Effect of Some Natural Oils on Prolonging the Storage Period of Winter Guava Fruits (*Psidium guajava* L.)

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ABSTRACT

Essential oils have antioxidant and antimicrobial properties, so it is considered one of the most suitable methods to maintain overall fruit quality, reduce decay and extend the shelf life of fruit during storage. Therefore, two experiments using fruits harvested from 14-year-old guava trees in a private farm located in Al-Busayli village, Rashied, Bohaira governorate, Egypt, during the 2021and 2022 seasons. The primary objective was to evaluate the influence of essential oils on the overall quality and extension of the shelf-life of winter guava fruit. The fruits were subjected to various treatments, including dipping in the following solutions (at 1000 ppm) for 5 minutes: control (distilled water), clove oil, eucalyptus oil, mustard oil, and jojoba oil. Subsequently, the coated fruits with essential oils were preserved in cold room with a temperature of 7±1°C and a relative humidity of 90 – 95 % for a duration of 24 days. The obtained data revealed that immersing in essential oils of winter guava fruits at concentration of 1000 ppm significantly reduced loss in weight of fruit, rot and respiration rate in addition its also improved fruit firmness. SSC%, acidity, SSC/acid ratio and ascorbic acid content compared to control treatment during cold storage. Moreover, the results show a significant reduction in loss of weight, decay, and respiration rate of guava fruits when Eucalyptus and clove oils were utilized. Furthermore, the applications of Eucalyptus and clove oils demonstrated effectiveness in keeping firmness, acidity, vitamin C content, SSC%, and SSC/acid ratio in guava fruits during the storage. In conclusion, Eucalyptus oil and cloves oil proved to be highly effective in reduce weight loss, decay, and respiration rates while concurrently maintaining the overall quality of winter guava fruits under cold storage conditions for a duration of 24 days, in comparison to the other treatments.

Key words: Guava, Winter, Oils, Weight.

INTRODUCTION

Guava (*Psidium guajava* L.) is considered an important economic crop in Egypt as well as in the tropical and subtropical region of the world (Abd El-Samie and Khalifa, 2011). This nutritional richness has led to its use in medicinal applications for treating conditions such as gastroenteritis, dysentery, wound healing, and rheumatic diseases (Kumari *et al.*, 2020). Despite its remarkable qualities (Vijaya Anand *et al.*, 2020; Kumar *et al.*, 2021; Shukla *et al.*, 2021 and Mohd Israfi *et al.*, 2022), guava faces challenges in terms of postharvest preservation. Being a climacteric fruit, guava exhibits a rapid rise in respiration rate and ethylene production, which limits its shelf-life to three or four days at room temperature (Yadav *et al.,* 2022). Unfortunately, this susceptibility to damage results in postharvest losses that surpass pre-harvest losses (Sanjay *et al.*, 2022). As guava fruit deteriorates, both physically and chemically, it becomes vulnerable to various physiological disorders including weight and dry matter lose, microbial attacks leading to decay and rot. These issues significantly impact the fruit's shelf life and marketability (Alba-Jiménez *et al.,* 2018 and Gill, 2018). These losses can be minimized and display healthy fruits in markets by using essential oils for control the postharvest problems and maintain overall fruit quality during storage (Ding and Lee, 2019).

The essential oils are natural antioxidants which are well known for their antimicrobial and biodegradable properties and do not leave any residual effect on fresh fruits (Taghavi *et al.*, 2018 and Bolouri *et al.*, 2022). In this respect, the antimicrobial activity of essential oils is related with the existence of secondary metabolites synthesized by plants (Hyldgaard *et al.*, 2012). Its mode of action involves the interaction of its hydrophobic components with the lipids present in the cell membrane of microorganism, resulting in metabolic damages and cell death (Chouhan *et al.,* 2017). Numerous studies highlight the crucial role of postharvest essential oil applications in preserving the overall quality and extending the shelf life of guava during storage. For instance, Singh *et al.* (2017) demonstrated that guava fruits immersed in 2% mustard oil, coconut oil, olive oil, almond oil, and grape seed oil exhibited superior quality during storage, evidenced by reduced physiological loss, mold and slower changes in fruit color and other quality characteristics compared to control treatment. Notably, olive oil emerged as a standout performer, extending the shelf life of guava fruit to 28 days in cold storage and to 16 days at ambient conditions. Similarly, El-Dengawy *et al.* (2018) found that immersing guava fruits in 2% Jojoba oil resulted in decreased weight loss, decay and peroxidase enzyme activity, while maintaining sugar content, vitamin C, and TSS/acidity during storage. Sebastian *et al.* (2018) suggested that essential oils of Tulsi, Neem,

DOI: 10.21608/asejaiqjsae.2023.319909

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Received, September 05, 2023, Accepted, October 03, 2023.

and Eucalyptus (2ml/l) effectively maintained overall quality parameters of guava fruits during 15 days of storage at room temperature (20 °C), thereby extending its shelf life. Arafat *et al.* (2020) and Shehabudheen *et al.* (2020) reported similar positive effects using rosemary oil, moringa oil, coconut oil, peppermint oil, Moringa gum, and cinnamon essential oil in different concentrations. In line with these findings, Moreira *et al.* (2021) demonstrated that the postharvest application of peppermint essential oil at concentrations of 0.5, 1 and 1.5% proved most effective in enhancing fresh fruit quality and extending the shelf life of guava fruits stored at 25±1°C for 15 days.

So, this study is conducted to evaluate the effects of postharvest application of some essential oils (clove, Eucalyptus, Mustard, and Jojoba) on decay control, quality maintenance, and shelf-life extension of winter guava fruits.

MATERIALS AND METHODS

The trial was conducted on fruits harvested from 14-year-old common guava (*Psidium guajava* L.) trees grown in a private farm at El-Bocelli village, Rashied, El-Bohaira governorate, Egypt. The trees were planted at 5×5 meters apart in clay soil under a drip irrigation system. The guava trees were forced to fruit during the winter season by preventing irrigation for four months starting after harvest until the end of July. The trees were then fully irrigated in August, and the trees were given their crop in January and February. The fruits were harvested at maturity stage on February 12^{th} and 7^{th} in 2021 and 2022, respectively when the peel was yellowish-green, according to Yusof *et al.* (1988). Fruit samples were directly transported to the laboratory of the Sakha Horticulture Research Station, Kafr El-Sheikh governorate. Fruits were selected for uniform size, color and were freedom from physical injuries, insect attacks, and damages. The selected fruits were cleaned, sterilize with sodium hypochlorite solution (0.02%) for 2 minutes, washed with clean water and allowed to air-dry. The fruit samples were split into six groups; the first group was used for determined the initial quality characters at harvest date. The other groups were immersing in the following aquatic solutions (at1000 ppm) for 5 minutes: distilled water as control; clove oil; eucalyptus oil; mustard oil and Jojoba oil. Afterward, the treated fruits (216 kg) were placed in carton boxes; each box contained 2kg of winter guava fruits. Each treatment was replicated three times for each sample date (18 kg), and the experiment was arranged in a randomized complete block design. The fruits were stored at 7±1°C with 90 – 95 % RH for 24 days. The variables were measured at 8 days intervals during the storage period as follows:

Weight loss %:

Guava fruits were weighed on the date of harvest and in each storage period, the weight loss was calculated as mentioned in the equation: Fruit weight loss %= (Weight before storage – Weight after storage / Weight before storage) × 100.

Fruit decay %:

Fruit decay was determined by counted the number of fruit decayed at the exit date of sample and calculated by using the following formula: decay % = {Number of decay fruits/Total number of stored fruits} x 100.

Fruit firmness (Newton):

Fruit firmness was measured using an Effegi penetrometer and the values are expressed as Newton.

Respiration rate (mg CO_2/kg/h):

One kg of guava fruits was placed in a desicator and connected to a tube containing with 25 ml of 1.0 N KOH. The CO_2, produced by the fruits, was measured by titration and after one h, the KOH was titrated with 1 N HCl using thymolplue indicator. The results expressed as mg of CO_2 kg^{-1} h^{-1}(Nascimento *et al.*, 2019).

Soluble solids%, Titratable acidity%, ascorbic acid and SSC/acid ratio:

Juice was extracted from fruit samples for determining juice quality as: Soluble solid content was measured by hand refractometer, titratable acidity as citric acid was determined by titration with 0.1M sodium hydroxide using a phenolphthalein indicator according to A. O. A. C. (1990), ascorbic acid as mg/100 ml juice by using 2, 6 dichlorophenol indophenol according to Ranganna (1977), and the SSC/acid ratio was estimated.

Statistical analysis:

Statistical analysis was done by using SAS software according to Snedecor and Cochran (1990), and the significant differences among means values show by using Duncan's multiple range tests (DMRT) at 0.05 levels, according to Duncan (1955).

RESULTS AND DISCUSSION

Fruit weight loss (%):

The results in Table (1) showed that loss in weight of winter guava fruits increased with the progression of the storage times at 7 ± 1°C with 90 ± 95% relative humidity for 24 days. Furthermore, it is evident that loss in fruit weight was significantly decreased by immersing in different solutions of essential oils during the storage period compared to control fruits. In the first season, Winter guava fruits dipped in Eucalyptus oil and Mustard oil gave the lowest values of weight loss through the storage period, while in the second season, Eucalyptus oil and Jojoba oil resulted in the lowest weight loss percentages. Conversely, guava fruits soaked in distilled water (control) exhibited the highest values of weight loss during the storage period at 7±1°C with 90 to 95% relative humidity for 24 days. These findings are consistent with the result of Kabbashi *et al.* (2017) and Othman *et al.* (2017) regarding guava fruits. El-Dengawy *et al.* (2018) also demonstrated that immersing guava fruits in Jojoba oil at 2% resulted in a reduction in weight loss and decay percentages during storage at 27±1°C for 12 days. Similarly, Arafat *et al.* (2020) revealed that post-harvest application of essential oil reduced weight loss incidence and decay during the cold storage of guava fruits. In this context, El-Shemy (2020) revealed that using essential oils as postharvest treatments significantly decreased the loss in weight of apricot fruits compared to untreated fruits during cold storage. Additionally, apricot fruit treated with thyme, Spearmint, Clove, Eucalyptus, or Mustard exhibited lowering loss in weight incidence during storage period. Mandal and Vanlalawmpuia (2020) revealed that loss of moisture significantly reduced in fruit dipped in essential oil enriched coatings. The reduction in fruit weight loss attributed to essential oil application may be due to the reduced evaporation of water, respiration rate, degradation processes, and ethylene production during cold storage, which in turn delayed the fruit's ripening and preserved its quality (Sanjay *et al.,* 2022).

Fruit decay (%):

The results presented in Table (2) demonstrate a significant increase in decayed fruit with the extension of the storage period in both seasons. Furthermore, the findings indicated that postharvest treatments with Jojoba oil, Clove oil, Eucalyptus oil, and Mustard oil had a positive impact on reducing fruit decay percentages compared to the control treatment. Notably, the highest decay percentage was detected in the control treatment. Eucalyptus and Clove treatments resulted in zero percent decayed fruits during storage period, highlighting their superior effectiveness in reducing fruit decay percentages at a concentration of 1000 ppm. These results are agreed with the findings of Shaarawi *et al.* (2017) who observed that plum fruits dipped in Clove oil exhibited the lowest fruit decay percentages compared to those dipped in Mint oil, Lemongrass oil, and ozone. Also, Othman *et al.* (2017) revealed that guava fruits dipped in a solution containing 0.5g/100 ml of sunflower seed oil and marjoram oil and stored at 7 ±1°C for 28 days maintained their quality without any signs of decay for up to 20 days, unlike control fruits stored under the same conditions. In line with these findings, El-Dengawy *et al.* (2018) demonstrated that guava fruits coated with 2% Jojoba oil exhibited the lowest levels of both weight loss and decay during storage for 12day. Additionally, Singh *et al.* (2021) reported similar results, showing that guava fruits treated with lemon grass oil and neem seed oil were the most effective treatments in minimizing fruit decay percentages.

Fruit firmness (Newton):

The results in Table (3) indicated that fruit firmness was gradually decreased with the increasing storage period in both seasons. Furthermore, it is noteworthy that fruit firmness was enhanced by all tested essential oils compared to the control treatment in both seasons. Eucalyptus oil and Clove oil coating guava fruits, in particular, recorded the highest values of firmness compared to other oil treatments in both seasons. Similar results were obtained by Amin (2016); Sebastian *et al.* (2018) and El-Salhy *et al.* (2020). In this study, all tested oils significantly contributed to maintaining the highest fruit firmness of winter guava fruits during the 24-day storage period compared to untreated fruits, with the highest firmness observed in fruits coated with Eucalyptus oil. The positive effect of essential oils in preserving firmness may be attributed to several factors, including reducing or delaying various aspects of fruit ripening by decreasing its sensitivity to ethylene (Solgi and Ghorbanpour, 2014), minimizing water lose and fruit senescence and inhibiting cell wall degradation by suppressing microbial activities (Taghavi *et al.,* 2018).These findings are in accordance with the results of Kabbashi *et al.* (2017), who reported that 1% mint oil was more effective in maintaining guava fruit firmness after 9 days of storage at room temperature. Essential oils prove effective in maintaining the firmness of guava during storage by maintaining the barrier to water vapor, reducing respiration and ethylene production, and restraining the activity of cell wall enzymes. These mechanisms collectively contribute to the retention of fruit firmness (Singh *et al.,* 2021 and Sanjay *et al.,* 2022).

Shelf life (days):

The data presented in Table (4) revealed that the shelf life of winter guava fruits was significantly extended with all tested essential oils compared to control in both seasons. The longest shelf life was obtained with fruits dipped in Eucalyptus oil followed by Clove oil in both seasons, respectively. In contrast, the shortest shelf life was observed in fruits treated with distilled water (control) in both seasons. Guava fruits coated with Mustard oil and Jojoba oil exhibited an intermediate shelf life. These results are consistent with those reported by Baiea and El-Badawy (2013); Nasrin *et al.* (2018) and El-Shemy (2020). In conclusion, Eucalyptus oil and Clove oil proved to be the most effective treatments for extending the shelf life of winter guava fruits during storage at 7 ±1◦C with 90 – 95 % RH for 24 days. These results may be attributed to reduced transpiration and respiration rates, as well as a decrease in microbial activity, leading to an increase in the shelf life of the fruits (Ding and Lee, 2019). The results obtained from the application of essential oils to prolong the shelf life of guava fruits align with those of Kabbashi *et al.* (2017) who found that guava fruits coated with 1% mint oil exhibited the longest shelf life in days compared to exposure to ultraviolet ray type C radiation and untreated fruits. Also, Singh *et al.* (2021) noted that the application of lemongrass oil and neem seed oil enhanced the shelf life of guava fruits.

Table 1. The effect of postharvest treatments with essential oils extracts on weight loss (%) of winter guava fruits during cold storage

Essential oil (1000 ppm)	Storage period (days)				
	2021 Season				
	0	**8**	**16**	**24**	**Mean**
Control	0.00 ±0.00	2.78^{c} ±0.03	3.10^{b} ±0.02	3.20^{a} ±0.05	2.27^{A} ±0.02
Jojoba oil	0.00 ±0.00	1.60^{ij} ±0.04	2.00^{f} ±0.03	2.19^{e} ±0.01	1.44^{C} ±0.01
Clove oil	0.00 ±0.00	1.93^{f} ±0.05	2.00^{f} ±0.02	2.26^{d} ±0.02	1.54^{B} ±0.01
Eucalyptus oil	0.00 ±0.00	1.49^{k} ±0.00	1.56^{jk} ±0.02	1.66^{hi} ±0.04	1.17^{E} ±0.01
Mustard oil	0.00 ±0.00	1.73^{h} ±0.01	1.83^{g} ±0.01	1.99^{f} ±0.02	1.38^{D} ±0.01
Mean	00.00^{D} ±0.00	1.90^{C} ±0.00	2.09^{B} ±0.01	2.26^{A} ±0.01	
Essential oil (1000 ppm)	**2022 Season**				
Control	0.00^{k} ±0.00	2.57^{c} ±0.02	2.68^{b} ±0.01	2.88^{a} ±0.02	2.03^{A} ±0.01
Jojoba oil	0.00^{k} ±0.00	1.15^{ij} ±0.01	1.24^{h} ±0.03	1.31^{f} ±0.02	0.92^{D} ±0.02
Clove oil	0.00^{k} ±0.00	1.26^{gh} ±0.03	1.40^{e} ±0.03	1.51^{d} ±0.02	1.04^{B} ±0.02
Eucalyptus oil	0.00^{k} ±0.00	1.11^{j} ±0.01	1.16^{i} ±0.02	1.22^{h} ±0.02	0.87^{E} ±0.00
Mustard oil	0.00^{k} ±0.00	1.25^{gh} ±0.01	1.29^{fg} ±0.01	1.40^{e} ±0.01	0.98^{C} ±0.01
Mean	0.00^{D} ±0.00	1.46^{C} ±0.01	1.55^{B} ±0.00	1.66^{A} ±0.01	

Values followed by the same letter are not significantly different by using Duncan's multiple range test, $P<0.05$.

Table 2. The effect of postharvest treatments with essential oils extracts on decay % of winter guava fruits during cold storage

Essential oil (1000 ppm)	Storage period (days)				
	2021 Season				
	0	**8**	**16**	**24**	**Mean**
Control	0.00^{i} ±0.00	7.53^{c} ±0.06	12.78^{b} ±0.11	16.24^{a} ±0.07	9.13^{A} ±0.06
Jojoba oil	0.00^{i} ±0.00	0.80^{h} ±0.21	1.41^{f} ±0.02	2.83^{d} ±0.02	1.26^{B} ±0.01
Clove oil	0.00^{i} ±0.00	0.00^{i} ±0.00	0.00^{i} ±0.00	0.00^{i} ±0.00	0.00^{D} ±0.00
Eucalyptus oil	0.00^{i} ±0.00	0.00^{i} ±0.00	0.00^{i} ±0.00	0.00^{i} ±0.00	0.00^{D} ±0.00
Mustard oil	0.00^{i} ±0.00	0.00^{i} ±0.00	0.93^{g} ±0.02	2.51^{e} ±0.05	0.86^{C} ±0.01
Mean	0.00^{D} ±0.00	1.66^{C} ±0.01	3.02^{B} ±0.16	4.31^{A} ±0.02	
Essential oil (1000 ppm)	**2022 Season**				
Control	0.00^{f} ±0.00	3.88^{c} ±0.08	8.69^{b} ±0.11	14.65^{a} ±0.11	6.80^{A} ±0.03
Jojoba oil	0.00^{f} ±0.00	0.00^{f} ±0.00	0.00^{f} ±0.00	1.73^{e} ±0.08	0.43^{C} ±0.02
Clove oil	0.00^{f} ±0.00	0.00^{f} ±0.00	0.00^{f} ±0.00	0.00^{f} ±0.00	0.00^{D} ±0.00
Eucalyptus oil	0.00^{f} ±0.00	0.00^{f} ±0.00	0.00^{f} ±0.00	0.00^{f} ±0.00	0.00^{D} ±0.00
Mustard oil	0.00^{f} ±0.00	0.00^{f} ±0.00	0.00^{f} ±0.00	3.48^{d} ±0.14	0.87^{B} ±0.04
Mean	0.00^{D} ±0.00	0.77^{C} ±0.02	1.73^{B} ±0.19	3.97^{A} ±0.07	

Values followed by the same letter are not significantly different by using Duncan's multiple range test, $P<0.05$.

Table 3.The effect of postharvest treatments with essential oils extracts on firmness (Newton) of winter guava fruits during cold storage

Essential oil (1000 ppm)	Storage period (days)				
	2021 Season				
	0	8	16	24	Mean
Control	7.27^{a} ±0.06	4.16^{h} ±0.04	3.19^{i} ±0.03	2.69^{j} ±0.01	4.32^{D} ±0.02
Jojoba oil	7.27^{a} ±0.06	5.75^{d} ±0.04	5.23^{e} ±0.06	4.42^{g} ±0.01	5.66^{BC} ±0.01
Clove oil	7.27^{a} ±0.06	5.94^{bc} ±0.02	5.20^{e} ±0.14	4.53^{g} ±0.02	5.73^{B} ±0.04
Eucalyptus oil	7.27^{a} ±0.06	6.09^{b} ±0.01	5.74^{d} ±0.05	5.02^{f} ±0.06	6.03^{A} ±0.03
Mustard oil	7.27^{a} ±0.06	5.89^{c} ±0.01	5.25^{e} ±0.04	4.03^{h} ±0.02	5.61^{C} ±0.02
Mean	7.27^{A} ±0.06	5.56^{B} ±0.00	4.92^{C} ±0.03	4.13^{D} ±0.02	
Essential oil (1000 ppm)	**2022 Season**				
Control	7.54^{a} ±0.04	4.00^{i} ±0.03	3.35^{j} ±0.05	3.00^{k} ±0.05	4.47^{D} ±0.01
Jojoba oil	7.54^{a} ±0.04	5.62^{d} ±0.01	5.15^{f} ±0.06	4.51^{h} ±0.04	5.70^{C} ±0.03
Clove oil	7.54^{a} ±0.04	5.90^{c} ±0.08	5.38^{e} ±0.07	4.84^{g} ±0.02	5.91^{B} ±0.02
Eucalyptus oil	7.54^{a} ±0.04	6.07^{b} ±0.03	5.85^{c} ±0.01	5.12^{f} ±0.02	6.14^{A} ±0.02
Mustard oil	7.54^{a} ±0.04	5.60^{d} ±0.09	5.16^{f} ±0.01	4.73^{g} ±0.02	5.75^{C} ±0.01
Mean	7.54^{A} ±0.04	5.43^{B} ±0.02	4.97^{C} ±0.01	4.44^{D} ±0.01	

Values followed by the same letter are not significantly different by using Duncan's multiple range test, P<0.05.

Table 4. The effect of postharvest treatments with essential oils extracts on shelf life (days) of winter guava fruits during cold storage

Essential oil (1000 ppm)	Storage period (days)				
	2021 Season				
	0	8	16	24	Mean
Control	11.14^{h} ±0.10	08.09^{m} ±0.02	07.32^{n} ±0.05	6.09^{o} ±0.02	08.16^{E} ±0.04
Jojoba oil	14.37^{d} ±0.06	13.07^{f} ±0.05	10.45^{i} ±0.03	8.92^{k} ±0.04	11.70^{D} ±0.02
Clove oil	16.20^{b} ±0.10	14.02^{e} ±0.00	11.38^{gh} ±0.07	9.44^{jk} ±0.06	12.76^{B} ±0.02
Eucalyptus oil	16.81^{a} ±0.25	15.09^{c} ±0.01	11.46^{g} ±0.05	9.61^{j} ±0.09	13.24^{A} ±0.06
Mustard oil	14.40^{d} ±0.11	13.16^{f} ±0.02	11.22^{gh} ±0.03	9.28^{k} ±0.03	12.01^{C} ±0.04
Mean	14.58^{A} ±0.02	12.68^{B} ±0.01	10.36^{C} ±0.02	8.66^{D} ± 0.05	
Essential oil (ppm)	**2022 Season**				
Control	11.00^{g} ±0.06	08.95^{i} ±0.040	07.28^{k} ±0.03	5.95^{l} ±0.23	08.29^{D} ±0.07
Jojoba oil	14.10^{c} ±0.09	11.96^{e} ±0.032	10.94^{g} ±0.05	7.98^{j} ±0.02	11.24^{C} ±0.02
Clove oil	16.04^{a} ±0.05	13.96^{c} ±0.046	11.53^{f} ±0.09	9.77^{h} ±0.05	12.82^{A} ±0.03
Eucalyptus oil	16.14^{a} ±0.04	13.96^{c} ±0.032	11.45^{f} ±0.10	9.95^{h} ±0.04	12.87^{A} ±0.04
Mustard oil	15.12^{b} ±0.01	12.95^{d} ±0.047	11.04^{g} ±0.15	8.95^{i} ±0.08	12.01^{B} ±0.06
Mean	14.48^{A} ±0.01	12.35^{B} ±0.003	10.44^{C} ±0.02	8.52^{D} ±0.08	

Values followed by the same letter are not significantly different by using Duncan's multiple range test, P<0.05.

Respiration rate (mg CO_2/kg/h):

Its cleared from data in Table (5) that, in general, the fruit's respiration rate decreased after 8 days of storage at 7 ± 1°C with 90-95% RH comparing to the initial harvest date. However, it increased with the prolonged storage period for all dates and treatments and this trend was consistent in both seasons. Guava fruit coated by Eucalyptus oil exhibited a lower respiration rate, followed by those coated with Clove oil, compared to the other treatments throughout the entire cold storage duration. The highest and significantly increased respiration rate was noticed in the control fruits. Similar results were obtained by Bron *et al.* (2005); Singh & Pal (2008); Mangaraj & Goswami (2011) and Mangaraj *et al.* (2014). In this context, Abd El-Wahab (2015) found that using some essential oil such rosemary, coriander, pepper mint, bergamot, lemon grass, dill, lavender and thyme be inclined effectively reduce the respiration rate of nectarine fruits during cold storage. The slower respiration rate observed in fruits treated with essential oils can be explained by the fact that fruit respiration is a major contributor to postharvest losses, as it accelerates the conversion of stored sugars or starch into energy in the presence of oxygen, leading to the advancement of ripening (Day, 1990). Reducing fruit respiration retards softening and slows down the ripening process (Kader, 1986), which in turn may result in reduced ethylene production. This finding is in line with the results reported by Abdolahi *et al.* (2010) and Abd El-Wahab *et al.* (2014).

Table 5. Effect of postharvest treatments with essential oils extracts on respiration rate (mg CO_2/kg/h) of winter guava fruits during cold storage

Essential oil (1000 ppm)	Storage period (days)				
	2021 Season				
	0	8	16	24	Mean
Control	$12.63^{a} \pm 0.05$	$6.60^{e} \pm 0.14$	$9.84^{b} \pm 0.13$	$7.62^{d} \pm 0.05$	$9.17^{A} \pm 0.09$
Jojoba oil	$12.63^{a} \pm 0.05$	$5.06^{g} \pm 0.11$	$8.00^{c} \pm 0.15$	$6.27^{e} \pm 0.05$	$7.99^{B} \pm 0.04$
Clove oil	$12.63^{a} \pm 0.05$	$4.54^{h} \pm 0.19$	$6.84^{e} \pm 0.07$	$5.01^{g} \pm 0.01$	$7.25^{D} \pm 0.04$
Eucalyptus oil	$12.63^{a} \pm 0.05$	$3.45^{j} \pm 0.18$	$3.80^{i} \pm 0.11$	$3.75^{ij} \pm 0.09$	$5.90^{E} \pm 0.03$
Mustard oil	$12.63^{a} \pm 0.05$	$5.04^{g} \pm 0.32$	$7.40^{d} \pm 0.05$	$5.61^{f} \pm 0.08$	$7.67^{C} \pm 0.00$
Mean	$12.63^{A} \pm 0.05$	$4.93^{D} \pm 0.00$	$7.17^{B} \pm 0.01$	$5.65^{C} \pm 0.02$	
Essential oil (1000 ppm)	**2022 Season**				
Control	$12.38^{a} \pm 0.10$	$7.62^{g} \pm 0.05$	$10.11^{c} \pm 0.22$	$10.91^{b} \pm 0.07$	$10.25^{A} \pm 0.11$
Jojoba oil	$12.38^{a} \pm 0.10$	$6.27^{i} \pm 0.05$	$08.35^{f} \pm 0.19$	$09.37^{d} \pm 0.11$	$09.09^{B} \pm 0.02$
Clove oil	$12.38^{a} \pm 0.10$	$5.01^{k} \pm 0.01$	$06.80^{h} \pm 0.06$	$08.36^{f} \pm 0.23$	$08.13^{D} \pm 0.05$
Eucalyptus oil	$12.38^{a} \pm 0.10$	$3.75^{l} \pm 0.09$	$04.65^{k} \pm 0.04$	$4.85^{k} \pm 0.40$	$06.40^{E} \pm 0.02$
Mustard oil	$12.38^{a} \pm 0.10$	$5.61^{j} \pm 0.83$	$06.98^{h} \pm 0.08$	$8.97^{e} \pm 0.02$	$08.48^{C} \pm 0.00$
Mean	$12.38^{A} \pm 0.10$	$5.65^{D} \pm 0.02$	$7.37^{C} \pm 0.03$	$8.49^{B} \pm 0.01$	

Values followed by the same letter are not significantly different by using Duncan's multiple range test, $P<0.05$.

Soluble solids content (SSC %):

It is evident from the data in Table (6) that the percentage of soluble solids content significantly increased as the storage period progressed in both seasons. In addition, winter guava fruits dipped in all essential oils exhibited significantly lower percentages of soluble solids content than fruits dipped in distilled water (control) during the storage period in both seasons. Specifically, the fruits treated with Eucalyptus and Clove oils showed a decrease in the percentage of soluble solids content, while the highest values were recorded in the control treatment in both seasons. These results are consistent with those obtained by Amin (2016); El-Shemy (2020) and El-Salhy *et al.* (2020). Similar responses were reported by Saleh *et al.* (2019), who found that essential oils preserved the total soluble solids content.

Therefore, it is evident from the above results and the data in Table (6) that postharvest application of essential oils, especially Eucalyptus and Clove oils, delayed fruit maturity, as indicated by the lower soluble solid content percentage and higher acidity percentage (Table 7) compared to the control. This effect persisted during the cold storage period, contributing to the delay in the ripening process. This explanation is in line with the findings of Abdolahi e*t al.* (2010) and Salimi *et al.* (2013), who explained that the positive effect on total soluble solids by essential oils may be due to the slowing of metabolic activity, reduced respiration rate, and vital process, which in turn, reduces the loss of total soluble solids during storage and prevents fruit degradation and over-ripening.

Titratable acidity (%):

The data presented in Table (7) showed the effect of essential oil applications on total acidity of winter guava fruits during the storage period at 7 ± 1°C with 90-95% relative humidity. Acidity values significantly decreased with the increasing storage period. Jojoba oil, Clove oil, Eucalyptus oil and Mustard oil treatments resulted in lower levels of titratable acidity in guava fruits during the storage period compared to the control. Among essential oil treatments, the highest values of titratable acidity were observed in fruits coated with Eucalyptus oil and Clove oil, as compared to fruits dipped in Jojoba and Mustard oil in both seasons. These results are consistent with those reported by Othman *et al.* (2017) and Singh *et al.* (2017) concerning guava fruits. In this context, El-Dengawy *et al.* (2018) revealed that immersing guava fruits in 2% Jojoba oil resulted in an increase in titratable acidity during storage. Also, El-Shemy (2020) revealed that postharvest application of Clove, Eucalyptus and Mustard oils at 1000 ppm led to increase acidity in apricot fruits. Titratable acidity is an important factor in maintaining the quality of plum fruits and is directly related to the organic acids content present in the fruit. Yadav *et al.* (2022) reported that the decrease in titratable acidity content could be attributed to the consumption of organic acids in fruits during respiration. According to our results, the essential oil treatments help in preserving the fruit's content of titratable acidity during storage. It appears that essential oil treatments have a positive effect on the respiration process, potentially leading to a reduction or delay respiration rate and the maintenance of titratable acidity content. These results are consistent with those of Barakat *et al.* (2015). This effect could be due to the delayed alterations in metabolism and a slowdown in the respiration rate induced by coating with essential oils (Abd El-Wahab *et al.*, 2014).

SSC/acid ratio:

As shown in Table (8), significant increases in the SSC/acid ratio during the storage period at 7±1°C with 90-95% RH were observed in all essential oil treatments in both seasons. The values of SSC/acid ratio were also significantly affected by essential oil treatments. Fruits treated with Jojoba oil, Mustard oil and control had the highest SSC/acid ratio values during cold storage. Conversely, the lowest values of SSC/acid ratio were found in fruits coated with Eucalyptus oil and Clove oil in both seasons, respectively, as compared to control fruits. These results are consistent with those obtained by El-Shemy (2020), who reported that apricot fruits treated with Thyme oil, Spearmint, Clove oil, Eucalyptus oil and Mustard oil had lower SSC/acid ratio values compared to fruits coated with 2% K_2CO_3, 2% $KHCO_3$, 3% $CaCl_2$ and 2% salicylic acid.

The data from this experiment showed that Eucalyptus oil and Clove oil at 1000 ppm were more effective in in slowing down the ripening process during the storage period. These findings are supported by El-Salhy *et al.* (2020), who revealed that postharvest application of essential oils delayed ripening by reducing total soluble solids % and total sugars % compared to the control. Also, Singh *et al.* (2017) and Sebastian *et al.* (2018) showed that guava fruits coated by dipping in essential oils such as Eucalyptus oil, neem oil, and coconut oil tended to delay fruit ripening, as evidenced by the lowest TSS% and the highest acidity% in the juice.

Ascorbic acid (mg/100 ml juice):

The results in Table (9) clearly demonstrate that ascorbic acid content in winter guava fruits stored at 7±1°C with 90-95% RH for 24 days gradually decreased with the progress of the storage period. Moreover, fruits coated by dipping in Jojoba oil, Clove oil, Eucalyptus oil and Mustard oil at 1000 ppm exhibited significantly higher levels of ascorbic acid content compared to those dipped in distilled water (control) during the storage period in both seasons. The data in Table (9) also revealed that the highest ascorbic acid content was observed in fruits dipped in Eucalyptus oil, followed by those in Clove oil, while the control treatment had the lowest value of ascorbic acid compared to the other treatments. In conclusion, it can be inferred that Eucalyptus and Clove oils at 1000 ppm are the most effective in preventing the loss of ascorbic acid from fruits during storage. This effect may be due to their ability to reduce fruit decay and dehydration, ultimately delaying the decline in fruit quality. This observation aligns with the previous studies conducted by Sebastian *et al.* (2018); Shehabudheen *et al.* (2020) and Singh *et al.* (2021), where postharvest application of essential oils was found to improve fruit characteristics such as firmness and vitamin C content while reducing fruit decay and weight loss of guava fruits during storage.

Table 6. The effect of postharvest treatments with essential oils extracts on SSC% of winter guava fruits during cold storage

Essential oil (1000 ppm)	Storage period (days)				
	2021 Season				
	0	**8**	**16**	**24**	**Mean**
Control	9.68^{i} ±0.08	13.70^{c} ±0.10	15.02^{b} ±0.08	15.85^{a} ±0.12	13.56^{A} ±0.00
Jojoba oil	9.68^{i} ±0.08	12.59^{fg} ±0.15	13.45^{cd} ±0.27	13.78^{c} ±0.25	12.37^{B} ±0.06
Clove oil	9.68^{i} ±0.08	12.51^{fg} ±0.04	12.52^{fg} ±0.26	13.18^{de} ±0.04	11.97^{C} ±0.05
Eucalyptus oil	9.68^{i} ±0.08	11.18^{h} ±0.07	12.10^{g} ±0.47	12.68^{ef} ±0.11	11.41^{D} ±0.13
Mustard oil	9.68^{i} ±0.08	12.60^{fg} ±0.01	13.68^{cd} ±0.05	13.68^{cd} ±0.03	12.41^{B} ±0.08
Mean	9.68^{D} ±0.08	12.51^{C} ±0.02	13.35^{B} ±0.09	13.83^{A} ±0.04	
Essential oil (1000 ppm)	**2022 Season**				
Control	9.83^{j} ±0.11	13.28^{f} ±0.08	15.08^{b} ±0.02	15.71^{a} ±0.04	13.47^{A} ±0.05
Jojoba oil	9.83^{j} ±0.11	12.95^{g} ±0.04	13.75^{de} ±0.08	14.55^{c} ±0.04	12.77^{B} ±0.02
Clove oil	9.83^{j} ±0.11	11.42^{i} ±0.15	12.38^{h} ±0.11	13.44^{ef} ±0.10	11.76^{D} ±0.06
Eucalyptus oil	9.83^{j} ±0.11	11.38^{i} ±0.02	12.21^{h} ±0.03	12.92^{g} ±0.00	11.58^{E} ±0.04
Mustard oil	9.83^{j} ±0.11	12.51^{h} ±0.21	13.58^{def} ±0.02	13.90^{d} ±0.08	12.45^{C} ±0.00
Mean	9.83^{D} ±0.11	12.30^{C} ±0.04	13.40^{B} ±0.02	14.10^{A} ±0.03	

Values followed by the same letter are not significantly different by using Duncan's multiple range test, $P<0.05$.

Table 7. The effect of postharvest treatments with essential oils extracts on acidity % of winter guava fruits during cold storage

Essential oil (1000 ppm)	Storage period (days)				
	2021 Season				
	0	**8**	**16**	**24**	**Mean**
Control	0.80^{a} ±0.03	0.77^{a} ±0.01	0.70^{abc} ±0.01	0.61^{cde} ±0.03	0.72^{A} ±0.02
Jojoba oil	0.80^{a} ±0.03	0.66^{bcd} ±0.03	0.55^{ef} ±0.06	0.49^{f} ±0.012	0.62^{B} ±0.00
Clove oil	0.80^{a} ±0.03	0.72^{ab} ±0.02	0.72^{ab} ±0.02	0.57^{def} ±0.20	0.70^{A} ±0.00
Eucalyptus oil	0.80^{a} ±0.03	0.74^{ab} ±0.02	0.74^{ab} ±0.08	0.60^{cde} ±0.03	0.72^{A} ±0.00
Mustard oil	0.80^{a} ±0.03	0.70^{abc} ±0.02	0.62^{cde} ±0.00	0.54^{ef} ±0.03	0.66^{AB} ±0.01
Mean	0.80^{A} ±0.03	0.71^{B} ±0.01	0.66^{B} ±0.03	0.56^{C} ±0.01	
Essential oil (1000 ppm)	**2022 Season**				
Control	0.75^{a} ±0.01	0.68^{b} ±0.20	0.59^{cd} ±0.00	0.56^{cde} ±0.00	0.64^{A} ±0.01
Jojoba oil	0.75^{a} ±0.01	0.50^{fg} ±0.01	0.48^{gh} ±0.00	0.39^{i} ±0.01	0.53^{D} ±0.00
Clove oil	0.75^{a} ±0.01	0.56^{cde} ±0.03	0.50^{fg} ±0.01	0.49^{gh} ±0.02	0.57^{BC} ±0.01
Eucalyptus oil	0.75^{a} ±0.01	0.60^{c} ±0.02	0.54^{def} ±0.01	0.51^{fg} ±0.01	0.60^{B} ±0.00
Mustard oil	0.75^{a} ±0.01	0.52^{efg} ±0.00	0.49^{gh} ±0.01	0.44^{h} ±0.01	0.55^{CD} ±0.01
Mean	0.75^{A} ±0.01	0.57^{B} ±0.00	0.52^{C} ±0.00	0.47^{D} ±0.01	

Values followed by the same letter are not significantly different by using Duncan's multiple range test, $P<0.05$.

Table 8. The effect of postharvest treatments with essential oils extracts on SSC/acid ratio of winter guava fruits during cold storage

Essential oil (1000 ppm)	Storage period (days)				
	2021 Season				
	0	8	16	24	Mean
Control	12.15^{i} ±0.15	17.80^{fgh} ±0.32	21.45^{def} ±0.19	26.14^{ab} ±0.12	19.38^{A} ±0.28
Jojoba oil	12.15^{i} ±0.15	19.15^{efg} ±0.57	25.32^{abc} ±0.54	28.21^{a} ±0.66	21.21^{A} ±0.17
Clove oil	12.15^{i} ±0.15	17.39^{gh} ±0.33	17.39^{gh} ±0.14	23.20^{bcd} ±0.80	17.53^{B} ±0.05
Eucalyptus oil	12.15^{i} ±0.15	15.13^{hi} ±0.35	17.02^{gh} ±0.51	21.23^{def} ±0.61	16.38^{B} ±0.05
Mustard oil	12.15^{i} ±0.15	18.02^{fgh} ±0.45	22.06^{cde} ±0.12	25.58^{abc} ±0.59	19.45^{A} ±0.06
Mean	12.15^{D} ±0.15	17.50^{C} ±0.27	20.65^{B} ±1.00	24.87^{A} ±0.63	
Essential oil (1000 ppm)	**2022 Season**				
Control	13.10^{j} ±0.13	19.57^{i} ±0.49	25.56^{ef} ±0.18	28.05^{cd} ±0.24	21.57^{C} ±0.15
Jojoba oil	13.10^{j} ±0.13	25.95^{def} ±0.71	28.64^{c} ±0.16	37.42^{a} ±0.30	26.27^{A} ±0.23
Clove oil	13.10^{j} ±0.13	20.60^{hi} ±0.40	24.82^{f} ±0.87	27.49^{cde} ±0.72	21.50^{C} ±0.37
Eucalyptus oil	13.10^{j} ±0.13	19.03^{i} ±0.66	22.62^{gh} ±0.39	25.37^{ef} ±0.65	20.03^{D} ±0.13
Mustard oil	13.10^{j} ±0.13	24.05^{fg} ±0.45	27.73^{cd} ±0.42	31.65^{b} ±0.74	24.13^{B} ±0.37
Mean	13.10^{D} ±0.13	21.84^{C} ±0.19	25.87^{B} ±0.24	29.99^{A} ±0.41	

Values followed by the same letter are not significantly different by using Duncan's multiple range test, P<0.05.

Table 9. The effect of postharvest treatments with essential oils extracts on vitamin C (mg/100ml juice of winter guava fruits during cold storage

Essential oil (1000 ppm)	Storage period (days)				
	2021 Season				
	0	8	16	24	Mean
Control	77.18^{a} ±0.86	68.56^{cd} ±1.21	63.38^{fg} ±0.03	60.33^{g} ±0.55	67.36^{B} ±0.29
Jojoba oil	77.18^{a} ±0.86	71.58^{bc} ±0.42	68.15^{cde} ±0.12	63.80^{fg} ±0.82	70.17^{A} ±0.50
Clove oil	77.18^{a} ±0.86	69.35^{bcd} ±0.56	66.51^{def} ±0.70	64.15^{ef} ±0.69	69.29^{AB} ±0.15
Eucalyptus oil	77.18^{a} ±0.86	72.75^{b} ±0.27	69.96^{bcd} ±0.03	65.17^{ef} ±0.14	71.26^{A} ±0.22
Mustard oil	77.18^{a} ±0.86	71.49^{bc} ±0.11	67.10^{def} ±0.05	65.06^{ef} ±0.05	70.20^{A} ±0.23
Mean	77.18^{A} ±0.86	70.74^{B} ±0.15	67.02^{C} ±0.11	63.70^{D} ±0.14	
Essential oil (1000ppm)	**2022 Season**				
Control	80.70^{a} ±1.31	72.43^{d} ±0.45	64.89^{g} ±0.31	59.11^{i} ±0.39	69.28^{D} ±0.42
Jojoba oil	80.70^{a} ±1.31	73.65c^{d} ±0.09	66.10^{fg} ±0.13	60.69^{hi} ±0.78	70.28^{CD} ±0.38
Clove oil	80.70^{a} ±1.31	75.67^{bc} ±0.29	68.10^{ef} ± 0.14	62.07^{h} ±0.07	71.63^{B} ±0.08
Eucalyptus oil	80.70^{a} ±1.31	76.69^{b} ±0.47	69.36^{e} ±0.06	64.79^{g} ±0.38	72.88^{A} ±0.42
Mustard oil	80.70^{a} ±1.31	75.22^{bc} ±0.15	67.55^{ef} ±0.18	61.71^{h} ±0.14	71.29^{BC} ±0.31
Mean	80.70^{A} ±1.31	74.73^{B} ±0.04	67.20^{C} ±0.04	61.67^{D} ±0.03	

Values followed by the same letter are not significantly different by using Duncan's multiple range test, P<0.05.

CONCLUSION

It can be concluded from the above results that fruit weight loss, decay, and respiration rate were significantly decreased by the use of Eucalyptus and clove oils. Additionally, immersing the fruits in a solution of Eucalyptus and clove oils resulted in increased fruit firmness, as well as higher levels of acidity, ascorbic acid, soluble solids, and SSC/acid ratio during the storage period. Therefore, Eucalyptus oil and cloves oil proved to be more effective in reducing weight loss, decay, and respiration rate, while simultaneously enhancing overall quality and extending the shelf life of winter guava fruits under cold storage conditions for 24 days, as compared to other treatments.

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الملخص العربي

تأثير بعض الزيوت الطبيعية على إطالة فترة تخزين ثمار الجوافة الشتوى

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تم إجراء الدراسة على ثمار تم جمعها من بستان أشجار جوافة، عمر الأشجار ١٤ سنة وتنمو في مزرعة خاصة بقرية البوصيلى مركز رشيد محافظة البحيرة، مصر خلال مواسم ٢٠٢١ و ٢٠٢٢ وذلك لدراسة تأثيرالزيوت العطرية على الجودة وإطالة العمر التسويقى لثمارالجوافة الشتوى. تم غمس الثمار فى واحد من المحاليل الآتية: الماء المقطر (كنترول)، زيت القرنفل، زيت الكافور، زيت الخردل و زيت الجوجوبا و ذلك بمعدل ١٠٠٠ جزء فى المليون لمدة خمس دقائق. تم تخزين الثمار المعاملة على درجة حرارة ٧ ± ١ درجة مئوية و رطوبة نسبية ٩٠ – ٩٥ ٪ لمدة ٢٤ يوما. أظهرت البيانات أن الغمر في الزيوت العطرية لثمار الجوافة الشتوية بتركيز ١٠٠٠ جزء في المليون أدي إلي تقليل فقدان وزن وتلف ومعدل تنفس الثمار بالإضافة إلي تحسين صلابة الثمار والمواد الصلبة القابلة للزوبان والحموضة، ونسبة SSC / الحمض ومحتوى حمض الأسكوربيك مقارنة بمعاملة التحكم أثناء التخزين البارد. علاوة على ذلك، أظهرت النتائج انخفاضًا ملحوظًا في فقدان الوزن والتلف و معدل التنفس فى ثمار الجوافة إنخفض بشكل كبيرباستخدام زيوت الكافور والقرنفل. كذلك، و جد أن إستخدام زيوت الكافور والقرنفل فعال فى الحفاظ على الصلابة والحموضة وحمض الأسكوربيك والمواد الصلبة القابلة للذوبان ونسبة المواد الصلبة القابلة للذوبان / الحموضة خلال فترة التخزين.

وفقًا لذلك، يعتبر زيت الكافور وزيت القرنفل أكثر فاعلية في تقليل فقدان الوزن والتلف ومعدل التنفس وكذلك الحفاظ على الجودة لثمار الجوافة الشتوية في ظروف التخزين المبرد لمدة ٢٤ يومًا و ذلك عند المقارنة مع المعاملات الأخرى.