Improving quality and prolonging shelf life of "Washington Navel" orange and guava (Psidium guajava L.) fruits by organic and inorganic compounds and plant extracts

تحسين الجودة و اطالة فترة الصلاحية لثمار البرتقال أبوسره و الجوافة بواسطة المركبات العضوية وغير العضوية والمستخلصات النباتية

By

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Abstract

The study was carried out during 2019-2020 and 2020-2021 seasons at Badaway, Al-Dakahlia Governorate, Egypt, using 20-year-old trees in commercial orange and guava orchards in which standard horticultural practices of commercial production were being carried out. The orange cultivar grown was "Washington navel orange" (*C. sinensis*) budded on sour orange (*C. aurantium*) rootstocks, with tree planting spaced at 5 x 5 m. For the guava (*P. guajava*) experiment, the cultivar "cv. Maamoura" This study was conducted during two seasons in 2019 and 2021 in Badaway, Al-Dakahlia Governorate, Egypt, to investigate the influence of some pre and post-harvest treatments on yield parameters, quality and self life of Washington Navel Orange and guava "cv. Maamoura." The experiment was laid out in Factorial Randomized Block Design with three replications. Among four different pre-harvest treatments, the treatment which comprised of 1.5% calcium chloride has recorded the highest fruit weight (332.93 and 168.19 g), yield (100.77 and 81.65 kg/tree), fruit firmness (25.10 and 11.77 kg/cm^2),TSS percentages (16.10 and 14.13 %), titratable acidity% (1.19 and 0.٦٣ %), ascorbic acid content (Vitamin C) (61.99 and 197.51 mg/100 ml juice) and total sugars percentage (11.55 and 10.55 %) of Washington navel orange and guava when compared to the control, respectively. The best performed trees which have received the treatment of calcium chloride at 1.5% were taken for postharvest treatment study with six treatments [Distilled water (control), Citric acid at 1%, Rosemary oil 4 %, Coconut oil 4 %, Moringa oil at 4 % and Peppermint oil 4 %]. It was found

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that the combined effect of the pre-harvest treatment with 1.5% calcium chloride with post harvest treatment of Moringa oil at 4% has increased the firmness (20.11 and 9.66 kg/cm^2), ascorbic acid content (68.31 and 200.55 mg /100 ml juice) and shelf life (35.33 and 10.20 days) and decreased physiological loss in weight (3.23 and 8.22 %), TSS (16.70 and 10.22 %), acidity (0.98 and 0.58 %), reducing sugar (4.07 and 5.17 %) and peroxidase activity (38 and 115 mg protein/min) of Washington navel orange and guava fruits stored under room temperature, respectively.

Keywords: Calcium chloride, Pre-harvest, Post-harvest Moringa oil, Washington navel orange and guava, self life, quality.

المستخلص:

أجريت هذه الدراسة خلال موسمين (٢٠١٩ و٢٠٢١) في بدواى، محافظة الدقهلية، مصر، لدراسة تأثير بعض معاملات ما قبل و بعد الحصاد على معايير المحصول والجودة ومدة الصلاحية لثمار البرتقال "واشنطن سرة" (*C. sinensis*) المزروعة على أصول البرتقال الحامض (*C. aurantium*) والجوافة (*P. guajava*) "صنف المعمورة". وقد أجريت التجربة بتصميم القطاعات التامة العشوائية العاملية بثلاثة مكررات. من بين الأربع معاملات ما قبل الحصاد، سجلت المعاملة التى تم فيها رش كلوريد الكالسيوم بتركيز ١.٥٪ أعلى وزن للفاكهة (١٦٨.١٩ و ٣٣٢.٩٣ جم)، والمحصول (٨١.٦٥ و ١٠٠.٧٧ كجم / شجرة)، وصلابة الثمار (١١.٧٧ و ٢٥.١٠ كجم/ سم ٢)، ونسبة المواد الصلبة الذائبة الكلية (١٤.١٣ و ١٦.١٠ ٪)، و نسبة الحموضة (٠.٦٣ و ١.١٩ ٪)، ومحتوى حمض الأسكوربيك (فيتامين ج) (١٩٧.٥١ و٦١.٩٩ مجم / ١٠٠ مل عصير) ، ونسبة السكريات الكلية (١٠.٥٥ و ١١.٥٥٪) فى برتقال سرة واشنطن والجوافة عند مقارنتها بالكنترول، على التوالي. تم أخذ ثمار من أفضل المعاملات (كلوريد الكالسيوم بنسبة ١.٥٪) لدراسة معاملات ما بعد الحصاد بستة معاملات (حامض الستريك بتركيز ١٪، زيت إكليل الجبل بتركيز ٤٪، زيت جوز الهند بتركيز ٤٪، زيت المورينجا (*M. oleifera*) بتركيز ٤٪ وزيت النعناع بتركيز ٤٪ والكنترول). وقد وجد أن التأثير المشترك لمعاملة ما قبل الحصاد بكلوريد الكالسيوم ١.٥% مع معاملة ما بعد الحصاد بمحلول زيت المورينجا بتركيز ٤% أدى إلى زيادة الصلابة (٩.٦٦ و ٢٠.١١ كجم/سم٢)، ومحتوى حمض الأسكوربيك (٢٠٠.٥٥ و٦٨.٣١

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مجم/ ١٠٠ مل عصير)، ومدة الصلاحية (١٠.٢٠ و ٣٥.٣٣ يومًا) وانخفاض الفقد الفسيولوجي في الوزن (٨.٢٢ و ٣.٢٣ ٪)، والمواد الصلبة الذائبة الكلية (١٠.٢٢ و ١٦.٧٠ ٪)، والحموضة (٠.٥٨ و ٠.٩٨ ٪) والسكر المختزل (٥.١٧ و ٤.٠٧ ٪) ونشاط انزيم البيروكسيديز (١١٥ و ٣٨ مجم بروتين / دقيقة) لثمار البرتقال ابوسرة واشنطن والجوافة المخزنة في درجة حرارة الغرفة، على التوالي.

الكلمات المفتاحية: كلوريد الكالسيوم، معاملات ما قبل الحصاد، معاملات ما بعد الحصاد، زيت المورينجا، برتقال ابوسرة واشنطن، الجوافة، فترة الصلاحية، الجودة.

Introduction

Egypt produces over 14 million tonnes of fruits accounting for about 1.53% of the world's production (FAOSTAT, 2022). Guava (*Psidium guajava* L.) is the eighth most important fruit crop which occupying 2.56 % of the total area under fruit cultivation and 3.08% of total fruit production (Ministry of Agriculture and Land Reclamation, Economic Affairs Sector, 2022). Washington navel orange (*Citrus sinensis* L. Osbeck) is the main cultivated variety of orange. The cultivated areas of Washington navel orange reached about 161.631 Fedden, representing about 46.8% of orange cultivated areas, producing about 1.6 million tons in 2022 (Ministry of Agriculture and Land Reclamation, Economic Affairs Sector, 2022). Fruit quality attributes and post-harvest shelf life are extremely important in Washington navel orange and guava industry, particularly when fruits are shipped for domestic and export markets (Silva *et al.*, 2021).

Fruit quality attributes and post-harvest shelf life are extremely important in Washington navel orange and guava industry, particularly when fruits are shipped for domestic and export markets. There are several possible treatments (both pre and post-harvest factors) used to improve postharvest quality and prolong shelf life of picked fruits including calcium chloride

(Gao *et al.,* 2019; Abbasi *et al.,* 2020) and moringa-oil-based coating (Silva *et al.,* 2021).

Pre-harvest calcium sprays are becoming part to new strategies within integrated fruit production systems, as it improves yield, quality attributes and extends the shelf life of many fruits (Karemera and Habimana, 2014; Gao, *et al.,* 2019 and Abbasi *et al.,* 2020). Pre-harvest calcium applications are generally reported to delay ripening as indicated by respiration rates or ethylene production, decrease the incidence of postharvest decay and alterations (Manganaris *et al.,* 2005 and Ghorbani et *al.,* 2021). Previous studies by Singh *et al.,* 2017; Irfan *et al.,* 2020; Lobos *et al.,* 2021 and Ghorbani *et al.,* 2021 have demonstrated the positive effect of pre-harvest calcium treatments on yield, fruit quality and postharvest shelf life. Irfan *et al.* (2020) reported that treatment of $CaCl_2$ at 1 % improved the yield and physico-chemical parameters of apple (*Malus domestica* Borkh.) fruits. Barwal *et al.* (2015) found that pre-harvest spray with $CaCl_2$ at 1% was the most effective in enhancing the fruit characteristics (soluble solids (TSS) and firmness) and the shelf life of apple. Moreover, Taduri *et al.* (2017) found that treatment of $CaCl_2$ at 1.5 % improved the physico-chemical parameters, organoleptic properties and extended the shelf life by 20.8 days on mango (*Mangifera indica* L.) cv. Amrapali fruits. The role of many essential oils in maintaining quality and extending the shelf-life of several fruit crops has been approved (Sivakumar and Bautista-Baños, 2014).

Moringa oil (*Moringa oleifera* L.) coatings have recently emerged as an innovative, effective, and sustainable technique for enhancing quality and shelf life of fruits during storage (Kubheka *et al.,* 2020). It helps to prolong the shelf life of fruits by providing a semi-permeable barrier to gases and water vapor and therefore, and it can reduce respiration, enzymatic browning

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and water loss (Lima *et al.,* 2018). The application of moringa-oil-based coating prolonged the postharvest shelf life of mango cv Tommy atkins by maintaining the physicochemical and physical properties during 12 days of storage at room temperature (Silva *et al.,* 2021). Abd El-Razek *et al.* (2019) revealed that coating mango cv. Zebda fruits with moringa leaves extract 10% led to reduce fruit weight loss%, fruit decay %, total acidity %, lipid peroxidation and increased TSS, TSS/acid ratio, vitamin C, antioxidant activity %, PAL enzyme and total phenols. Tesfay and Magwaza (2017), who demonstrated that the application of moringa leaf extracts coating significantly reduced respiration, retained firmness and delayed ripening in 'Fuerte' and 'Hass' avocados. Therefore, the objective of this study was to assess the effect of some pre and postharvest treatments on quality and shelf life of Washington Navel orange and *P. guajava*.

Material and methods

The study was carried out during 2019-2020 and 2020-2021 seasons at Badaway, Al-Dakahlia Governorate, Egypt (Latitude: 31.05˚ N, Longitude: 31.38˚ E and 2.89 m altitude above sea level), using 20-year-old trees in commercial orange and guava orchards in which standard horticultural practices of commercial production were being carried out. The orange cultivar grown was "Washington navel orange" (*C. sinensis*) budded on sour orange (*Citrus aurantium* L.) rootstocks, with tree planting spaced at 5 x 5 m. For the guava (*P. guajava*) experiment, the cultivar "cv. Maamoura" was used, the trees being spaced at 4 × 4 m. In both cases, trees grown in clay-loam soil under a surface irrigation system received common horticultural practices recommended by the Egyptian Ministry of Agriculture and land reclamation. The physicochemical properties of the soil at the experimental site are described in Table 1.

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Table 1. Physiochemical characteristics of the soil at the experimental site (Page *et al.*, 1984; Arnold and Page,1986).

Properties	Washington navel orchard	Guava orchard
Sand %	27.64	25.33
Silt %	31.72	33.23
Clay %	40.74	41.44
Texture class	Clay- loam	Clay- loam
pH **	7.8	7.64
E.C. (dS/m)	1.52	1.32
Organic matter %	1.091	1.08
CaCO3 %	17.52	16.22
Total N mg/kg soil	99.81	99.73
K^+ mg/kg soil	421.21	422.11
P mg/kg soil	3.36	3.51
Ca^{2+}mg/kg soil	324.13	331.21
Mg^{2+} mg/kg soil	1103.38	1116.43
Zn mg/kg soil	0.99	0.95

Twenty four trees with similar yields, crown sizes, and tree vigor were selected, divided in to four groups and each group was sprayed twice at full bloom and three weeks before harvesting with one of the following concentrations: 0, 1, 1.5 and 2% of calcium chloride ($CaCl_2$).

The studied treatments were as the following:

T1= control (Tap water only)

T2 = $CaCl_2$ at 1 %

T3 = $CaCl_2$ at 1.5 %

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T4 = $CaCl_2$ at 2 %

Fruits were harvested at a commercial maturity stage, and measured, fruit calcium content (Waling *et al.*, 1989), fruit weight (g), number of fruits per tree, yield (kg/tree) and fruit quality attributes (firmness, total soluble solids (TSS), titratable acidity% (Ac), ascorbic acid content (Vitamin C) and total sugar %).

In post-harvest study, fruits of the best performed pre-harvest treatment viz., T٣= $CaCl_2$ at 1.5 % was used for postharvest treatment. Ninety healthy fruits were divided into six groups (15 fruits each), and separately soaked in solutions of distilled water (Control), citric acid at 1%, rosemary oil 4 %, coconut oil 4 %, moringa oil (*M. oleifera*) at 4 % and peppermint oil 4 % for 5 minutes. Afterward, the treated fruits of orange and guava were stored at ambient conditions (27 ± 2°C and 55-65% relative humidity RH) and (23 ± 2°C and 70-80% relative humidity RH), respectively. When the spoilage of fruits under different treatments exceeded 50%, it was considered as the end of storage period. Fruit samples were taken at the beginning and end of the storage period to the following determinations:

Physiological weight loss (%)

The physiological weight loss (%) was calculated according to the following equation (A.O.A.C., 2001):

$$PWL=Wi-Ws/Wi\times100$$

Where, Wi = fruit weight at initial period, Ws = fruit weight at day of observation.

Firmness

Firmness of fruits was determined by using a handheld fruit firmness tester ("Penetrometer" (Model FT 327, QA Supplies, Norfolk, VA, USA), and data were expressed as kg/m^2.

Total soluble solid (TSS)

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TSS (%) was determined by using a Hand Refractometer (0-32°Brix) at a temperature correction 20 °C (Chawla *et al.,* 2018).

Titratable acidity (TA)

The titratable acidity% in fruit juice was determined by titrating with 0.01N NaOH in the presence of phenolphthalein as an indicator (El-Sisy, 2013). The obtained data were expressed as citric acid %.

Ascorbic acid content (vitamin C)

Ascorbic acid content was determined in fruit juice according to El-Sisy (2013) by the oxidation of ascorbic with 2, 6 dichlorophenol endophenol dye and the results were expressed as mg ascorbic acid per 100 mL juice.

Reducing sugars %

Reducing sugars percentage was determined using phenol-sulfuric acid method and the 3, 5-dinitrosalicylic acid (DNS) method, respectively (Lam *et al.,* 2021).The results were expressed as a percentage (%).

Peroxidase (POX) U/mg protein/min

Peroxidase activity of guava fruits was determined as described by Abbasi *et al.* (1998) with slight modification. The reaction mixture was consisted of 1.7 ml, 15 mM $NaKPO_4$ buffer (pH 6.0), two substrates include 500 µl of 0.1 mM guaiacol and 500 µl of 1.0 mM H_2O_2, and 300 µl enzyme extract in a 3 ml cuvette. Peroxidase activities were noted for optical density change during 3 minutes at 470 nm and the results were expressed as milligram of protein per minute.

Shelf life

Shelf life was determined by conducting a visual observation to recorder the number of days the fruits remained in good condition (taste, texture and appearance) without spoilage in each replication during storage (Embuscado and Huber, 2009).

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Statistical Analysis

The experimental design was block completely randomized with three replications. Data was analyzed using the SPSS 17.0 (Statistical Packages for the Social Sciences, released 23 August 2008). Analysis of variance was used and means were separated by Least Significant Difference (LSD) Test ($p \leq 0.05$).

Results and Discussion

Effect of calcium chloride pre-harvest treatments on fruit calcium content, yield components and fruit quality parameters of Washington navel orange and guava.

Regarding the fruit calcium content of Washington navel orange and guava, results showed that, responded significantly affect ($p \leq 0.05$) to all calcium chloride treatments as compared to control (Figure 1 A). Calcium content of Washington navel orange and guava was increased in a quadratic manner, until 1.5% $CaCl_2$ (0.44 and 0.87 g/kg DW); therefore, an increase of 37.50 and 33.84 % when compared to the control treatment (0.32 and 0.65 g/kg DW), respectively. Moreover, there was significant difference ($p \leq 0.05$) between the calcium levels obtained with concentrations between 1 and 2 % $CaCl_2$ in the fruits of Washington navel orange and guava (Figure. 1 A). The similar results were conformity with Shiri *et al.* (2016) in kiwifruit *Actinidia chinensis* (Planch.). Foliar application of calcium chloride at 15 g/l considerably increased the calcium content in kiwifruit fruits. Modesto *et al.* (2020) concluded that spraying blackberry (*Rubus fruticosus* 'Tupy') trees with $CaCl_2$ have a positive effect on fruit calcium content. Moreover, similar results were obtained by Chen *et al.* **(**2024) where pre-harvest application of calcium increased the calcium content in Nanfeng tangerine (*Citrus reticulata* Blanco cv. '*Kinokuni'*) fruit.

The data regard to the yield components [yield (kg/tree), fruit weight (g)] of Washington navel orange and guava fruits are

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given in the (Figure 1B, C). The analysis of the variance showed that fruit weight (g), yield (kg/tree) were significantly ($p \leq 0.05$) affected by $CaCl_2$ levels. The analysis of variance showed significant differences ($p \leq 0.05$) for fruit weight and yield of Washington navel orange and guava. Among different pre-harvest treatments, 1.5 % calcium chloride (T3) has showed the highest fruit weight (332.93 and 168.19 g), yield (100.77 and 81.65 kg/tree) of Washington navel orange and guava fruit, respectively (Figure 1). These results are in line with the findings of Ramezanian *et al*. (2010) in pomegranate (*Punica granatum* L.), Irfan *et al*. (2020) in apple, Zhang *et al.* (2021) in Pomelo (*Citrus maxima* Merr.), El-Alakmy (2012) in peaches (*Prunus persica* L.) and Kirmani *et al.* (2013) in plum(*Prunus salicina* L. cv. 'French'). The increment in the yield of Washington navel orange and guava may be due to increase in fruit calcium content. Calcium (Ca^{2+}) is conceder one of the most important macronutrient for fruit crops, since it is needed for cell division, cell elongation, nutrient uptake, enzymes activity (phospholipase, arginine kinase, amylase and adenosine triphosphatase ATPase) and photosynthate accumulation (Marschner, 2011 and Tejashvini *et al.*, 2018). Calcium also enhance the nutrient status of plants by increasing the ammonium absorption, which improve photosynthesis and CO_2 intake which ultimately resulted in elevating fruit weight, number of fruits/tree and yield. Ca improves the nutrient status of plants by increasing the K content of plants (Abbasi *et al.*, 2013).

Data pertaining fruit quality attributes [firmness, total soluble solids (TSS), titratable acidity% (Ac), ascorbic acid content (Vitamin C) and total sugar (%)] of Washington navel orange and guava are showed in figure 1 D, E, F, G, H. The analysis of variance showed significant differences ($p \leq 0.05$) for

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fruit quality attributes of Washington navel orange and guava. Among different pre-harvest treatments, 1.5 % calcium chloride (T3) has showed the highest fruit firmness (25.10 and 11.77 kg/cm^2) of Washington navel orange and guava fruit, respectively (Figure 1 D), increased fruit firmness in T3 this could be **attributed** to **the binding role of calcium with the complex polysaccharides and proteins, stabilizing and strengthening the cell wall** (Ramezanian *et al.*, 2010 and Kaur, 2017). Calcium plays a role in maintaining or reinforcing cell membrane and cell wall integrity, inhibiting cell wall component degradation, reducing fruit respiration and ethylene synthesis, and regulating senescence-related enzyme activities and metabolism (Jain et al., 2019). Moreover, it has been reported that calcium can reduce the activity of hydrolytic enzymes (pectin methylesterase (PME) and polygalacturonase (PG)) of the cell wall (Ranjbar *et al.,* 2018 and Jain *et al.,* 2019). Similar results have been reported by Wahdan *et al.* (2011) in "Succary Abiad" mango and Farag *et al.* (2012) in apricot (*Prunus armeniaca* L.); Zhang *et al.* (2021) in pomelo (*Citrus grandis* L. Osbeck) and Peng *et al.* (2022) in ‘Feizixiao’ Litchi (*Litchi chinensis* Sonn.).

Treatment T3 (calcium chloride at 1.5%) recorded the highest TSS percentages (Washington navel orange and guava) over control (16.10 and 14.13 %) at harvest time, respectively. The maximum total sugars percentage (11.55 and 10.55 %) of Washington navel orange and guava fruits was also found in 1.5% $CaCl_2$ treatment and lowest value (3.52 and 4.08 %) was recorded in control, respectively. Similar results have been reported by Wahdan *et al.* (2011) in "Succary Abiad" mango and Farag *et al.* (2012) in apricot; Zhang *et al.* (2021) in pomelo and Peng *et al.* (2022) in ‘Feizixiao’ Litchi (*Litchi chinensis* Sonn.).

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Total soluble solids (TSS %) contain 75% sugars and are considered important as they are determinant of the quality of fruits (EL-Akram et al., 2013). The increase in fruit Ca content facilitates the transport of carbohydrates to storage organs through the phloem, which can effectively increase the sugar content of fruit (Liaquat et al., 2019). Moreover, the photosynthetic efficiency is also related to the sugar content of fruits (Liaquat et al., 2019). Foliar application of Ca enhanced photosynthesis (Peng et al., 2022).

The highest acidity of Washington navel orange and guava fruits (1.19 and 0.٦٣ %) was recorded in T3 which received calcium chloride at 1.5% followed by T4 = calcium chloride at 1.5% (1.09 and 0.53%) and the lowest acidity recorded in control (0.97 and 0.48%), respectively. These results were in line with the studies of El-Hilali *et al.* (2004) where calcium application increased titrable acidity in 'Fortune' mandarin (*Citrus reticulata* Blanco) fruit. Calcium chloride increased the titratable acidity of Washington navel orange and guava fruits as calcium delayed the ripening by decreased hydrolysis of organic acids and respiration rate (Gupta *et al.*, 2011).

Among the calcium chloride treatments, ascorbic acid content (vitamin C content) in the fruit of Washington navel orange and guava significantly differed ($p \leq 0.05$) from 71.61 and 209.13 mg /100 ml juice T2 ($CaCl_2$ at 1.5%) to 61.99 and 197.51 mg /100 ml juice T1 ($CaCl_2$ at 1%), respectively. The maximum ascorbic acid was recorded in T2 ($CaCl_2$ at 1.5%) followed by T4 ($CaCl_2$ at 2%) and the minimum (50.19 and 185.05 mg /100 ml juice) was recorded in control. Pre-harvest spray of calcium increased ascorbic acid of Washington navel orange and guava fruits. This result occurred due to the increase in the calcium content in fruits; this macronutrient improves the

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ascorbate-glutathione cycle, consequently leading to the great synthesis of ascorbic acid (Huang *et al*., 2007 and Bhat *et al*., 2012). Ali *et al*. (2014) reported that the pre-harvest application of $CaCl_2$ at 1% significantly increases the ascorbic acid content in peach fruits.

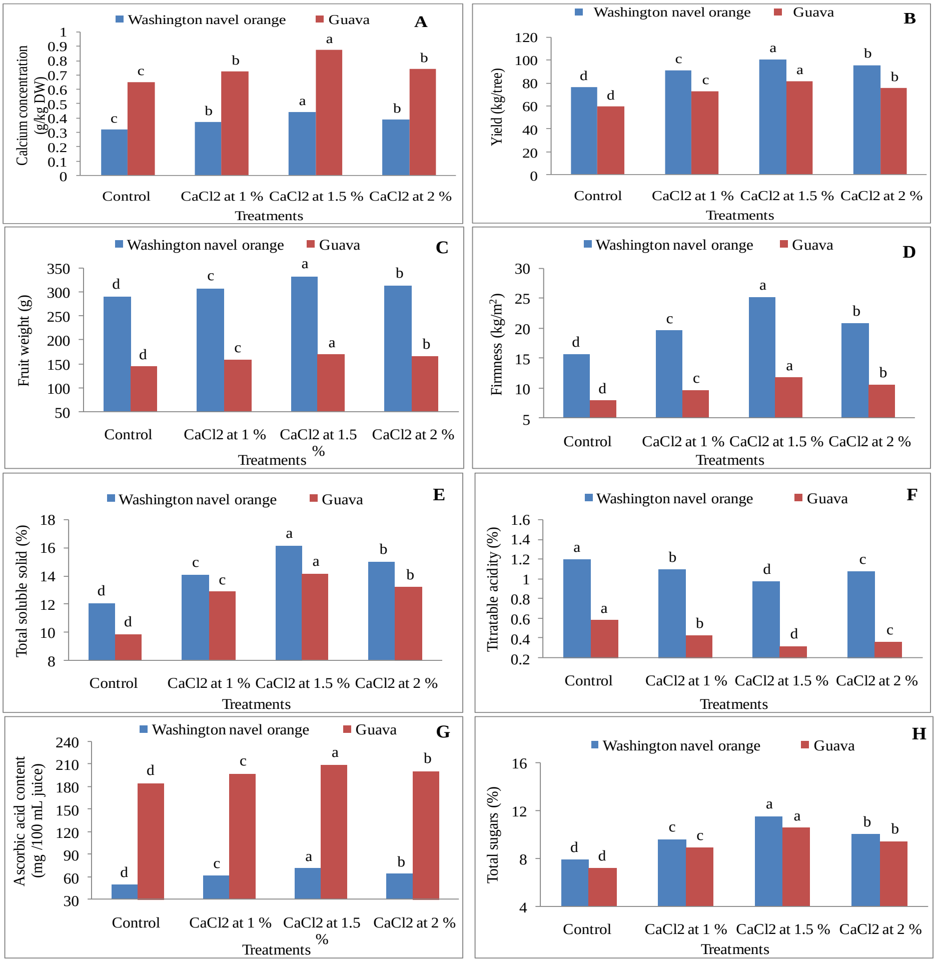

Figure 1. Effect of calcium chloride pre-harvest treatments on (A) calcium concentration, (B) yield, (C) fruit weight, (D)

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firmness, (E) total soluble solid (TSS), (F) titratable acidity percentage, (G) ascorbic acid content, (H) total sugars percentage of Washington navel orange and guava fruits, plodded data of two seasons 2019-2020 and 2020-2021. Values in the bar followed by the same letter(s) are not significantly different at a 5% level of probability.

Effect of pre-harvest treatment with 1.5 % calcium chloride combined with post-harvest treatments of essential oils on fruit quality parameters (firmness, TSS, acidity, ascorbic acid content (Vitamin C), reducing sugar %, physiological loss in weight and shelf life) of Washington navel orange and guava fruits stored under room temperature.

The data of the combined effect of 1.5 % calcium chloride pre-harvest and essential oils postharvest treatments on quality parameters of Washington navel orange and guava fruits are given in tables 2 and 3, respectively. The analysis of variance showed significant differences ($p \leq 0.05$) for quality parameters of Washington navel orange and guava fruits viz., firmness, TSS, acidity, ascorbic acid content (Vitamin C), reducing sugar %, physiological loss in weight, fruit peroxidase activity and shelf life.

The pre-harvest treatment with 1.5% $CaCl_2$ combined with post-harvest treatment of Moringa oil at 4 % has increased the firmness (20.11 and 9.66 kg/cm^2), ascorbic acid content (68.31 and 200.55 mg /100 ml juice) and shelf life (35.33 and 10.20 days) and decreased physiological loss in weight (3.23 and 8.22 %), TSS (16.70 and 10.22 %), acidity (0.98 and 0.58 %), reducing sugar (4.07 and 5.17 %) and fruit peroxidase activity (38 and 115 mg protein/min) of Washington navel orange and guava fruits stored under room temperature, respectively. These results are in line with those of Silva *et al.* (2021) on mango fruits and El-Dengawy *et al.* (2018) on guava fruits.

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The loss of fruit weight is related to the loss of water, inducing changes in appearance such as withering and wrinkling. This may be due to retention of the treated fruits, with moringa oil at 4 %, with their water content and non evaporation due to the waxing the skin of the fruit. Moreover, our results provided supporting evidence that coating guava fruits with moringa oil at 4 % helped to delay ripening and preserve fruit quality. The application of moringa oil coating prolonged the postharvest quality and shelf-life of the Tommy Atkins mango by controlling the physical and chemical properties during 12 days of storage at room temperature when compared to the control treatment (Silva *et al.*, 2021).

Regarding the influence of postharvest treatments on peroxidase activity, the results determined that all essential oils treatments were able to considerably reduce the increase in peroxidase compared to the control and citric acid treatment in Washington navel orange and guava fruits. Noting that moringa oil was the most efficient in lowering peroxidase activity, followed by coconut oil, while peppermint was the least effective. These findings are consistent with those of Elkeleny *et al.* (2023) on husk tomato (*Physalis pruinosa* L). The study indicated that foliar application of moringa leaf aqueous extract reduced peroxidase activity. The decrease in peroxidase activity might be attributed to moringa oil high antioxidant content of tocopherols, carotenoids, ascorbic acid, flavonoids, and several other phenolic compounds that inhibit peroxidase activity (Thanaa *et al.*, 2017).

Table 2. Effect of pre-harvest treatment with 1.5 % calcium chloride combined with post-harvest treatments of essential oils on fruit quality parameters (firmness, physiological loss in weight, TSS, acidity, ascorbic acid content, reducing sugar % and fruit peroxidase activity) and shelf life of Washington navel

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orange fruits stored under room temperature, plodded data of 2019-2020 and 2020-2021 seasons.

Treatment	Firmness (kg/cm^2)	Fresh weight loss (%)	Total soluble solid (%)	Titratable acidity (%)	Ascorbic acid content (mg /100 ml juice)	Reducing sugars (%)	Fruit peroxidase activity (mg protein/min)	Shelf life (days)
Control	11.45 f	19.50 a	20.31 a	0.68 f	57.14 f	8.72 a	75f	10.50 f
Citric acid at 1%	13.67 e	16.62 b	19.00 b	0.72 e	59.44 e	7.12 b	69e	15.60 e
Rosemary oil 4%	17.40 c	8.77 c	18.00 c	0.85 c	63.51 c	5.11 d	50c	27.50 c
Coconut oil 4%	18.60 b	7.33 d	17.60 d	0.88 b	65.62 b	5.50 e	41b	29.50 b
Moringa oil at 4 %	20.11 a	3.23 e	16.70 e	0.98 a	68.31 a	4.07 f	38a	35.33 a
Peppermint oil 4%	16.00 d	8.93 c	18.00 c	0.82 d	61.22 d	6.00 c	58d	25.50 d

Values in the column followed by the same letter(s) are not significantly different at a 5% level of probability.

Table 3. Effect of pre-harvest treatment with 1.5 % calcium chloride combined with post-harvest treatments of essential oils on fruit quality parameters (firmness, physiological loss in weight, TSS, acidity, ascorbic acid content, reducing sugar % and fruit peroxidase activity) and shelf life of guava fruits stored under room temperature, plodded data of 2019-2020 and 2020-2021 seasons.

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Treatment	Firmness (kg/cm^2)	Fresh weight loss (%)	Total soluble solid (%)	Titratable acidity (%)	Ascorbic acid content (mg /100 ml juice)	Reducing sugars (%)	Fruit peroxidase activity (mg protein/mi)	Shelf life (days)
Control	3.55 f	26.80 a	15.56 a	0.40 f	168.61 d	10.31 a	197f	2.54 f
Citric acid at 1%	5.33 e	20.32 b	14.66 b	0.45 e	173.51 c	9.00 b	188e	4.70 e
Rosemary oil at 4%	7.00 c	13.51 d	12.00 d	0.49 c	189.81 b	7.11 d	135c	8.44 c
Coconut oil at 4%	8.04 b	11.50 e	11.47 e	0.51 b	190.33 b	6.70 e	122b	8.50 b
Moringa oil at 4 %	9.66 a	8.22 f	10.22 f	0.58 a	200.55 a	5.17 f	115a	10.20 a
Peppermint oil at 4%	6.50 d	15.78 c	12.60 c	0.47 d	189.45 b	7.60 c	148d	7.99 d

Values in the column followed by the same letter(s) are not significantly different at a 5% level of probability.

Conclusions

It can be concluded that the pre-harvest treatment of 1.5% calcium chloride has a higher overall yield and a better positive effect than other treatments on quality parameters (firmness, TSS, acidity, ascorbic acid content and reducing sugar) of Washington navel orange and guava fruits. Moreover, the combination of 1.5% calcium chloride and 4% moringa oil coating effectively maintained Washington navel orange and guava fruits with acceptable sensory quality (weight loss, firmness, TSS, acidity, ascorbic acid content and reducing sugar) for 35.33 and 10.20 days at room temperature, respectively.

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