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Evaluating the Efficacy of Essential Oils and Chitosan in Reducing Post-Harvest Decay of Elmamora Winter Guava

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ABSTRACT

Guava is a perishable fruit that peaks and spoils quickly after harvest. This study investigates the effects of post-harvest treatments using essential oils, chitosan, and nano-chitosan on guava fruits' storage potential and quality. The experiment was conducted during the 2023 season using fruits from 14-year-old guava trees on a private farm in El-Qalubia Governorate, Egypt. The treatments included immersing the fruits for 5 minutes in solutions of distilled water (control), moringa oil, lemongrass oil, rosemary oil, marjoram oil, and chitosan at concentrations of 1%, 2%, and nano-chitosan at 100 & 200 ppm, respectively. The treated fruits were stored at 8±1°C and 90% relative humidity for 24 days. Results indicated that essential oils significantly reduced fruit rot and weight loss while improving fruit firmness, TSS%, acidity, TSS/acid ratio, and ascorbic acid content compared to the control. Moringa oil (1% & 2%) and nano-chitosan (100 ppm) were particularly effective in maintaining the firmness, acidity, vitamin C content, TSS%, and TSS/acid ratio of guava fruits during storage. The study concludes that moringa oil and nano-chitosan are highly effective in reducing weight loss, decay, and fruit quality while preserving the overall quality of winter guava fruits under cold storage conditions for 24 days.

Keywords: Guava, coating, essential oils, postharvest disease, fruit quality.

INTRODUCTION

In Egypt and throughout the tropical and subtropical regions of the world, guava (*Psidium guajava L.*) is regarded as a significant economic crop **[1].** Due to its high nutritional content, it has been used medicinally to cure a variety of ailments, including rheumatic disorders, gastroenteritis, diarrhea, and wound healing **[2].** Guava has exceptional properties, but postharvest preservation is a challenge for it **[3-5].** As a climacteric fruit, guavas have a short shelf life of three or four days at room temperature due to their quick rise in respiration rate and ethylene production **[6].**

Regretfully, postharvest losses exceed preharvest losses because of this vulnerability to harm **[7].** Guava fruit is susceptible to several physiological conditions as it ages, including weight loss and dry matter loss, as well as microbial invasions that cause rot and decay. The fruit's marketability and shelf life are greatly impacted by these problems **[8, 9].** By employing essential oils, chitosan, and nano-chitosan to manage postharvest issues and preserve overall fruit quality during storage, these losses can be reduced, and markets can showcase healthy fruits **[10].**

According to **[11, 12],** essential oils are natural antioxidants that are well known for their antibacterial and biodegradable qualities. They also have no lasting effect on fresh fruits. Accordingly, the presence of secondary metabolites produced by plants is associated with the antibacterial action of essential oils **[13].** Its hydrophobic components interact with the lipids in the microorganism's cell membrane to cause metabolic harm and cell death **[14].** This is how it works.

Several studies demonstrate how important it is to apply essential oils after harvest to protect guavas' overall quality and lengthen their shelf life while they are being stored. **[15],** for example, showed that guava fruits stored in 2% mustard oil, coconut oil, olive oil, almond oil, and grape seed oil showed better quality than the control treatment. This was indicated by a decrease in physiological loss, mold growth, and slower alterations in fruit color and other quality attributes. Significantly, olive oil proved to be an exceptional performer, increasing the shelf life of guava fruit to 28 days when kept cold and 16 days when kept at room temperature.

Comparably, **[16]** discovered that soaking guava fruits in 2% Jojoba oil preserved their sugar content, vitamin C, and TSS/acidity throughout storage while reducing weight loss, decay, and peroxidase enzyme activity. According to **[17],** guava fruits' overall quality metrics were efficiently preserved by essential oils of eucalyptus, Tulsi, and neem (2 ml/l) during a 15-day storage period at room temperature (20 °C), increasing the fruit's shelf life. Similar beneficial benefits were documented by **[18, 19]** when various quantities of cinnamon essential oil, coconut oil, peppermint oil, rosemary oil, and moringa gum were used. Consistent with these results, **[20]** showed that the best way to improve the quality of fresh fruit and prolong the shelf life of guava fruits stored at 25±1°C for 15 days was to apply peppermint essential oil postharvest at concentrations of 0.5, 1, and 1.5%. In addition to the benefits observed with essential oils, the application of chitosan and nano-chitosan has also shown promise in preserving fruit quality post-harvest during cold storage. Chitosan, a natural polysaccharide derived from chitin, and its nano-sized counterpart, nano-chitosan, forms a protective coating on the fruit surface, creating a barrier against moisture loss, gas exchange, and microbial invasion **[21].** This protective layer helps maintain fruit firmness, acidity, vitamin C content, soluble solids content (SSC %), and the SSC/acid ratio throughout storage **[22].** Furthermore, chitosan and nano-chitosan have been reported to exhibit antimicrobial properties, inhibiting the growth of pathogens responsible for fruit decay **[23].** Consequently, the combined use of moringa oil, chitosan, and nano-chitosan presents a comprehensive approach to post-harvest preservation, ensuring the prolonged storage of winter guava fruits while preserving their quality attributes for an extended period under cold storage conditions.

Therefore, the purpose of this study is to assess how applying certain essential oils, such as moringa, lemongrass, marjoram, rosemary, chitosan, and nano-chitosan postharvest, affects the prevention of decay, preservation of quality, and extension of the shelf life of winter guava fruits.

MATERIALS AND METHODS

The current study was carried out in the 2023 season. The winter guava fruit cultivar "Elmamora" was harvested in the second week of February at the maturity stage (yellowish green) according to **[24]**. Guava trees were grown in a commercial farm at El-Qalubia Governorate, Egypt. The trees were 14 years old, planted in loamy clay soil, a surface irrigation system was applied, and all recommended agricultural practices were followed. The fruits were nearly identical, seemingly uniform in size, and devoid of any obvious signs of infection. Fruits were selected and brought straight to the postharvest laboratory at the agriculture college, Ain Shams University, Shoubra El Kheima. All faulty fruits, including those with wounds and other conditions, were removed. The sound fruits at the same stage of maturity were cleaned on their surface for two minutes using a tap water solution, and they were then allowed to dry in the air at room temperature until all traces of moisture were removed from their surfaces. Five groups of clean fruits were created by random selection. For every examination period, there were three replicates in each treatment, and each replicate had 20 distinct fruits. The sample was taken every four days.

The treatments of Guava fruits:

Guava fruits were immersed in an aqueous solution as follows:

T n.	Treatments	T n.	Treatments
T1	Distilled water (control)	T8	lemon grass oil 1%
T2	Chitosan 1%	T89	lemon grass oil 2%

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T3	Chitosan 2%	T10	Marjoram 1%
T4	Nano chitosan 100ppm	T11	Marjoram 2%
T5	Nano chitosan 200ppm	T12	Rosemary 1%
T6	Moringa oil 1%	T13	Rosemary 2%
T7	Moringa oil 2%		

To increase wettability and adhesion to the surface of the guava fruit, five liters of an aqueous solution containing Tween-80 0.05% (v/v) were immersed in the fruit for five minutes. The fruits were air-dried for 30 min at ambient humidity using an electric fan following a dipping procedure. All fruits were packed in cardboard boxes measuring 45 × 35 × 10 cm. Experimental boxes were kept for 24 days at 8±1°C and 90% relative humidity. To study the effect of post-harvest treatments on the physical and chemical properties and diseases that appear, determine the type of disease, and measure the efficiency of the treatment used with guava fruits, each treatment was evaluated at the time of harvest and then every four days thereafter.

Symptomatology and isolation of post-harvest pathogens:

The symptoms were characterized by a brown center irregular circular shape found on control fruits (T1), with a focus on the shape, size, and color. The fruits were rinsed with alcohol, and isolation was done on potato dextrose agar (PDA) media for 5 days. The growing pathogen was later transferred to a new malt extract agar media to obtain pure culture, which was further incubated at room temperature for 7 days. Whereas the other treatments did not show any symptoms on treated fruits.

Morphology of isolated pathogen observation:

Pestalotiopsis species grown on petri dishes were observed macroscopically and microscopically. The macroscopic aspect focused on the colony shape, color, and mycelial growth. In microscopic characterization, 20 to 30 conidia were measured for the shape, size, median cell color, number and shape of the apical appendage **[25, 26].**

The Physical Characteristics Measurements

Weight loss percentage:

Guava fruits were weighed on the day of harvest, and the weight loss throughout each storage period was computed using the following equation: Fruit weight reduction percentage = (weight before storage - weight following storage / weight before storage) x 100.

Fruit firmness (Newton):

A penetrometer was used to measure fruit firmness; the results are given in Newton.

The Chemical Characteristics Measurements

The following measurements are made using the juice that is obtained from crushing the guava fruit pulp and filtered through a muslin cloth:

- The vitamin C content, expressed as mg/100 ml of juice, was calculated using **[27]** as a guide.

- According to **[27],** total soluble solids (TSS) and titratable acidity (TA) levels were determined using a hand refractometer for TSS and as grams of citric acid per 100 milliliters of juice for acidity.

- The TSS/TA ratio was computed by dividing the total acidity by the TSS values.

Ascorbic acid, total soluble solids, titratable acidity%, and TSS/acid ratio:

Fruit samples were juiced to assess the quality of the juice as follows: The SSC/acid ratio was estimated, the soluble solid content was measured using a hand refractometer, the titratable acidity as citric acid was determined by titrating with 0.1M sodium hydroxide using a phenolphthalein indicator, by **[28],** and ascorbic acid was measured as mg/100 ml juice using 2, 6 dichlorophenol indophenol, by **[29].**

Statistical analysis

There was total randomization in the arrangement of this experiment. Statistical analysis of the recorded data was performed using the MSTAT-C statistical program **(M-STAT, 1993)** and analysis of variance **(ANOVA).** Duncan's multiple range tests **(DMRT)** were used to compare means with a probability of < 0.05.

RESULTS AND DISCUSSION

The results of isolation revealed that the fruits were infected with *Pestalotiopsis* sp.

Symptoms of fruits

Symptomatology and isolation of post-harvest pathogens:

Five fruits had been taken from the control treatment, showing symptoms of black spots and brown center irregular circular shape all over the fruit and showing aggregates of spots on the fruit end stylet (fig. 1 and 2).

Fig. 1 shows black spots with brown centers and irregular circular shapes all over the fruit.

Fig. 2 shows the aggregates of spots on the fruit end stylet.

Morphology of isolated pathogen observation:

Results of isolation revealed that the pathogen on potato dextrose agar (PDA), as shown in the figure, after 5 days was then transferred to a new malt extract agar media to obtain pure culture of the growing a pure isolate pathogen, which was further incubated at room temperature for 7 days. Fig. 3 and fig. 4 showed that the colony

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shape, color, and mycelial growth were related to *Pestalotiopsis* species. After that, microscopic examination for the characterization of the isolated conidia after measuring for spore size was determined by measuring the length and width of 20 to 30 selected conidia from a conidial suspension. The isolates were identified initially by comparing morphological and cultural characteristics (i.e., size of conidia, color and length of median cells, thickness and length of apical appendages, and length of basal appendage) to those described in Guba's monograph, which showed that the isolated post-harvest pathogen is *Pestalotiopsis* species (fig. 5 and 6).

Fig. 3 shows the isolated fungi on PDA after 5 days.

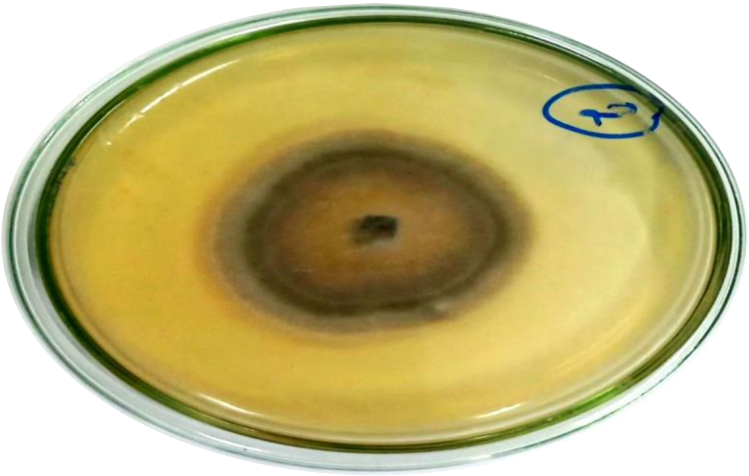

Fig. 4 shows the isolated fungi on malt extract agar media after 7 days.

Microscopic examination

After microscopic examination of the fungi after purification the results showed that its *Pestalotiopsis sp.*

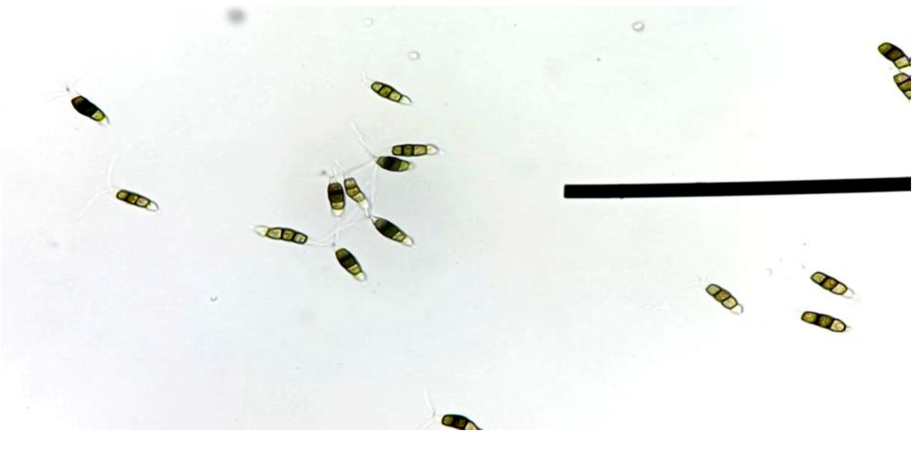

Fig. 5 shows the conidial spores of *Pestalotiopsis* sp.

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume X Issue IV April 2025

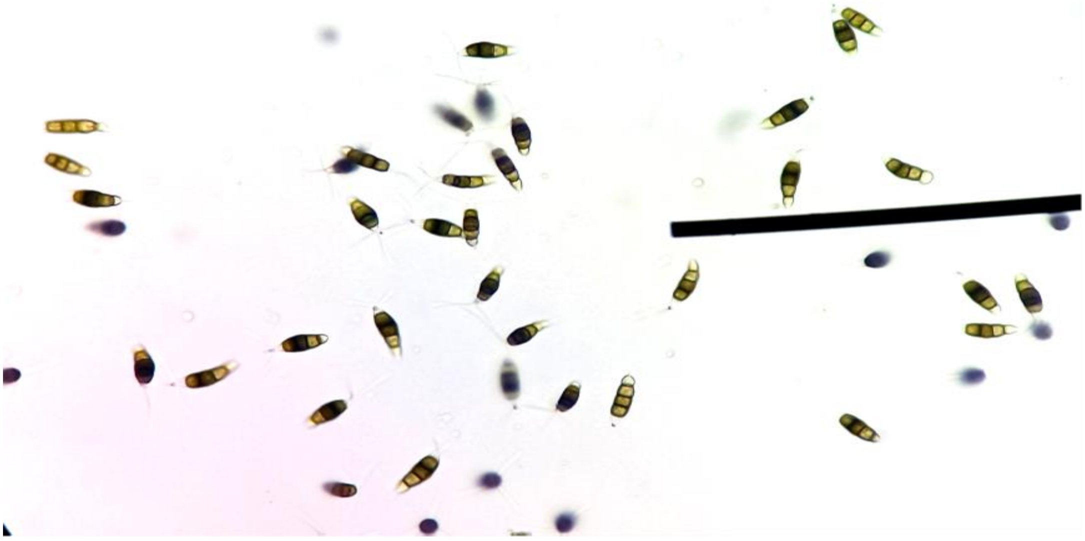

Fig. 6 shows the conidial spores of *Pestalotiopsis* sp.

Fruit weight loss (%):

The findings in Table (1) demonstrated that the weight loss of 'Elmamora' cv. winter guava fruit was affected by the treatments during the storage conditions for 24 days at 8 ± 1°C and 90% relative humidity. Additionally, when compared to control fruits, fruit weight loss was considerably reduced when immersed in various essential oil solutions throughout the storage period. Winter guava fruits dipped in moringa oil and nano-chitosan throughout the first season's storage period showed the least amount of weight loss, while in the second season, the two oils that produced the lowest percentages of weight reduction were moringa oil and nano-chitosan. In contrast, guava fruits. The control group, which was submerged in distilled water, showed the greatest weight loss values during the 24-day storage period at 8±1°C and 90% relative humidity. These results align with the findings of **[30, 31]** regarding guava fruits.

[32] also showed that soaking guava fruits in nano-chitosan 100 ppm decreased the amount of weight loss and the percentage of deterioration after 12 days of storage at 27 ± 1°C. In a similar vein, **[18]** found that applying essential oil after harvest decreased the incidence of weight loss and degradation during the cold storage of guava fruits.

Table 1. Effect of essential oils and chitosan on weight loss % during cold storage conditions (at 8±1°C and 90% RH) of 'Elmamora' cv. winter guava fruits in 2023.

Treatments	Days after Storage					
	4	8	12	16	20	24
Control	17.5a	29.5d	37.66b	-	-	-
Chitosan 1%	13.08b-d	18.7h	25.6d	31.82b	38.81a	-
Chitosan 2%	12.87b-d	15.77i	21.05f	23.89d	34.63b	34.2a
Nano chitosan 100ppm	12.35de	16.28i	19.39g	23.55de	24.63e	31.74c
Nano chitosan 200ppm	12.77c-e	34.62c	-	-	-	-
Moringa oil 1%	11.83e	14.8j	17.44h	23.58d	27.75d	32.61b
Moringa oil 2%	11.87e	15.77i	18.23h	22.54e	24.88e	28.74d
lemongrass oil 1%	12.78c-e	35.55b	-	-	-	-
lemongrass oil 2%	13.73bc	39.52a	-	-	-	-
Marjoram 1%	12.74de	27.59e	39.05a	-	-	-
Marjoram 2%	13.8b	25.26f	30.1c	38.35a	-	-
Rosemary 1%	13.2b-d	19.77g	23.88e	25.54c	32.76c	-
Rosemary 2%	12.52de	15.67i	17.4h	23.58d	27.75d	-

Means in each column had identical letters do not differ appreciably at the 5% level.

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume X Issue IV April 2025

Fruit firmness (Newton):

The findings presented in Table (2) demonstrated that during both seasons, fruit hardness progressively declined as the storage period increased. It is also interesting that, in both seasons, fruit firmness was improved by all tested essential oils when compared to the control treatment.

In comparison to alternative oil treatments, guava fruits coated with eucalyptus and clove oils showed the highest values of firmness in both seasons **[33]**.

[34, 17, 35] all produced comparable findings. When compared to untreated fruits, all tested oils in this study significantly maintained the highest fruit firmness of winter guava fruits throughout the 24-day storage period, with moringa oil-coated fruits exhibiting the highest firmness.

The beneficial impact of essential oils in maintaining firmness can be linked to several factors, such as minimizing water loss and fruit senescence, inhibiting cell wall degradation by suppressing microbial activities, reducing or delaying various aspects of fruit ripening by decreasing its sensitivity to ethylene **[36],** and so on **[11].** These results are consistent with those of **[31],** who found that after nine days of room temperature storage, 1% mint oil was more successful in preserving the firmness of guava fruit. Essential oils work well to keep guava solid during storage by limiting the activity of cell wall enzymes, lowering respiration and ethylene production, and preserving the barrier to water vapor. All these processes work together to keep fruit firm **[7, 15].**

Table 2. Effect of essential oils and chitosan on firmness (N/cm^2) during cold storage conditions (at 8±1°C and 90% RH) of 'Elmamora' cv. winter guava fruits in 2023.

Treatments	Days after Storage					
	4	8	12	16	20	24
Control	4.07ab	3.96bc	3.85bc	-	-	-
Chitosan 1%	4.25ab	4.62ab	4.66ab	4.6a	4.41b	-
Chitosan 2%	5.16a	4.62ab	4.82ab	4.6a	5.62a	4.91a
Nano chitosan 100ppm	5.18a	5.41a	5.07a	4.74a	5.57a	5.07a
Nano chitosan 200ppm	3.74ab	3.07cd	-	-	-	-
Moringa oil 1%	5.26a	5.24a	4.74ab	4.41a	5.57a	4.12a
Moringa oil 2%	5.26a	5.41a	4.74ab	4.74a	5.57a	4.91a
lemongrass oil 1%	3.41b	2.74d	-	-	-	-
lemongrass oil 2%	3.41b	3.91b-d	3.41c	-	-	-
Marjoram 1%	4.69ab	4.57ab	4.41a-c	4.41a	-	-
Marjoram 2%	4.7ab	4.74ab	4.57ab	4.57a	-	-
Rosemary 1%	4.73ab	4.91ab	5.07a	4.57a	3.41c	-
Rosemary 2%	4.67ab	4.41ab	4.74ab	4.57a	3.57c	-

Means in each column had identical letters do not differ appreciably at the 5% level.

Total Soluble Solids:

The results in Table (1) showed that the Total Soluble Solids of guava fruits were affected by the treatments during the cold storage period. Treatment with chitosan at 2%, nano-chitosan at 100 ppm, and moringa oil at 1% and 2% helped to increase the total soluble solids, especially after 16 days of cold storage. On the other hand, the fruit quality deteriorated after 8 days of cold storage when treated with lemongrass oil and treated with nano-chitosan at 200 ppm.

The findings of **[37-40]** indicate that essential oils can help preserve fruit quality by slowing down metabolic activity and respiration rates. This reduction in metabolic processes helps prevent the loss of total soluble solids, which are crucial for the fruit's taste and texture, thereby reducing degradation and over-ripening during storage.

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume X Issue IV April 2025

Table 3. Effect of essential oils and chitosan on total soluble solids (°Brix) during cold storage conditions (at 8±1°C and 90% RH) of 'Elmamora' cv. winter guava fruits in 2023.

Treatments	Days after Storage					
	4	8	12	16	20	24
Control	10.08a	10.31d-f	11.40a	-	-	-
Chitosan 1%	9.61cd	10.12e-g	10.83c	11.03c	10.61b	10.61b
Chitosan 2%	9.61d	10.31d-f	10.75c	11.40a-c	11.73a	11.73a
Nano chitosan 100ppm	9.61a-c	10.40c-e	10.72c	11.12bc	11.42a	11.42a
Nano chitosan 200ppm	9.61a	11.10a	-	-	-	-
Moringa oil 1%	9.61b-d	10.62b-d	10.81c	11.41a-c	11.56a	11.56a
Moringa oil 2%	9.61b-d	10.90ab	11.03b	11.73a	11.93a	11.93a
lemongrass oil 1%	9.61a	10.79a-c	-	-	-	-
lemongrass oil 2%	9.61ab	10.80a-c	-	-	-	-
Marjoram 1%	9.61d	9.70h	10.09e	-	-	-
Marjoram 2%	9.61b-d	9.96f-h	10.13e	9.55d	-	-
Rosemary 1%	9.61d	9.88gh	10.42d	11.14bc	9.08c	9.08c
Rosemary 2%	9.61b-d	10.12e-g	10.73c	11.52ab	9.25c	9.25c

Means in each column had identical letters do not differ appreciably at the 5% level.

Titratable acidity (%):

The data presented in Table 4 showed the effect of essential oils and chitosan on titratable acidity during cold storage conditions (at 8±1°C and 90% RH) of 'Elmamora' cv. winter guava fruits. Acidity values significantly increased with the increasing storage period. In general, treatment with chitosan 1%, nano-chitosan at 100 ppm, and moringa oil 1% resulted in a decrease in the estimated acidity during the storage period compared to the other treatments. Our results indicate that essential oil treatments help preserve the titratable acidity of fruits during storage. Essential oil treatments appear to positively affect the respiration process, potentially reducing or delaying the respiration rate and maintaining titratable acidity. These results are consistent with those of **[41]**, possibly due to delayed metabolic alterations and a slowdown in respiration induced by essential oil coatings **[42]**.

Table 4. Effect of essential oils and chitosan on titratable acidity (%) during cold storage conditions (at 8±1°C and 90% RH) of 'Elmamora' cv. winter guava fruits in 2023.

Treatments	Days after Storage					
	4	8	12	16	20	24
Control	0.78a	0.82a	0.84bc	-	-	-
Chitosan 1%	0.76a-d	0.77cd	0.79d-f	0.87c	0.88b	-
Chitosan 2%	0.76a-d	0.77cd	0.78ef	0.83d	0.84bc	0.91b
Nano chitosan 100ppm	0.75cd	0.77cd	0.79d-f	0.81de	0.8bc	0.92b
Nano chitosan 200ppm	0.78a	0.8a-c	-	-	-	-
Moringa oil 1%	0.78ab	0.77cd	0.79d-f	0.82d	0.88b	0.92b
Moringa oil 2%	0.75b-d	0.77cd	0.78f	0.78e	0.79c	0.96a
lemongrass oil 1%	0.77a-c	0.79a-c	-	-	-	-
lemongrass oil 2%	0.74d	0.76d	-	-	-	-
Marjoram 1%	0.78a	0.82a	0.9a	-	-	-
Marjoram 2%	0.78a	0.79b-d	0.88ab	0.99a	-	-
Rosemary 1%	0.78a	0.81ab	0.83cd	0.91b	1.01a	-
Rosemary 2%	0.77a-c	0.8a-c	0.82c-e	0.88bc	1.03a	-

Means in each column had identical letters do not differ appreciably at the 5% level.

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume X Issue IV April 2025

TSS/acidity ratio:

As shown in Table (5), The values of the TSS/acidity ratio increased when Elmamora' cv. winter guava fruits were treated with chitosan 1%, nano-chitosan 100 ppm, and moringa oil 1% during the first 20 days under refrigerated storage conditions, then began to decrease after 24 days, while the TSS/acidity ratio rate began to deteriorate after 8 days of storage in the other treatments. These findings are supported by **[33]**, who revealed that postharvest application of essential oils delayed ripening by reducing total soluble solids and total sugars compared to the control. Similarly, **[15, 17, 40]** demonstrated that guava fruits coated with essential oils such as eucalyptus oil, neem oil, coconut oil, and moringa oil tended to delay ripening. This was evidenced by the lowest total soluble solids (TSS) percentage and the highest acidity percentage in the juice.

Table 5. Effect of essential oils and chitosan on TSS/acidity ratio during cold storage conditions (at 8±1°C and 90% RH) of 'Elmamora' cv. winter guava fruits in 2023.

Treatments	Days after Storage					
	4	8	12	16	20	24
Control	12.92bc	12.57ef	13.52bc	-	-	-
Chitosan 1%	12.65b-d	13.08de	13.71a-c	12.73cd	12.06d	-
Chitosan 2%	12.54cd	13.33cd	13.78ab	13.68b	14.02bc	12.34ab
Nano chitosan 100ppm	13.24ab	13.46cd	13.63a-c	13.73b	14.28ab	12.48a
Nano chitosan 200ppm	12.87bc	13.87a-c	-	-	-	-
Moringa oil 1%	12.5cd	13.73a-c	13.68a-c	13.92b	13.09cd	12.48a
Moringa oil 2%	12.87bc	14.1ab	14.2a	14.97a	15.17a	11.9b
lemongrass oil 1%	13.04a-c	13.6b-d	-	-	-	-
lemongrass oi l2%	13.54a	14.22a	-	-	-	-
Marjoram 1%	12.09d	11.89g	11.21e	-	-	-
Marjoram 2%	12.47cd	12.67ef	11.56e	9.68e	-	-
Rosemary 1%	12.22d	12.2fg	12.61d	12.2d	8.99e	-
Rosemary 2%	12.58cd	12.65ef	13.09cd	13.04c	8.99e	-

Means in each column had identical letters do not differ appreciably at the 5% level.

L-Ascorbic Acid:

The results in Table 6 clearly show that the ascorbic acid content in winter guava fruits stored at 8±1°C with 90% relative humidity gradually decreased over the 24-day storage period. Moreover, fruits coated by moringa oil exhibited significantly higher levels of ascorbic acid content compared to other treatments, especially after 24 days. Plant-based edible coatings applied to citrus fruits, such as Jara lebu (*Citrus medica*), have been shown to significantly prolong shelf life and retain essential nutrients, including vitamin C **[43]**. Edible coatings can enhance the hardness, titratable acidity, and vitamin C content in whole fruits **[44]**.

Table 6. Effect of essential oils and chitosan on L-Ascorbic Acid (mg/100 ml of the juice) during cold storage conditions (at 8±1°C and 90% RH) of 'Elmamora' cv. winter guava fruits in 2023.

Treatments	Days after Storage					
	4	8	12	16	20	24
Control	33.11b	31.54cd	29.98bc	-	-	-
Chitosan 1%	33.16b	31.29d	30.38b	30.19d	28.07d	-
Chitosan 2%	33.13b	32.27b	31.05b	30.44d	29.34c	27.65d
Nano chitosan 100ppm	33.6ab	31.96b-d	31.18b	29.43e	29.33c	28.49c
Nano chitosan 200ppm	33.06b	29.58ef	-	-	-	-
Moringa oil 1%	33.23b	34a	33.06a	32.49b	31.05b	29.41b
Moringa oil 2%	34.08a	34.12a	33.07a	32.94a	32a	29.93a
lemongrass oil 1%	33.23b	28.37h	-	-	-	-

lemongrass oil 2%	33.28b	28.73gh	-	-	-	-
Marjoram 1%	32.13c	30.09e	28.59c	-	-	-
Marjoram 2%	32.2c	29.31fg	29.8bc	23.29g	-	-
Rosemary 1%	33.26b	32.07bc	29.85bc	25.79f	23.01e	-
Rosemary 2%	33.23b	32.18bc	33.11a	30.99c	28.12d	-

Means in each column had identical letters do not differ appreciably at the 5% level.

CONCLUSIONS

The study concludes that post-harvest treatments using Moringa oil and nano-chitosan are highly effective in reducing weight loss, decay, and maintaining the overall quality of winter guava fruits during cold storage for 24 days. These treatments significantly improved fruit firmness, acidity, vitamin C content, TSS%, and the TSS/acid ratio compared to the control. The use of essential oils and chitosan-based treatments presents a promising approach to enhancing the storability and marketability of guava fruits.

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