

Effect of leaf and seed powder based edible coating with beeswax and Clove essential oil on the shelf life of guava (*Psidium guajava*) cv. Allahabad Safeda

Abstract

The guava is thought to be India's most significant commercial fruit crop. Due to their high respiration rate, vulnerability to different pathogens, and mechanical damage that can quickly deteriorate the quality and concised its shelf life. Nonetheless, the purpose of the experiment was to investigate how guava's edible coatings affected its postharvest quality and shelf life. Guava fruits were treated by seven treatments of different concentrations of beeswax, guava leaf powder, neem leaf powder, tamarind seed powder, and clove oil with different combinations were used as edible coating were studied in a Factorial Completely Randomized Design (CRD) with three replications. All seven treatments were used to examine the impact of edible coating materials on the physical and chemical properties. Under ambient conditions, the variations in physiological and chemical parameters were seen. The findings of present study showed maximum fruit weight (120.29 g), highest vitamin C (163.19 mg/100g), maximum acidity (0.49%) and antioxidant activity (35.43%) obtained from T4 [Neem leaves powder (2%) + Beeswax (1%)+ clove oil (1%)] compared with untreated fruits. The result suggested that the applications of [Neem leaves powder (2%) + Beeswax (1%) + clove oil (1%)] as an edible coating material in guava fruit is more effective than other treatments to improve the shelf life of Guava.

Keywords: edible powder, beeswax, clove oil, bioactive compound, antioxidants

Introduction

The guava (*Psidium guajava* L.) is a well-known tropical and subtropical fruit that is grown all over the world. Guava belongs to the Myrtaceae family. More than 3800 different species of shrubs belong to the genus *Psidium*. Guava is a tropical fruiting tree that grows annually, is the toughest among tropical fruiting trees, and is the most tolerant of all environmental conditions (Jain *et al.*, 2024). The guava fruit is rich in minerals and vitamins C, A, B1, and B2. The main components of red fleshed guava are the nutraceuticals, namely alpha-carotene, lycopene, and phenolic compounds along with high levels of vitamin C, all of which have antioxidant properties (Jumrah *et al.* 2024). The use of edible coatings is simple, inexpensive, and environmentally friendly. Biopolymers derived from natural sources, such as polysaccharides, proteins, lipids, or a multi-component mixture, are the basis for edible films and coatings (Basharat *et al.* 2024). These edible coatings serve as physical barriers on the surfaces of fruits and vegetables, reducing their permeability to O₂, CO₂, and water vapor, which lowers their respiration and transpiration rate. This is the main benefit of edible coatings, which has been shown in a wide range of fruits and vegetables, including apple, papaya, guava, plum, mango and apricot (Pillai *et al.* 2024). Clove oil is a natural product derived from the fragrant flower buds of the *Syzygium aromaticum* tree. It includes multiple compounds, but the most active ones are eugenol, eugenyl acetate, and caryophyllene. Eugenol is the primary component, comprising (70-90%) of the oil. Other components are eugenyl acetate (10-40%), β -caryophyllene, and α -humulene. Clove essential oil has sparked significant attention due to its widespread use in the perfume, cosmetic, health, medical, flavoring, and culinary industries (Pandey *et al.* 2024). It possesses biological activity that benefits human health, including antibacterial, antioxidant, and insecticidal properties. Beeswax is a natural glazing agent that can be used in food to stop water loss and offer

protection while being stored. Beeswax's oxygen moisture barrier properties fall between low and high density polyethylene (Hosseini *et al.* 2023). A study revealed the effect of sodium alginate coating and combination of Sodium Alginate (2%) and Neem Leaf Extract (20%) coatings which maintained the antioxidant capacity and overall physiochemical properties on kinnnow (Kaur *et al.* 2024). Zaidi *et al.* (2023) investigated to improve the shelf life of guavas by coating them with garlic extract (GRE), ginger extract (GNE), gum arabic (GA), and Aloe vera (AV) by coated and stored for 15 days. The treated guavas showed improvements in total flavonoids, total sugar content, taste and aroma scores, and lowered total soluble solids and juice pH (more acidic). Majeed *et al.* (2024) disclosed that mango leaf extract, lemon leaf extract (500-2000mg/l) and Gum Arabic (5%-15%) coating had good potential in preserving the guava fruits for longer period of time and maintained its physical appearance and quality. Post-harvest quality preservation of guava continues to be a production challenge because of the less post-harvest life due to its high rate of respiration, high ethylene rate, rapid firmness loss, and decay loss during storage. Due to the high level of postharvest losses in guava, innovative techniques were needed to preserve the fruit's quality through the prudent application of post-harvest treatments (Bisht *et al.* 2024).

A potential research gap to examine these coatings affect the fruit's long-term physical and biochemical properties could be one area of unfulfilled research need. A dearth of studies investigating the long-term performance of these coatings may exist, despite the fact that many studies concentrate on their immediate impacts. Producers and consumers alike may benefit from knowing how long these coatings last and how effective they are over time, especially in areas where guava is a major agricultural crop and storage conditions might vary greatly. Further research may also be necessary to examine the scalability and economic viability of applying such coatings on a commercial basis. These approaches have shown promise as potential strategies to boost the profitability and shelf life of guava fruit with the help of edible coating.

A scientific study aimed at transforming guava and neem leaves, as well as tamarind seeds, into a highly valuable product for the guava industry. As a result, the purpose of this study was to assess the antioxidant and antibacterial properties of films containing leaf and seed extract that had both antioxidant and antimicrobial properties that helps in enhancing the shelf life of guava. The external and internal changes of guava fruit were measured during storage. The findings are examined and presented, along with appropriate explanations.

MATERIALS AND METHODS

The Guava fruits with variety "Allahbad safeda" were acquired from the local farmer of 'Punjab' of uniform size, color, free of physical damage and fungal infection were selected and washed with distilled water. The guava leaves and Neem leaves used in treatments were taken from the Herbal Garden of Lovely Professional University (LPU), Phagwara, Punjab and tamarind seeds from the local market of Phagwara, Punjab. About 294 fruits were taken for experiment for the analysis of chemical and physical properties with 7 treatments and their 3 replications. The coating of fruits were done with several combinations of Guava leaf powder, Neem leaf powder, Tamarind seed powder, Bees wax and clove oil by dipping the fruits for 5 minutes in solution. Samples of both treated and control were taken out on every 3, 6, 9, and 12 days at ambient temperature for physiochemical analysis.

Preparation of coating materials

Tamarind seeds were purchased from the local seed market and immediately transferred to the laboratory. They were soaked overnight in water (1:3 w/v) and washed using distilled water. The cleaned seeds were air-dried in hot air oven at 343 K temperature for 14 days. The seed powder was prepared by using a grinder. The powder was sieved through a 250 µm mesh and stored in an airtight container in a freezer at $-18 \pm 2^\circ\text{C}$ before use.

Preparation of tamarind (*Tamarindus indica*) seed powder with preserved antimicrobial activity was performed according to the method described by (Natukunda *et al.* 2016).

Mature guava and neem leaves obtained from Herbal garden of LPU, Punjab and washed with distilled water. Then, the Guava and neem leaves were dried in a hot-air oven at the temperature of 343 K for 8 h and then ground to fine powder using grinder. The beeswax and clove essential oil were obtained from the laboratory of Department of Horticulture, LPU, Punjab. The clove essential oil was used in the pure form. The wax coating was made by dissolving 150g of bee wax in 10 ml of water on a hot plate and making sure that every part of the beeswax was completely hydrated. The melted bee wax solution was then added with 20 ml of oleic acid and 60 ml of triethanolamine (TEA). Finally, water was added until the solution reached a volume of 1 liter. The clove essential oil was used in the pure form. The coating materials will be dissolved in appropriate amount of solvent and solution were subjected to homogenization at 10,000 rpm for 10 minutes

Physical parameters

Fruit weight (g) of selected fruit was weighed with the help of electronic balance; the average weight of fruit was calculated and expressed in grams. Fruit length of fruit was measured from calyx end to the pointed end or apex of the fruit with the help of vernier caliper and expressed in inch. Fruit Width of fruit was measured from the shoulders of the fruit with the help of vernier calliper and expressed in inch. Decay Loss (%) was determined by taking spoiled fruit upon total number of fruits taken and expressed in percentage.

$$\text{Decay loss (\%)} = \frac{\text{Number of rotten fruits}}{\text{Initial no of fruits taken}} \times 100$$

Fruit Firmness was analyzed with the help of Penetrometer. Firmness was measured as the maximum penetration force (N) reached during tissue breakage and determined with a 5 mm diameter flat probe. The penetration depth was 5 mm and cross head speed was 5 mm/s (Hung *et al.* 2001).

Chemical Parameters

For chemical analysis T.S.S (° Brix), Titratable acidity (%), Ascorbic acid (mg/100g flesh), Reducing sugar (%), Non reducing sugar (%), Total sugar (%), Antioxidants activity (%) were measured with different methods.

The TSS of fruit was determined with the help of a digital refractometer (0-32 °brix) by putting a few drops of juice on the prism.

Acidity was determined by using the specified method (A.O.A.C, 1975) by titrating a known volume of fruit sample against 0.1N NaOH solutions using phenolphthalein as an indicator up to the end point (light pink colour). It is expressed in percent, as per formula given below:

$$\text{Acidity (\%)} = \frac{\text{Titre} \times \text{Normality of NaOH} \times \text{Vol. made up} \times \text{Equivalent weight of acid} \times 100}{\text{Volume of sample taken} \times \text{Aliquot Taken} \times 100}$$

Ascorbic acid was determined by using 2, 6-dichlorophenol-indophenol dye through visual titration method (Freed, 1966). Total sugars were estimated methods given by Lane and Eynon (1923). Antioxidant activity of fruit juice was determined on the basis of its radical scavenging effect on the DPPH

free radical (Brand-Williams *et al.*, 1995). Both DPPH reagent and sample were prepared in (70%) methanol. In a test tube, 100 µl of sample was taken, to which 3.9 ml of DPPH was added and the optical density was measured at 517 nm.

Statistical Analysis

The experiment comprises of seven treatments of Neem leaf powder, Guava leaf powder, Tamarind seed powder, clove essential oil and beeswax. The following treatments were compared. Experiment was laid out in factorial Complete Randomized Design (CRD) with three replications.

Applied treatments

T₀: control, T₁: Guava leaf powder (1%) + Bees wax (1%) + clove oil (1%), T₂: Guava leaf powder (2%) + Bees wax (1%) + clove oil (1%), T₃: Neem leaf powder (1%) + Bees wax (1%) + clove oil (1%), T₄: Neem leaf powder (2%) + Bees wax (1%) + clove oil (1%), T₅: Tamarind Seed powder (1%) + Bees wax (1%) + clove oil (1%), T₆: Tamarind Seed powder (2%) + Bees wax (1%) + clove oil (1%).

RESULTS AND DISCUSSION

Physical parameters

(1) **Fruit weight (g)**: There was a decrease in fruit weight over time in all treatments, on the 6th day the fruit weight of the untreated fruits was found to be lowest (116.94 g) in T₀ treatment, while the fruit weight of the T₄ treatment was the greatest (121.19 g) compared to the other treatments. In a similar way, the weight of uncoated guava fruits kept at room temperature dropped to 107.31 g on 12th day as rather than T₄ (114.43 g) on the same day for coated fruits followed by T₁ (114.12 g) which was statistically at par with T₅ (113.41 g) and T₃ (113.11 g) as shown in (Table 1). The result indicated that coating formulations act positively as a conservative agent which delayed the loss in weight of coated fruits. Neem contains a number of active ingredients that are antibacterial and antifungal, including nimbidin, nimbin, and nimbidol. Neem leaf extracts may be a viable alternative in the fight against pathogens that cause guava to deteriorate. These results are consistent with those reported by (Freitas *et al.* 2018) who observed least reduction in fruit weight with neem leaf extract (5% and 10%) coatings during storage period of papaya fruit.

(2) **Fruit Length (cm)**: The fruit length was significantly affected both coating and non coated fruits. Fruits which are not treated gradually drop to (7.47 cm), whereas the T₄ treatment shows a fall of (7.62 cm) on the 3rd day. In a similar vein, on the 12th day, the length of uncoated guava fruits kept at room temperature was shorter (6.04 cm) than that of T₄ (7.13 cm) followed by T₅ (7.17 cm), which was statistically at par T₁ (7.12 cm), T₃ (7.13 cm) with as described in (Table 1). This may be attributed to the anti-senescent properties of coatings that hindered the production of ethylene, prevented the activity of enzymes necessary for cell maturation, and avoided cell degradation. These properties allow for decreased moisture loss and a decreased transfer of respiratory gas, which in turn slowed senescence and decreased the percentage of shrinkage. This was consistent to report of Bee wax and essential oil coating useful in maintaining the fruit length of guava (Varma *et al.* 2022).

Table 1: Effect of edible coating on fruit weight (g), fruit length (cm), fruit width (cm) of guava cv. Allahabad Safeda

Treatments	Fruit weight (g)					Fruit length (cm)					Fruit width (cm)				
	Storage Days					Storage days					Storage days				
	0	3	6	9	12	0	3	6	9	12	0	3	6	9	12
T ₀	121.46	119.29	116.94	112.99	107.31	7.59	7.47	7.38	7.15	6.04	6.82	6.74	6.64	6.48	5.98
T ₁	123.88	123.08	120.44	117.11	114.12	7.66	7.59	7.52	7.38	7.12	6.92	6.86	6.8	6.72	6.36
T ₂	121.74	120.09	118.14	114.29	110.43	7.6	7.48	7.41	7.21	7.03	6.83	6.76	6.68	6.59	6.12
T ₃	125.53	121.99	119.98	115.98	113.11	7.63	7.53	7.47	7.28	7.13	6.88	6.81	6.74	6.65	6.25
T ₄	124.88	123.19	121.24	117.69	114.43	7.67	7.62	7.56	7.42	7.28	6.94	6.89	6.84	6.76	6.46
T ₅	123.04	122.69	120.24	116.6	113.41	7.64	7.57	7.5	7.34	7.17	6.9	6.83	6.76	6.68	6.32
T ₆	123.28	120.39	118.74	115.79	112.39	7.61	7.49	7.43	7.24	7.07	6.86	6.78	6.7	6.61	6.21
C.D	0.473	0.438	0.346	0.448	0.414	0.02	0.04	0.03	0.07	0.05	0.044	0.089	0.071	0.054	0.108
SE (m)	0.252	0.241	0.113	0.244	0.135	0.009	0.015	0.012	0.024	0.019	0.015	0.029	0.023	0.018	0.035

(3) Fruit Width (cm): As storage days increases the untreated fruits shows sudden decrease in fruit width as compared to treated fruit. The fruit width gradually reduced to 6.74 cm in the T₀ treatment on the 3rd day of storage, compared to 6.89 cm in the T₄ treatment. On the 12th day, the width of the uncoated guava fruits reduced to 5.98 cm, while the highest fruit width was showed in T₄ (6.46 cm) followed by T₁ (6.36 cm) and T₅ (6.32 cm) as mentioned in (Table 1). T₄ shows better results among all treatments. Similar results were obtained by Tigga et al. (2024) who used essential edible oil coatings of rice bran oil, olive oil, coconut oil, cinnamon oil, and mustard oil under cold storage condition on cape gooseberry

(4) Firmness (kg/cm²): The fresh fruit had good firmness and its decreases with storage period of time. The firmness of the uncoated fruits gradually reduces to (3.67 kg/cm²) on the 6th day, as indicated in (Table 2), contrast to (4.86 kg/cm²) in the T₄ treatment, followed by T₁ (4.81 kg/cm²) which was statistically at par with T₅ (4.74 kg/cm²). Similar to T₄ (3.65 kg/cm²) in coated fruits, the hardness of uncoated guava fruits kept at room temperature dropped to (1.9 kg/cm²) when compared to T₆ (3.44 kg/cm²) followed by T₂ (3.41 kg/cm²) and T₃ (3.36 kg/cm²) on the 12th day. During storage, fruits that are coated maintain their firmness whereas uncoated fruits get softer. The softness in the texture is positively associated with the level of ethylene which enhanced 4 to 6 days after harvest. This demonstrates the effectiveness of coating treatments in delaying maturation and metabolic processes, and consequently, the decomposition of fruit pulp. It was justified with the report of (Seun et al. 2022) used guava leaf powder and aloe vera effective in extending the shelf-life and firmness of orange fruits (Seun et al. 2022).

Table 2: Effect of edible coating on firmness (kg/cm²) and decay loss (%) of guava cv. Allahabad Safeda

Treatments	Firmness (kg/cm ²)					Decay loss (%)				
	Storage Days					Storage days				
	0	3	6	9	12	0	3	6	9	12
T ₀	5.19	4.36	3.67	2.65	1.9	0	0	4.24	6.41	11
T ₁	5.34	5.14	4.81	4.24	3.53	0	0	0	0	0
T ₂	5.27	4.89	4.53	4	3.41	0	0	0	0	2.34
T ₃	5.25	4.68	4.44	3.8	3.36	0	0	0	0	0
T ₄	5.39	5.21	4.86	4.48	3.65	0	0	0	0	0
T ₅	5.32	4.92	4.74	4.22	3.47	0	0	0	0	0
T ₆	5.29	4.75	4.58	4.07	3.44	0	0	0	0	2.28
C.D	0.09	0.36	0.31	0.45	0.41			0.07	0.11	2.62
SE (m)	0.03	0.11	0.10	0.17	0.13			0.023	0.038	0.857

(5) Decay loss (%): It shows significant differences among treatments during storage period. The decay loss (%) of the uncoated fruits and coating fruits did not show any spoilage up to 3rd day in all treatment. Maximum spoilage was shown in untreated fruit (4.24 %) on 6th day against other treatments which show no decay loss (%) up to 9 days. No decay loss (%) shown in T₁, T₃, T₄, T₅ followed by T₂ (2.34 %) and T₆ (2.28 %), **highest in uncoated fruits T₀ (11%)** at 12th day of storage at room temperature as shown in (Table 2). The lowest proportion of spoiling may be attributed to microbiological agent suppression and moisture prevention. On the other hand, low concentrations of oil preserve food during storage by preventing the spread of postharvest diseases such fruit rot. Similar findings of (Lakmali *et al.* 2019) used beeswax (1%) and essential oil which minimized the decay loss upto 12 days of storage period reported in guava fruit.

Chemical Parameters

(1) TSS (%): The total soluble solid of the uncoated and coated fruits increased continuously up to 9 days of storage and then decreased in all treatments. On the 9th day, the TSS in uncoated treatments increases to (10.53 °Brix), which was still lower than in T₄ treatment (11.8 °Brix). TSS of uncoated guava fruits held at room temperature reached (8.66 °Brix), while T₄ (10.63 °Brix) was recorded **followed by T₁ (10.55 %), which was statistically at par with T₅ (10.22 %) and T₃ (10.16 %)** on the 12th day in coated fruits as discussed in (Table 3). The conversion of complex carbohydrates into water-soluble sugars causes a TSS rise in the ripening of climacteric fruits, indicating that the fruits are going through this process. Moreover, edible coating alters the fruit's internal environment by raising CO₂ levels, which inhibits the synthesis of ethylene and delays the ripening of the fruit. Reduced temperature slows down the ripening process, which in turn slows down the breakdown of starch into soluble sugars. The favorable effect of chitosan (1%) and thymol oil in increasing the TSS has been reported in Pomegranate fruit by (Malekshahi *et al.* 2021).

(2) Acidity (%): Acidity of guava fruits decreased with increase in storage period up to 12 days. Coated fruits showed a slower decline in acidity than untreated fruits. The acidity of the uncoated fruits T₀ lowered to (0.58%) as rather than (0.69%) in T₄ treatment, followed by T₁ (0.64%) and T₅ (0.63%) on the 3rd day, as shown in Table 3. Likewise, acidity of uncoated guava fruits held at room temperature declined up to (0.49%), compared to T₃ (0.52%) followed by T₆ (0.51 %) and T₂ (0.5 %) on the 9th day in coated fruits and remained highest in T₄ (0.56 %). Guava with coating had a lower decline in total acid content compared to those without, possibly due to the calyx coating continuing to provide carbohydrate and vitamins even after harvest. Fruit cells use organic acids for respiration and convert acids into total sugars, which may explain why fruit acid content decreases as storage time increases. Similar reduction in acidity in guava is recorded with composite coating application of alginate (2%) and *Cyclea barbata* leaves powder (0.8%) by Utama *et al.* (2022).

Table 3: Effect of edible coating on TSS (°Brix) and acidity (%) of guava cv. Allahabad Safeda on shelf life

Treatments	TSS (%)					Acidity (%)				
	Storage Days					Storage days				
	0	3	6	9	12	0	3	6	9	12
T ₀	9.65	9.8	10.23	10.53	8.66	0.64	0.58	0.53	0.49	0.4
T ₁	10.08	10.87	11.59	11.65	10.55	0.74	0.64	0.6	0.55	0.46
T ₂	9.79	10.14	10.52	10.77	10.07	0.65	0.6	0.55	0.5	0.42
T ₃	9.86	10.07	10.77	10.89	10.16	0.69	0.62	0.57	0.52	0.44
T ₄	10.26	11.44	11.73	11.8	10.63	0.75	0.69	0.62	0.56	0.49
T ₅	9.94	10.57	10.89	11.02	10.22	0.7	0.63	0.58	0.53	0.45
T ₆	9.83	10.37	10.76	10.98	10.05	0.67	0.61	0.56	0.51	0.43
C.D	0.06	0.10	0.18	0.07	0.1	0.044	0.035	0.028	0.037	0.027
SE(m)	0.02	0.03	0.06	0.02	0.03	0.015	0.012	0.009	0.012	0.009

(3) Total Sugars (%): The total sugars in the uncoated fruits and coated fruit increased continuously up to 9 days of storage and then decreased in all treatments. The total sugars in uncoated treatments increase up to (9.52 %) but minimum than T₄ (10.5 %) treatment on 9th day. In the same way the total sugars of uncoated guava fruits decreases to (8.56 %) in comparison with T₄ (9.52 %) followed by T₁ (9.4 %) which was at par with T₅ (9.27 %) on 12th day in coated fruits as shown in (Table 4). As guava grew more mature, their total sugar content increased as a result of the starch being hydrolyzed into sugars. This increased sugar content peaked during the climacteric peak ripening stage, after which it was linked to an increase in the activity of the enzymes that hydrolyze starch and a decrease in the rate at which sugar degradation occurs through respiration. Murmu *et al.* (2018)

found that similar differences in total sugars between coated and uncoated mandarin fruits with application of (1.5%) sodium alginate, (0.7%) citric acid and (1.0%) sucrose ester.

(4) Reducing sugars (%): The data represented that the reducing sugars in the uncoated fruits and coated fruit increased continuously up to 9 days of storage and then decreased in all treatments. On the 9th day, T₄ had the highest decreasing sugar (5.76%), while uncontrolled treatment T₀ shown the lowest (5.06%) among all treatments as shown in (Table 4). After 9th days there were decrease in reducing sugars, uncoated fruits have least T₀ (4.36 %) and T₄ (5.17 %) have highest sugars followed by T₁ (5.03 %) and T₅ (4.94 %) on 12th day in coated fruits. The climacteric fruits may exhibit a significant shift in decreasing sugar content as they mature, converting starch and sucrose into glucose. In addition (Murmu *et al.* 2018) successfully used the Arabic gum, (1%) sodium caseinate, (1%) cinnamon oil based coating reduced the loss of reducing sugar.

(5) Non reducing sugars (%): Different treatments had a substantial effect on non-reducing sugars (Table 4). Various edible coating treatments have a substantial effect on non-reducing sugars (%). After 9 days of storage, T₄ had the highest non-reducing sugar content (4.74%) and T₀ had the lowest (4.46%) in uncoated guava fruits held at room temperature. On the 12th day of storage, T₄ had the highest non-reducing sugar percentage (4.39%) followed by T₁ (4.37 %), which is statistically at par with T₅ (4.33 %), T₃ (4.28 %), T₆ (4.26 %), T₂ (4.23 %) and T₀ had the lowest (4.2%) across all treatments. Other studies showed the effective use of Chitosan edible coating on strawberry fruit reported by (Petriccione *et al.* 2015).

Table 4: Effect of edible coating on sugars (%) of guava cv. Allahabad Safeda

Treatments	Total sugars (%)					Reducing sugars (%)					Non-reducing sugars (%)				
	Storage Days					Storage days					Storage days				
	0	3	6	9	12	0	3	6	9	12	0	3	6	9	12
T ₀	8.29	8.74	9.08	9.52	8.56	4.23	4.6	4.89	5.06	4.36	4.06	4.15	4.18	4.46	4.2
T ₁	8.46	9.11	9.55	10.33	9.4	4.31	4.9	5.14	5.65	5.03	4.15	4.32	4.4	4.68	4.37
T ₂	8.33	8.82	9.19	9.73	8.85	4.25	4.66	4.95	5.23	4.62	4.08	4.17	4.23	4.5	4.23
T ₃	8.39	9.02	9.37	10.07	9.09	4.28	4.78	5.06	5.49	4.81	4.11	4.25	4.3	4.58	4.28
T ₄	8.51	9.34	9.69	10.5	9.56	4.34	5.03	5.23	5.76	5.17	4.17	4.35	4.45	4.74	4.39
T ₅	8.43	9.08	9.43	10.2	9.27	4.3	4.85	5.1	5.6	4.94	4.13	4.27	4.32	4.6	4.33
T ₆	8.37	8.94	9.29	9.87	8.96	4.27	4.73	5.07	5.34	4.7	4.09	4.22	4.28	4.53	4.26
C.D	0.072	0.104	0.116	0.107	0.089	0.054	0.097	0.084	0.081	0.108	0.026	0.035	0.054	0.027	0.035
SE (m)	0.023	0.034	0.038	0.035	0.029	0.018	0.032	0.027	0.026	0.035	0.008	0.012	0.018	0.009	0.012

(6) Ascorbic acid (mg/100g): The data appeared shown the decrease in ascorbic acid with increase in storage period up to 12 days. On the 6th day of storage, as indicated in Table 5, the coated fruits of T₄ (227.19 mg/100g) were superior to the uncoated treatment T₀ (195.85 mg/100g). Comparably, on the 12th day of storage at room temperature, ascorbic acid in T₀ steadily decreased to (101.52 mg/100g) as contrasted with T₄ (163.19 mg/100g), which was followed by T₁ (162.52 mg/100g) and T₅ (161.85 mg/100g). As fruit ripens, ascorbic acid usually rises and falls with over-ripening. A decrease in ascorbic acid signifies the production of enzymes and the build-up of organic acids. One possible explanation for the decreased ascorbic acid loss in coated guava fruits could be the coatings' low oxygen permeability, which inhibits enzyme activity and hence stops ascorbic acid oxidation (Mitcham et al. 2024). Our results are in one line with findings of Maftoonazad *et al.* (2019) used pectin based coating maintained the ascorbic acid content in coated fruits that helps in maintaining the shelf life of the Lime fruit.

(7) Antioxidant activity (%): It shows that the antioxidant content of guava fruit noticed a gradual reduction during storage for up to 12 days, with the loss of antioxidant content during storage was faster in treatment T₀ (control). The result shows that treatment T₄ had the maximum antioxidant activity (39.45%) followed by T₁ (39.05%) which was statistically at par with T₅ (38.35%), T₃ (37.79%), T₆ (37.52%), T₂ (36.62%) on the 6th days of storage as discussed in (Table 5). The minimum values of antioxidant content (30.27%) were found in treatment T₀ (control) on the 12th days of storage among all treatments. This could be due to coatings that form a barrier around the fruit surface, reducing the oxygen supply required for enzymatic oxidation of phenolics and retaining DDPH activity. The same tendency was observed by Kumar *et al.* (2023) in which mint leaves extract based coating maintained the antioxidant activity of Ber fruit.

Table 5: Effect of edible coating on ascorbic acid (mg/100g) and antioxidant activity (%) of guava cv. Allahabad Safeda on shelf life

Treatments	Ascorbic acid (mg/100g)					Antioxidant activity (%)				
	Storage Days					Storage days				
	0	3	6	9	12	0	3	6	9	12
T ₀	243.19	211.19	195.85	170.52	101.52	42.71	39.39	36.02	33.83	30.27
T ₁	244.85	235.19	216.52	192.19	162.52	45.32	40.99	39.05	38.16	33.62
T ₂	244.52	226.19	215.19	190.44	160.31	43.18	38.59	36.62	35.36	31.32
T ₃	244.85	221.85	215.52	191.52	161.52	44.25	40.03	37.79	36.66	32.27
T ₄	246.89	235.52	227.19	195.85	163.19	45.91	41.36	39.45	38.6	35.43
T ₅	244.19	227.85	216.19	191.85	161.85	45.91	40.41	38.35	37.36	32.3
T ₆	244.85	225.19	211.19	191.52	160.85	43.36	39.56	37.52	36.46	31.61
C.D	0.316	0.319	0.317	0.305	0.297	0.099	0.301	0.398	0.257	0.294
SE (m)	0.103	0.104	0.103	0.099	0.097	0.032	0.098	0.130	0.084	0.096

Conclusion

It has been concluded that the application of T₄ [Neem leaves powder (2%) + Bees wax (1%) + clove oil (%)] on guava fruit is suitable to extend the shelf life as well as improving the overall quality parameters of the guava fruit. The appropriate amount of neem leaves was effective in maintaining the quality parameters of guava and higher amount of neem powder may leads to bitter taste due to the presence of nimbidin and nimbin compounds. The maximum antioxidant activity and ascorbic acid obtained in T₄ followed by T₁ was effective for maintaining its chemical attributes. The Neem is an edible coating material which has many benefits for human health shows the best results as compared to other treatments. Coatings delayed the ripening process which protected the fruits from weight loss, maintained its antioxidant activity, TSS, and other physio-chemical parameters of guava fruit when compared to the uncoated fruits, allowing up to 12 days of storage conditions suitable for consumption in higher proportion. Hence this study recommends treatment T₄ is very effective for edible coating material for extend the shelf life of guava under ambient condition.

Disclaimer (Artificial intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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