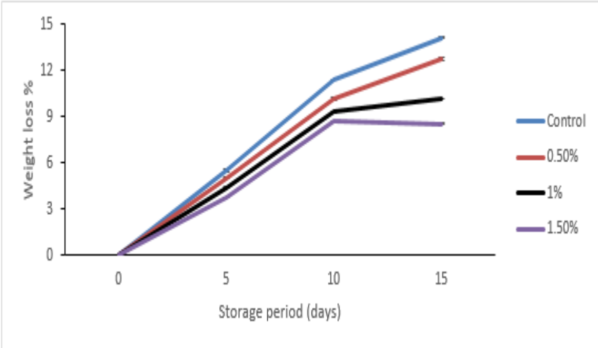

Fig. 1. Effect of different calcium citrate concentrations on fruit weight loss (%) of winter guava fruits during ambient storage.

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 $CaCl_2$, $CaSO_4$, Ca $(NO_3)_2$ each at 1and 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 1. Effect of different calcium citrate concentrations on fruit decay (%) of winter guava fruits during ambient storage (average of the two seasons).

Treatments	Stored at room temperature 20±1°C with 70±5% RH			
	0	5	10	15
Control	0.00 a ± 0.00	2.79 a ± 0.041	5.75 a ± 0.056	8.89 a ± 0.195
Calcium citrate 0.5	0.00 a ± 0.00	0.00 b ± 0.00	0.00 b ± 0.00	0.00 b ± 0.00
Calcium citrate 1%	0.00 a ± 0.00	0.00 b ± 0.00	0.00 b ± 0.00	0.00 b ± 0.00
Calcium citrate 1.5%	0.00 a ± 0.00	0.00 b ± 0.00	0.00 b ± 0.00	0.00 b ± 0.00
LSD ($p \leq 5\%$)	ns	0.10	0.08	0.06

Mean value ± stander error, mean values within column have the same letters are not significant according to LSD at $p \leq 5$

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 thus retaining the cell wall structure, enhancing rigidity, slowing down the respiration rate, delaying the ripening process (Alba Jimenez *et al.*, 2018).

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 distill 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).

Treatments	Stored at room temperature 20±1°C with 70±5% RH			
	0	5	10	15
Control	7.29 a ± 0.103	4.92 b ± 0.134	4.47 c ± 0.067	2.85 c ± 0.026
Calcium citrate 0.5	7.29 a ± 0.103	5.56 b ± 0.079	5.77 b ± 0.122	4.09 b ± 0.054
Calcium citrate 1%	7.29 a ± 0.103	6.71 a ± 0.118	6.09 ab ±0.087	4.34 ab ± 0.040
Calcium citrate 1.5%	7.29 a ± 0.103	7.14 a ± 0.100	6.51 a ± 0.028	4.83 a ± 0.038
LSD ($p \leq 5\%$)	ns	0.90	0.50	0.59

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

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 on 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 Bhooriya *et al.*, (2018), who noted that the minimum TSS% was found in fruits soaked in 1% $Ca(NO_3)_2$ 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 $CaCl_2$ 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% $Ca(NO_3)_2$ and 2% $CaCl_2$ 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).

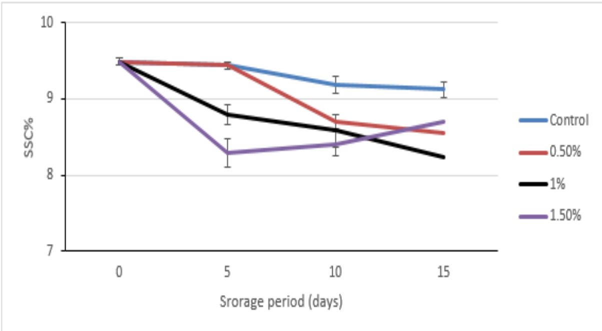

Fig. 2. Effect of different calcium citrate concentrations on fruit SSC (%) of winter guava fruits during ambient storage (average of the two seasons).

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 comparison 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).

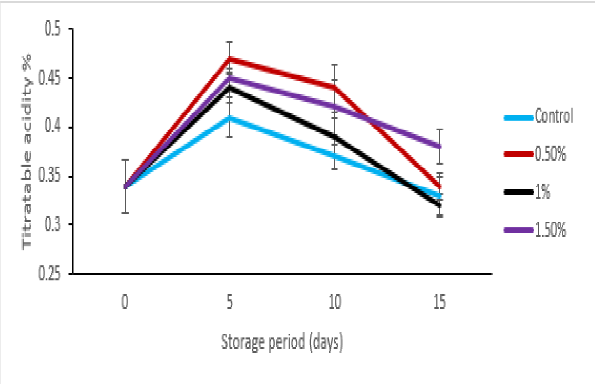

Fig. 3. Effect of different calcium citrate concentrations on fruit acidity (%) of winter guava fruits during ambient storage (average of the two seasons).

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).

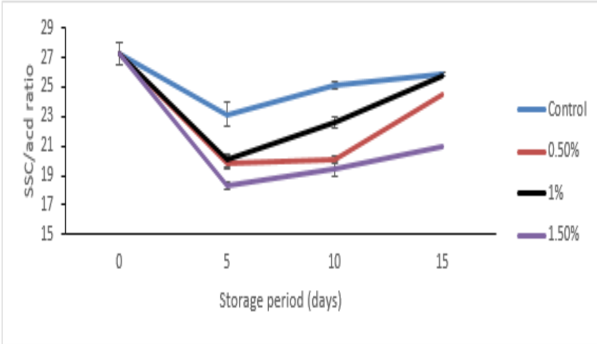

Fig. 4. Effect of different calcium citrate concentrations on fruit SSC/acid ratio of winter guava fruits during ambient storage (average of the two seasons).

Vitamin C:

Guava fruit content of vitamin C was reduced as the storage period advanced (Table 3). The maximum values of vitamin C were observed in the beginning of storage time compared to the end ones. These findings are confirmed with Mohamed and Abd El-Khalek (2009) concluded that the vitamin C content in guava fruit was decreased under storage at room temperature. Also, data in Table 3 demonstrated that guava fruits dipped in different concentrations of calcium citrate maintained high values of vitamin C as comparison with fruit dipped in water (control) duration storage. Mahitha *et al.*, (2018) showed that $CaCl_2$ and $Ca(NO_3)_2$ at 2% caused a significant impact on maintaining vitamin C content in guava fruits through storage time. Moreover, calcium citrate is at 1.5% found to be more effective in keeping vitamin C in winter guava fruits under ambient storage at 20±1°C with 70 ± 5 % RH for 15 days.

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).

Treatments	Stored at room temperature 20±1°C with 70±5% RH			
	0	5	10	15
Control	74.41 a ± 0.832	66.21 b ± 0.402	60.19 b ± 0.659	57.94 a ± 0.481
Calcium citrate 0.5	74.41 a ± 0.832	68.76 ab ± 0.201	64.73 ab ± 0.335	59.00 a ± 0.756
Calcium citrate 1%	74.41 a ± 0.832	69.69 a ± 0.353	66.35 a ± 0.745	60.31 a ± 0.307
Calcium citrate 1.5%	74.41 a ± 0.832	70.75 a ± 0.836	66.73 a ± 0.335	62.19 a ± 0.217
LSD ($p \leq 5\%$)	ns	2.80	5.70	6.90

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

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.

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فعالية سترات الكالسيوم فى تحسين جودة و إطالة عمر ثمار الجوافة الشتوى أثناء التخزين فى جو الغرفة

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الملخص

يمكن تحقيق أرباح عالية من خلال استخدام مركبات طبيعية آمنة للحفاظ على جودة الثمار الطازجة أثناء التخزين وزيادة صلاحية الثمار للأسواق، فضلا عن خلق فرص للتصدير إلى الأسواق البعيدة. لذلك تم تنفيذ هذه التجربة خلال موسمي 2021 و 2022 لتقييم فعالية سترات الكالسيوم لتحسين الجودة وإطالة العمر الافتراضي للجوافة الشتوية. تم جمع الثمار فى مرحلة النضج (أخضر مصفر)، تم نقلها الى المعمل و اعدادها للنقع في عدة تركيزات مختلفة من محلول سترات الكالسيوم بنسب 0.5، 1، 1.5%. بالإضافة إلى معاملة الكنترول (الماء فقط) لمدة 5 دقائق. بعد ذلك، تم حفظ الثمار المنقوعة في درجة حرارة الغرفة درجة حرارة 20 ± 1 درجة مئوية ورطوبة نسبية 70 ± 5٪ لمدة 15 يومًا. أظهرت النتائج المتحصل عليها أن فقدان الوزن والتدهور في ثمار الجوافة انخفض بشكل ملحوظ عند استخدام سترات الكالسيوم مقارنة بالكنترول. كما أن ثمار الجوافة المعاملة بتركيزات مختلفة من سترات الكالسيوم حافظت على جودتها الطبيعية والكيميائية المرغوبة عند تخزينها في درجة حرارة الغرفة. وعلى وجه التحديد، أثبتت معاملة ما بعد الحصاد باستخدام سترات الكالسيوم بنسبة 1.5% فعاليتها بشكل استثنائي في تقليل فقدان الوزن والتدهور وتأخير انخفاض الحموضة وفيتامين C وSSC% ونسبة SSC/الحموضة لثمار الجوافة الشتوية. وبالتالي أظهرت هذه المعاملة نتائج متفوقة من حيث إطالة العمر الافتراضي لثمار الجوافة والحفاظ على جودتها بعد الحصاد عن طريق تأخير عمليات النضج والشيخوخة.