Effect of Pre-Storage Edible Coating on Post Harvest Quality of Guava Fruits cv. Lalit Under Ambient Condition

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Original Research Article

ABSTRACT

A significant fruit crop, the guava (*Psidium guajava* L.), is grown around the world in a wide range of tropical and subtropical climates. The shelf life of guavas is short, and they ripen quickly after being harvested. This limited shelf life necessitates effective management techniques to ensure a consistent market supply through post-harvest treatments to extend the storage life. In this study, we aimed to assess the impact of different treatments on the quality attributes of guava fruit cv. Lalit at 3-day intervals during storage. The experiment was carried out in the Postharvest Laboratory, Department of Horticulture, Banaras Hindu University, Varanasi. The findings from our investigation revealed that guava fruits harvested at the mature green stage and treated with Carboxy methylcellulose (CMC) and sodium alginate, maintained their desirable chemical and functional qualities for an extended period, up to 12 days of storage. Specifically, the post-harvest treatment using CMC (1.5%) proved to be exceptionally effective in reducing physiological weight loss and decay loss and retarding the increase in total carotenoids and lycopene content. Additionally, it

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delayed the decline in total soluble solids, ascorbic acid content, chlorophyll content, total antioxidant capacity and phenolic content throughout the storage period. Therefore, this treatment showed excellent results in extending the shelf life of guava fruits and maintaining their post-harvest quality by delaying the processes of ripening and senescence, lowering spoilage, and improving marketability and appearance.

Keywords: Carboxymethyl cellulose; guava; post harvest quality; shelf life and storage.

1. INTRODUCTION

"The renowned subtropical fruit guava (*Psidium guajava* L.) finds widespread cultivation across tropical and subtropical regions worldwide. However, its delicate nature, limited postharvest life, and susceptibility to chilling injury and diseases pose challenges for its commercialization. Guava's high perishability is evident as it rapidly ripens within a few days of harvest under ambient conditions. This fruit follows a climacteric pattern, marked by increased ethylene production and respiratory activity as it ripens" [1,2,3]. Guava is renowned for its rich nutrient content, boasting significant amounts of vitamins A, Thiamine, Riboflavin, and Ascorbic acid. Notably, its vitamin C content surpasses that of citrus fruits, reaching 2–5 times higher levels [4], with an impressive 260 mg/100 gm FW [5]. Despite its nutritional excellence, guava's rapid ripening and high respiration rate make it prone to spoilage throughout storage [6]. To address these challenges and prolong the shelf life while maintaining quality, edible coatings have emerged as a novel approach for both whole and sliced fruits. These coatings serve as selective barriers, regulating oxygen, carbon dioxide, and moisture transfer. Consequently, they delay the ripening process, reduce moisture loss, and help preserve the fruit's fresh aroma and flavor [7]. Moreover, in the context of fresh-cut fruits, edible coatings are employed to transport active substances, such as anti-browning, anti-microbial, and texture-enhancing agents, thereby enhancing overall quality [8]. The increasing interest in the development of eco-friendly, biodegradable edible coatings are driven by public concerns related to both the environment and human health. These coatings, by modifying the internal environment, enable control over fruit metabolism and moisture loss, ultimately extending the fruit's shelf life. Therefore, exploring the application of edible coatings to enhance the quality of guava fruits during storage presents a compelling and urgent solution to reduce decay incidence and improve overall postharvest quality.

2. MATERIALS AND METHODS

In this study, we conducted experiments using uniform, medium-sized guava fruits harvested at the mature green stage. The research took place in the Postharvest Laboratory of the Department of Horticulture at BHU, Varanasi. To prepare the fruits for experimentation, we meticulously removed any dirt and extraneous materials, followed by a thorough wash with tap water and subsequent air-drying. After eliminating any fruits displaying signs of disease, spots, or bruises, the remaining fruits were categorized into distinct groups. To ensure the fruits were free from any contaminants, we disinfected them by immersing them in a 2% sodium hypochlorite solution for 2 minutes. Subsequently, the fruits were air-dried and subjected to various treatments using aqueous solutions of carboxymethyl cellulose and sodium alginate at concentrations of 0.5%, 1.0%, and 1.5% (w/v). These treatments involved immersing the fruits in the respective solutions for 5 minutes, after which they were drained and surface-dried. As a control, some fruits were immersed in distilled water for the same duration. Following air-drying at room temperature, we divided the treated and untreated fruits into different lots and placed them in an open environment within the postharvest laboratory. The experimental design followed a factorial completely randomized pattern with three replications for each treatment. Assessments were conducted at 3-day intervals during storage under ambient conditions, characterized by a temperature of $21 \pm 3°C$ and relative humidity of $75 \pm 5\%$. The treatments encompassed carboxymethyl cellulose (0.5%), carboxymethyl cellulose (1.0%), carboxymethyl cellulose (1.5%), sodium alginate (0.5%), sodium alginate (1.0%), sodium alginate (1.5%), and a control, denoted as T_1, T_2, T_3, T_4, T_5, T_6, and T_7, respectively. The effect of applying an edible coating on postharvest quality characteristics of guava fruits was assessed under ambient storage conditions. Physiological weight loss (PLW) was determined by dividing the weight lost in grams by the initial weight and expressed as a percentage. Decay loss was determined by examining visible signs of fungal growth or rotting, irrespective of its

severity, and the results were expressed as percentages. The total soluble solids (TSS) content of guava fruits during storage was measured using a digital refractometer (Atago, Tokyo, Japan) and reported in degrees Brix (Brix). Titratable acidity was determined through a titration method [9]. The quantitative estimation of total chlorophyll content was conducted following the procedure outlined by Arnon [10], while the determination of carotenoids was carried out according to Duxbury and Yentsch [11]. Lycopene content was quantified using a spectrophotometric method [12], and the ascorbic acid content of guava was assessed based on the procedure provided by Jones and Hughes [13]. The total phenolic content of guava fruit was estimated using the method described by Singleton et al. [14], and the total antioxidant capacity was determined using the CUPRAC assay (Cupric Reducing Antioxidant Capacity) developed by Apak et al., [15]. The data collected during the experiment regarding various parameters throughout the storage period underwent analysis of variance (ANOVA), with treatments and storage duration considered as sources of variation. The significance of differences between means was determined using HSD Tukey's test (p ≤ 0.05) via IBM SPSS Statistics 26.

3. RESULTS AND DISCUSSION

The outcomes of the current investigation, along with pertinent discussions, have been categorized into the following sections:

3.1 Weight Loss

The collected data clearly demonstrates that the weight loss of guava fruits increased as the storage period advanced. After 12 days of storage, the minimum weight loss (14.97%) were observed in CMC (1.5%), followed by 17.94% in SA (1.5%) which was statistically at par with CMC (1.0%), followed by 20.86% in SA (1.0%), which was statistically similar with CMC (0.5%), followed by 24.51% in SA (0.5%). In contrast, the maximum weight loss (30.23%) was recorded in the control. Notably, among the guava fruits treated with CMC and SA, CMC (1.5%) and SA (1.5%) exhibited a more pronounced impact in reducing weight loss compared to their lower concentrations. Weight loss in fresh fruits primarily results from water loss induced by transpiration and respiration processes. The rate of water loss is influenced by the difference in water pressure between the fruit tissue and the

surrounding atmosphere, as well as the storage temperature. Edible coatings, besides acting as a protective barrier, decrease respiration and transpiration rates through the fruit's surface [16], safeguard the fruit skin from mechanical damage, and facilitate the healing of minor injuries. Similar findings have been reported by Pandey et al., [17] and Dutta et al., [18] in guava fruits and Nasrin et al., [19], in Mandarin fruits.

3.2 Decay Loss

The results indicated that decay loss in guava fruits increased as the storage period lengthened. After 12 days of storage, CMC (1.5%) treatment was found most effective in reducing decay loss (13.88%), which was statistically at par with SA (1.5%), followed by 22.22% in CMC (1.0%), which was statistically similar with SA (1.0%), followed by 27.78% in CMC (0.5%), which was statistically at par with SA (0.5%). In contrast, control fruits displayed a considerably higher decay loss at 38.89%, whereas all of the treated fruits showed a considerable reduction in decay loss. Guava fruits tend to soften rapidly after a few days of storage due to ripening, rendering them susceptible to attack by various disease-causing microorganisms, and leading to rapid deterioration. The application of edible coatings helps maintain low oxygen concentration and high carbon dioxide levels in the atmosphere surrounding the fruit, which contributes to reducing fruit decay. Various fungi can be responsible for fruit decay, with rot causing fruits to become mushy, develop undesirable odors, and undergo inherent metabolic changes. Similar findings have been reported by Nasrin et al.,[19] and Singh et al., [20] in the case of Mandarin and guava fruits, respectively.

3.3 Total Soluble Solids

The total soluble solids content of guava fruits exhibited an initial increase during storage, reaching its peak at 9 days, after which it steadily declined as the storage duration extended. However, after 12 days of storage, CMC (1.5%) had higher total soluble solids (12.85°Brix), followed by 12.78°Brix in SA (1.5%), which was statistically at par with CMC (1.0%), SA (1.0%), CMC (0.5%), and SA (0.5%), while control had recorded minimum total soluble solids (12.46°Brix). Notably, in this investigation, CMC (1.5%) proved to be the most effective treatment in delaying the reduction in total soluble solids. Total soluble solids play a pivotal role in enhancing fruit quality and provide an indication

of sweetness. TSS may have increased initially because starch is being converted to sugar, and it may have decreased later because the rate of respiration is slowing down and sugars are being converted to organic acids [21]. The depletion of total soluble solids in the fruit could be attributed to the high metabolic activity of the fruit and the onset of senescence processes. Variations in total soluble solids content can be influenced by several factors, including the season, soil conditions, and meteorological variables [22].

3.4 Titratable Acidity

In this study, the titratable acidity level in guava fruit exhibited a linear decrease with an increase in storage time, up to 12-day duration. In the last days of storage, the maximum titratable acidity (0.35) was recorded in CMC (1.5%), which was statistically at par with SA (1.5%), CMC (1.0%), SA (1.0%), CMC (0.5%), and SA (0.5%), while the minimum titratable acidity was observed in control (0.21). Conversely, the control displayed the lowest titratable acidity, measuring at 0.21. The most prominent organic acid in guava fruit is citric acid [23]. The decline in acidity could be attributed to the activities of enzymes like carboxylase and malic dehydrogenase, which are directly linked to the rate of respiration, or it could result from acid utilization during the respiration process. The slower reduction in acidity observed in treated fruits compared to the control could be attributed to the delayed senescence of the fruits and their lower respiration rate. Similar findings have been reported by Kumar et al.,[24], Mahmoud et al., [25], Hazarika et al., [26] in the context of guava, pomegranate, and strawberry fruits, respectively. Titratable acidity provides insights into the presence of total organic acids in the fruit and plays a significant role in determining fruit flavour.

3.5 Total Chlorophyll Content

As per the findings, it was observed that the total chlorophyll content in guava fruits decreased as the storage duration increased. Likewise, after 12 days of storage, the maximum total chlorophyll content (4.46 mg/100 g FW) was exhibited in CMC (1.5%), followed by 4.08 mg/100 g FW in SA (1.5%), and the minimum total chlorophyll content (2.38 mg/100 g FW) was recorded in control. On the other hand, the total chlorophyll content (3.40 mg/100 g FW) was recorded in

CMC (1.0%), which was found statistically at par with SA (1.0%), and the treatment CMC (0.5%) and SA (0.5%) were also found statistically at par. Chlorophyll pigment imparts the green color of the fruit skin. Due to the degradation of chlorophyll as the fruit ripens, the loss of green hue is a sign of maturity [27]. The transition of guava peel colour from green to yellow occurs during ripening [28]. The loss of the green surface colour may be linked to the natural ripening process triggered by ethylene, which leads to the breakdown of chlorophyll molecules concurrent with an increase in carotene content [29]. The decline in chlorophyll content during storage is associated with the conversion of chloroplasts into chromoplasts containing yellow and red carotenoid pigments. Variations in chlorophyll levels are likely influenced by fluctuations in the activity of enzymes responsible for chlorophyll degradation, such as chlorophyllase, chlorophyll oxidase, and peroxidase, during ripening.

3.6 Total Carotenoids Content

The total carotenoids content in guava fruits exhibited a significant increase with the progression of the storage period in all treated and control fruits in this study. However, control fruits showed a notably faster increase in total carotenoids content compared to the other treatments, and this trend persisted until the end of the storage period. However, after 12 days of storage, the control had the highest total carotenoids content (147.54 mg/100 g FW), followed by 135.34 mg/100 g FW in SA (0.5%), which was statistically at par with CMC (0.5%), SA (1.0%), and CMC (1.0%). Conversely, the lowest total carotenoids content (106.45 mg/100 g FW) was observed in CMC (1.5%), which was statistically equivalent to SA (1.5%). CMC (1.5%) was found to be more effective in slowing down the increase in total carotenoids content in guava fruits during storage. The reduced level of carotenoids may be associated with the delayed breakdown of chlorophyll pigment. Consequently, the breakdown of chlorophyll pigment was hindered, leading to a delay in carotenoid pigment synthesis [30]. Furthermore, the fruit coating formed a thin layer on the fruit's surface, creating a barrier to gas exchange. This, in turn, resulted in increased carbon dioxide and oxygen concentrations around the fruit surface, reducing the synthesis and activity of ethylene and impeding carotenoid synthesis.

Table 1. Effect of pre-storage edible coating on Weight loss (%) of guava fruits cv. Lalit during storage at ambient condition

Treatments	Weight loss (%)				
	Days after storage (DAS)				
	0 DAS	3 DAS	6 DAS	9 DAS	12 DAS
Carboxymethyl cellulose (0.5%)	0	6.89 ± 0.38 bc	12.95 ± 0.24 b	17.99 ± 0.42 b	21.94 ± 0.27 bc
Carboxymethyl cellulose (1.0%)	0	5.31 ± 0.45 cd	10.05 ± 0.87 c	14.48 ± 0.44 c	18.89 ± 0.18 d
Carboxymethyl cellulose (1.5%)	0	3.92 ± 0.21 d	7.27 ± 0.26 d	11.06 ± 0.28 d	14.97 ± 0.20 e
Sodium alginate (0.5%)	0	7.28 ± 0.38 b	13.10 ± 0.31 b	18.73 ± 0.35 b	24.51 ± 0.67 b
Sodium alginate (1.0%)	0	5.78 ± 0.19 bcd	10.21 ± 0.36 c	15.21 ± 0.36 c	20.86 ± 0.37 c
Sodium alginate (1.5%)	0	4.84 ± 0.32 d	8.65 ± 0.43 cd	13.59 ± 0.33 c	17.94 ± 0.24 d
Control	0	9.38 ± 0.61 a	16.66 ± 0.79 a	23.44 ± 0.48 a	30.23 ± 1.26 a

Table 2. Effect of pre-storage edible coating on Decay loss (%) of guava fruits cv. Lalit during storage at ambient condition

Treatments	Decay loss (%)				
	Days after storage (DAS)				
	0 DAS	3 DAS	6 DAS	9 DAS	12 DAS
Carboxymethyl cellulose (0.5%)	0	0	5.55 ± 2.78 b	13.88 ± 2.78 b	27.78 ± 2.78 abc
Carboxymethyl cellulose (1.0%)	0	0	0	11.11 ± 5.55 b	22.22 ± 2.78 bc
Carboxymethyl cellulose (1.5%)	0	0	0	5.55 ± 2.78 c	13.88 ± 2.78 c
Sodium alginate (0.5%)	0	0	11.11 ± 5.55 ab	19.44 ± 2.78 b	30.55 ± 2.78 ab
Sodium alginate (1.0%)	0	0	0	13.88 ± 2.72 b	25.00 ± 2.78 bc
Sodium alginate (1.5%)	0	0	0	11.11 ± 2.78 b	19.44 ± 2.78 c
Control	0	0	13.88 ± 2.78 a	27.77 ± 2.78 a	38.89 ± 5.55 a

Values are mean ± standard error of three replicate determinations (n=3). According to HSD Tukey's test, values in the same column with different letters are significantly different (p < 0.05)

Table 3. Effect of pre-storage edible coating on total soluble solids (°Brix) of guava fruits cv. Lalit during storage at ambient condition

Treatments	Total soluble solids (°Brix)				
	Days after storage (DAS)				
	0 DAS	3 DAS	6 DAS	9 DAS	12 DAS
Carboxymethyl cellulose (0.5%)	12.16 ± 0.11 a	12.55 ± 0.41 a	12.78 ± 0.39 a	12.93 ± 0.14 a	12.53 ± 0.08 ab
Carboxymethyl cellulose (1.0%)	12.16 ± 0.11 a	12.57 ± 0.17 a	12.84 ± 0.08 a	13.06 ± 0.10 a	12.72 ± 0.13 ab
Carboxymethyl cellulose (1.5%)	12.16 ± 0.11 a	12.64 ± 0.22 a	13.05 ± 0.11 a	13.18 ± 0.10 a	12.85 ± 0.04 a
Sodium alginate (0.5%)	12.16 ± 0.11 a	12.37 ± 0.13 a	12.65 ± 0.08 a	12.89 ± 0.15 a	12.49 ± 0.08 ab
Sodium alginate (1.0%)	12.16 ± 0.11 a	12.48 ± 0.10 a	12.77 ± 0.05 a	13.03 ± 0.06 a	12.65 ± 0.13 ab
Sodium alginate (1.5%)	12.16 ± 0.11 a	12.59 ± 0.18 a	12.87 ± 0.23 a	13.11 ± 0.10 a	12.78 ± 0.10 ab
Control	12.16 ± 0.11 a	12.33 ± 0.18 a	12.56 ± 0.19 a	12.81 ± 0.22 b	12.46 ± 0.18 b

Table 4. Effect of pre-storage edible coating on titratable acidity (%) of guava fruits cv. Lalit during storage at ambient condition

Treatments	Titratable acidity (%)				
	Days after storage (DAS)				
	0 DAS	3 DAS	6 DAS	9 DAS	12 DAS
Carboxymethyl cellulose (0.5%)	0.56 ± 0.04 a	0.43 ± 0.04 a	0.39 ± 0.03 a	0.32 ± 0.03 a	0.26 ± 0.05 a
Carboxymethyl cellulose (1.0%)	0.56 ± 0.04 a	0.47 ± 0.04 a	0.43 ± 0.05 a	0.34 ± 0.04 a	0.31 ± 0.04 a
Carboxymethyl cellulose (1.5%)	0.56 ± 0.04 a	0.51 ± 0.03 a	0.46 ± 0.07 a	0.39 ± 0.04 a	0.35 ± 0.04 a
Sodium alginate (0.5%)	0.56 ± 0.04 a	0.37 ± 0.05 a	0.36 ± 0.04 a	0.29 ± 0.06 a	0.22 ± 0.03 a
Sodium alginate (1.0%)	0.56 ± 0.04 a	0.45 ± 0.04 a	0.41 ± 0.04 a	0.33 ± 0.09 a	0.28 ± 0.03 a
Sodium alginate (1.5%)	0.56 ± 0.04 a	0.48 ± 0.07 a	0.44 ± 0.05 a	0.37 ± 0.03 a	0.33 ± 0.04 a
Control	0.56 ± 0.04 a	0.34 ± 0.06 a	0.31 ± 0.02 a	0.24 ± 0.03 a	0.21 ± 0.03 a

Values are mean ± standard error of three replicate determinations (n=3). According to HSD Tukey's test, values in the same column with different letters are significantly different ($p < 0.05$).

Table 5. Effect of pre-storage edible coating on total chlorophyll content (mg/100 g FW) of guava fruits cv. Lalit during storage at ambient condition

Treatments	Total chlorophyll content (mg/100 g FW)				
	Days after storage (DAS)				
	0 DAS	3 DAS	6 DAS	9 DAS	12 DAS
Carboxymethyl cellulose (0.5%)	7.57 ± 0.35 a	6.20 ± 0.36 a	5.06 ± 0.37 a	3.93 ± 0.23 c	3.00 ± 0.19 cd
Carboxymethyl cellulose (1.0%)	7.57 ± 0.35 a	6.67 ± 0.36 a	5.31 ± 0.40 a	4.62 ± 0.14 abc	3.70 ± 0.06 bc
Carboxymethyl cellulose (1.5%)	7.57 ± 0.35 a	6.95 ± 0.28 a	6.05 ± 0.43 a	5.13 ± 0.20 a	4.46 ± 0.28 a
Sodium alginate (0.5%)	7.57 ± 0.35 a	6.09 ± 0.22 a	4.88 ± 0.09 a	3.81 ± 0.10 c	2.70 ± 0.09 cd
Sodium alginate (1.0%)	7.57 ± 0.35 a	6.39 ± 0.38 a	5.16 ± 0.46 a	4.07 ± 0.35 bc	3.24 ± 0.20 c
Sodium alginate (1.5%)	7.57 ± 0.35 a	6.78 ± 0.31 a	5.89 ± 0.32 a	5.06 ± 0.21 ab	4.08 ± 0.19 ab
Control	7.57 ± 0.35 a	5.99 ± 0.32 a	4.72 ± 0.05 a	3.62 ± 0.20 c	2.38 ± 0.12 d

Table 6. Effect of pre-storage edible coating on total carotenoids content (mg/100 g FW) of guava fruits cv. Lalit during storage at ambient condition

Treatments	Total carotenoids content (mg/100 g FW)				
	Days after storage (DAS)				
	0 DAS	3 DAS	6 DAS	9 DAS	12 DAS
Carboxymethyl cellulose (0.5%)	46.67 ± 4.03 a	73.58 ± 2.77 b	97.31 ± 2.88 b	122.16 ± 1.86 bc	135.34 ± 4.63 abc
Carboxymethyl cellulose (1.0%)	46.67 ± 4.03 a	70.65 ± 3.81 b	93.28 ± 2.60 b	113.46 ± 2.62 bc	128.14 ± 4.26 abc
Carboxymethyl cellulose (1.5%)	46.67 ± 4.03 a	66.62 ± 2.56 b	87.19 ± 3.28 b	99.73 ± 4.09 d	106.45 ± 6.78 c
Sodium alginate (0.5%)	46.67 ± 4.03 a	77.09 ± 2.26 b	102.43 ± 6.88 b	123.96 ± 3.16 b	141.21 ± 4.18 ab
Sodium alginate (1.0%)	46.67 ± 4.03 a	73.54 ± 1.65 b	99.23 ± 3.31 b	118.28 ± 1.80 bc	130.09 ± 7.83 abc
Sodium alginate (1.5%)	46.67 ± 4.03 a	69.95 ± 1.64 b	90.30 ± 1.74 b	110.27 ± 1.59 cd	122.81 ± 9.02 bc
Control	46.67 ± 4.03 a	93.10 ± 2.36 a	116.16 ± 2.56 a	133.62 ± 2.71 a	147.54 ± 3.69 a

Values are mean ± standard error of three replicate determinations (n=3). According to HSD Tukey's test, values in the same column with different letters are significantly different ($p < 0.05$).

Table 7. Effect of pre-storage edible coating on lycopene content (mg/100g FW) of guava fruits cv. Lalit during storage at ambient condition

	Lycopene content (mg/100 g FW)				
Treatments	**Days after storage (DAS)**				
	0 DAS	**3 DAS**	**6 DAS**	**9 DAS**	**12 DAS**
Carboxymethyl cellulose (0.5%)	0.09 ± 0.01 a	0.22 ± 0.02 a	0.38 ± 0.03 a	0.59 ± 0.04 a	0.73 ± 0.01 ab
Carboxymethyl cellulose (1.0%)	0.09 ± 0.01 a	0.20 ± 0.01 a	0.36 ± 0.03 a	0.54 ± 0.05 a	0.69 ± 0.03 ab
Carboxymethyl cellulose (1.5%)	0.09 ± 0.01 a	0.17 ± 0.00 a	0.31 ± 0.03 a	0.51 ± 0.04 a	0.62 ± 0.02 b
Sodium alginate (0.5%)	0.09 ± 0.01 a	0.22 ± 0.02 a	0.39 ± 0.02 a	0.62 ± 0.03 a	0.76 ± 0.01 ab
Sodium alginate (1.0%)	0.09 ± 0.01 a	0.20 ± 0.01 a	0.37 ± 0.02 a	0.56 ± 0.04 a	0.71 ± 0.03 ab
Sodium alginate (1.5%)	0.09 ± 0.01 a	0.19 ± 0.01 a	0.36 ± 0.02 a	0.53 ± 0.05 a	0.65 ± 0.02 b
Control	0.09 ± 0.01 a	0.24 ± 0.02 a	0.45 ± 0.05 a	0.65 ± 0.03 a	0.82 ± 0.02 a

Table 8. Effect of pre-storage edible coating on ascorbic acid content (mg/100 g FW) of guava fruits cv. Lalit during storage at ambientcondition

	Ascorbic acid content (mg/100 g FW)				
Treatments	**Days after storage (DAS)**				
	0 DAS	**3 DAS**	**6 DAS**	**9 DAS**	**12 DAS**
Carboxymethyl cellulose (0.5%)	281.89 ± 11.21 a	267.36 ± 8.22 a	255.67 ± 8.99 a	246.57 ± 7.16 a	238.62 ± 3.84 a
Carboxymethyl cellulose (1.0%)	281.89 ± 11.21 a	271.28 ± 7.52 a	261.28 ± 7.63 a	254.24 ± 6.80 a	243.96 ± 7.29 a
Carboxymethyl cellulose (1.5%)	281.89 ± 11.21 a	276.74 ± 10.70 a	270.14 ± 7.68 a	262.46 ± 5.56 a	249.42 ± 2.53 a
Sodium alginate (0.5%)	281.89 ± 11.21 a	263.18 ± 4.72 a	252.86 ± 5.88 a	241.33 ± 6.32 a	234.46 ± 8.13 a
Sodium alginate (1.0%)	281.89 ± 11.21 a	265.09 ± 8.52 a	257.61 ± 8.90 a	248.05 ± 8.32 a	240.57 ± 8.00 a
Sodium alginate (1.5%)	281.89 ± 11.21 a	273.14 ± 8.25 a	265.27 ± 7.77 a	259.41 ± 10.09 a	245.52 ± 5.47 a
Control	281.89 ± 11.21 a	260.17 ± 9.78 a	246.23 ± 1.82 a	237.53 ± 12.04 a	220.51 ± 7.85 b

Values are mean ± standard error of three replicate determinations (n=3). According to HSD Tukey's test, values in the same column with different letters are significantly different (p < 0.05).

Table 9. Effect of pre-storage edible coating on total phenolics content (mg GAE/100 g FW) of guava fruits cv. Lalit during storage at ambient condition

Treatments	Total phenolics content (mg GAE/100 g FW)				
	Days after storage (DAS)				
	0 DAS	3 DAS	6 DAS	9 DAS	12 DAS
Carboxymethyl cellulose (0.5%)	396.57 ± 4.84 a	353.86 ± 6.25 ab	310.12 ± 2.86 ab	280.23 ± 7.54 ab	242.08 ± 9.00 bc
Carboxymethyl cellulose (1.0%)	396.57 ± 4.84 a	358.48 ± 4.56 ab	322.26 ± 6.90 ab	281.99 ± 3.82 ab	252.78 ± 6.44 abc
Carboxymethyl cellulose (1.5%)	396.57 ± 4.84 a	368.57 ± 7.87 a	335.57 ± 7.36 a	312.92 ± 9.66 a	293.44 ± 10.51 a
Sodium alginate (0.5%)	396.57 ± 4.84 a	334.02 ± 8.93 ab	301.37 ± 4.59 ab	253.32 ± 5.72 b	230.67 ± 6.56 cd
Sodium alginate (1.0%)	396.57 ± 4.84 a	356.22 ± 6.97 ab	321.43 ± 3.73 ab	275.33 ± 6.49 ab	247.62 ± 7.43 bc
Sodium alginate (1.5%)	396.57 ± 4.84 a	363.98 ± 6.47 ab	328.29 ± 10.56 ab	300.67 ± 12.70 a	277.94 ± 6.98 ab
Control	396.57 ± 4.84 a	328.47 ± 10.19 b	292.82 ± 16.66 b	242.11 ± 12.75 b	218.79 ± 11.04 d

Table 10. Effect of pre-storage edible coating on total antioxidant capacity (µmol TE/g FW) of guava fruits cv. Lalit during storage at ambient condition

Treatments	Total antioxidant capacity (µmol TE/g FW)				
	Days after storage (DAS)				
	0 DAS	3 DAS	6 DAS	9 DAS	12 DAS
Carboxymethyl cellulose (0.5%)	8.08 ± 0.33 a	6.62 ± 0.39 a	5.62 ± 0.25 a	4.71 ± 0.23 a	3.77 ± 0.10 bcd
Carboxymethyl cellulose (1.0%)	8.08 ± 0.33 a	6.77 ± 0.24 a	5.65 ± 0.40 a	4.78 ± 0.34 a	4.01 ± 0.10 ab
Carboxymethyl cellulose (1.5%)	8.08 ± 0.33 a	6.99 ± 0.22 a	6.01 ± 0.18 a	5.28 ± 0.27 a	4.45 ± 0.19 a
Sodium alginate (0.5%)	8.08 ± 0.33 a	6.44 ± 0.18 a	5.56 ± 0.24 a	4.41 ± 0.17 a	3.64 ± 0.06 cd
Sodium alginate (1.0%)	8.08 ± 0.33 a	6.64 ± 0.23 a	5.63 ± 0.26 a	4.76 ± 0.18 a	3.90 ± 0.09 abc
Sodium alginate (1.5%)	8.08 ± 0.33 a	6.87 ± 0.24 a	5.82 ± 0.18 a	4.81 ± 0.25 a	4.12 ± 0.08 a
Control	8.08 ± 0.33 a	6.42 ± 0.52 a	5.42 ± 0.19 a	4.40 ± 0.15 a	3.55 ± 0.11 d

Values are mean ± standard error of three replicate determinations (n=3). According to HSD Tukey's test, values in the same column with different letters are significantly different (p < 0.05)

3.7 Lycopene Content

The findings revealed that the lycopene content in guava fruits increased as the storage duration progressed up to 12 days under ambient conditions. However, after 12 days of storage, among the CMC and SA treatments, the highest value of lycopene content (0.82 mg/100 g FW) was recorded in control, followed by 0.76 mg/100 g FW in SA (0.5%), which was statistically at par with CMC (0.5%), SA (1.0%), and CMC (1.0%), Conversely, the lowest lycopene content value (0.62 mg/100 g FW) was noted in CMC (1.5%), which was statistically equivalent to SA (1.5%). These treatments were effective in slowing the increase in lycopene content during guava fruit storage.Lakade et al.,[22] and Chandrika et al.,[31] in cv. Lalit found similar results. The development of lycopene content is closely linked to the ripening process [32]. Similar results were obtained when tomato fruits were stored at 4°C [33]. Furthermore, it has been observed that lycopene production during storage is influenced by temperature conditions and respiration rates [32].

3.8 Ascorbic Acid Content

In this study, the ascorbic acid content exhibited a decline with increasing storage time. However, various post-harvest treatments had a significant impact on the ascorbic acid content of guava fruits. After 12 days of storage, the highest value of ascorbic acid content (249.42 mg/100 g FW) was recorded in CMC (1.5%), which was statistically at par with SA (1.5%), CMC (1.0%), SA (1.0%), CMC (0.5%), and SA (0.5%), and the lowest value of ascorbic acid content was observed in control (220.51 mg/100 g FW). These results are consistent with those of Kumar et al.,[34], who observed a reduction in ascorbic acid levels with prolonged storage in kinnow fruits. Ascorbic acid, owing to its antioxidant properties, plays a role in safeguarding the plant from oxidative damage. Nevertheless, due to its water-soluble nature, this vitamin undergoes rapid degradation through oxidation during postharvest storage. The presence of oxygen within the storage environment affects the activities of enzymes responsible for ascorbic acid oxidation, namely, ascorbic acid oxidase and phenol oxidase [35].

3.9 Total Phenolics Content

In this experiment, regardless of the treatment applied, the total phenolics content in the fruits showed a consistent decrease throughout the entire storage period. This trend was observed across various treatments up to the 12th day of storage. After 12 days of storage, Among the CMC and SA treatments, the highest value of total phenolics content (293.44 mg GAE/100 g FW) was observed in CMC (1.5%), followed by 277.94 mg GAE/100 g FW in SA (1.5%), which was statistically at par with CMC (1.0%), followed by 247.62 mg GAE/100 g FW in SA (1.0%), which was statistically at par with CMC (0.5%). Meanwhile, the lowest total phenolics content value (218.79 mg GAE/100 g FW) was observed in the control, which was statistically similar to SA (0.5%). It was found that the treatments CMC (1.5%) and SA (1.5%) were more effective in preserving higher total phenolics content. The reduction in phenolics within the fruit can be attributed to structural breakdown during senescence. Edible coatings act as barriers, preventing the oxygen and moisture necessary for the enzymatic oxidation of phenolic compounds. This phenomenon could be linked to increased activity of polyphenol oxidase and peroxidase enzymes in control fruits, leading to a rapid decline in total phenolics [36]. Phenolic compounds are secondary metabolites synthesized by plants, and their quantity decreases with fruit ripening over time [37]. Guava contains significant phenolic compounds, including gallic acid, ellagic acid, and quercetin [38], with both the pulp and peel having high phenolic content [39].

3.10 Total Antioxidant Capacity

The total antioxidant capacity demonstrated a significant decline as the storage period extended up to 12 days under ambient conditions. After 12 days of storage, among the CMC and SA treatments, the highest value of total antioxidant capacity (4.45 µmol TE/g FW) was recorded in CMC (1.5%), which was statistically at par with SA (1.5%), followed by 4.01 µmol TE/g FW in CMC (1.0%), which was statistically at par with SA (1.0%), followed by 3.77 µmol TE/g FW in CMC (0.5%), which was statistically similar with SA (0.5%), Conversely, the lowest total antioxidant capacity (3.55 µmol TE/g FW) was observed in the control. The fruit's antioxidant activity relies on various bioactive components, including phenolics, flavonoids, and ascorbic acid. These bioactive compounds, especially vitamins like ascorbic acid, polyphenols, and flavonoids, contribute to the overall total antioxidant capacity [40,41]. This study employed two independent methods,

CUPRAC and the DPPH test, to determine total antioxidant capacity. Additionally, the CMC coating established a semi-permeable barrier on the fruit's surface, altering the surrounding atmosphere and maintaining higher total antioxidant capacity.

4. CONCLUSION

This study was conducted to evaluate the impact of various treatments on the qualitative traits of guava fruits (cv. Lalit) throughout the storage period at 3-day intervals. Guava fruits that were harvested at the mature green stage and treated with 1.5% CMC solution displayed notable effectiveness in mitigating physiological weight loss, decay, and the gradual increase in lycopene and total carotenoids content during the storage period. Furthermore, this treatment delayed the reduction in total soluble solids, ascorbic acid content, chlorophyll content, total antioxidant capacity, and phenolic content. The outcome of this treatment demonstrated superior results in terms of extending the shelf life of guava fruits and preserving their post-harvest quality by slowing down the processes of ripening and senescence.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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