



Edible coating functionalized with ornamental plant extracts affect the postharvest quality of guava (*Psidium guajava*) during storage

LEKSHMI S G¹, SHRUTI SETHI^{1*}, RAM ASREY¹, A NAGARAJA², KANWAR PAL SINGH¹, NAMITA¹, RAJU KUMAR³ and ANAGHA P K¹

ICAR-Indian Agricultural Research Institute, New Delhi 110 012, India

Received: 14 November 2023; Accepted: 03 April 2024

ABSTRACT

Present study was carried out during 2021–23 at ICAR-Indian Agricultural Research Institute, New Delhi to investigate the efficacy of active edible coatings, incorporated with extracts from rose leaves and marigold petals in preserving the quality of mature green guava (*Psidium guajava* L.) cv. Allahabad Safeda during storage at both ambient (25±2°C) and cold (10±1°C) conditions. The coatings, particularly carboxy methyl cellulose combined with rose leaf extract (CMC+RL) demonstrated the highest effectiveness in minimizing per cent firmness reduction (PFR; 77.02% and 84.71%) compared to the control (89.95% and 89.73%) after 4 and 18 days of ambient and cold storage, respectively. Additionally, the coatings significantly influenced total soluble solids (TSS), total sugar content (TSC) and yellowness index (YI) showing potential in slowing down the fruit ripening. Moreover, the coatings demonstrated notable antioxidant activity with CMC+RL coating exhibited the highest activity. Furthermore, the coatings exhibited a substantial inhibitory effect on polygalactouronase (PG) activity, indicating a potential to mitigate cell wall degradation. Overall, the results highlight the promise of these biodegradable coatings as an alternative to synthetic preservatives in preserving postharvest quality and enhancing the shelf-life of guava fruits.

Keywords: CMC, Edible coating, Guava, Gum Arabic, Marigold, Plant extracts, Rose

Guava (*Psidium guajava* L.) is commercially cultivated in many tropical and sub-tropical countries of the world. The fruit is abundant in vitamin C, fibre and antioxidants. Due to the robust nutritional profile, it plays a vital role in strengthening the immune system, promoting digestive health and combating oxidative stress. Widely cultivated in tropical regions, guava serves as a vital food source, supporting local economies and providing income for farmers. Its adaptability, low environmental impact, and potential for value-added products further underscore its significance. Guava, being a climacteric fruit, faces substantial postharvest losses due to its rapid ripening process. Its delicate peel and high polyphenol content contribute to its perishable nature. This susceptibility to postharvest issues hampers both national and international trade. Presently, the estimated postharvest loss for guava is 16.92%, as reported by NABCONS (2022).

Recently, there has been a surge in use of edible coatings to extend the shelf-life of fruits and vegetables.

These coatings act as barriers, regulating gas levels and minimizing water loss, preserving quality and reducing mass loss during storage. They are typically derived from proteins, carbohydrates, fats, or a combination thereof. These coatings offer advantage such as edibility, biocompatibility, non-toxicity, eco-friendliness and cost-effectiveness. They can also serve as carriers for additives such as antioxidants and antimicrobials. Common edible coatings include beeswax, shellac, carnauba wax, chitosan, alginate, gelatin, casein, carboxymethyl cellulose (CMC), gum arabic (GA), and starch. CMC is a biodegradable, water-soluble polysaccharide, characterized by being odorless, tasteless, and non-toxic characters. Gum arabic, another polysaccharide-based polymer, is sourced from Acacia trees, known for its high solubility and low viscosity. Extracts from the ornamental crops, marigold and rose, are abundant in phenolics known for their antimicrobial properties. This natural plant extracts offer a safe and eco-friendly alternative compared to synthetic chemicals. Meeting consumer demands for healthier options, they effectively combat postharvest diseases while ensuring human and environmental safety. Therefore, the present study was carried out to identify the best edible coating functionalized with rose and marigold extracts for the postharvest quality management of guava.

¹ICAR-Indian Agricultural Research Institute, New Delhi;
²ICAR-Indian Institute of Horticultural Research, Bengaluru, Karnataka; ³ICAR-Indian Agricultural Statistics Research Institute, New Delhi. *Corresponding author email: docsethi@gmail.com

MATERIALS AND METHODS

The study was carried out during 2021–23 at ICAR-Indian Agricultural Research Institute, New Delhi. Rose (cv. Rose Sherbath) leaves, marigold (cv. Pusa Arpita) flowers and guava fruits (cv. Allahabad Safeda) were collected from ICAR-Indian Agricultural Research Institute, New Delhi. The experiment was laid out in a two factorial completely randomized design (CRD) with first factor (coating formulations) at 7 levels and second factor (storage days) at 5 and 7 levels for ambient and cold storage conditions, respectively in triplicate for each treatment. Marigold petals and rose leaves were cabinet dried at 40°C, powdered and the extracts were prepared by soaking the powder (1 g/10 ml w/v) overnight in ethanol (80% v/v). After soaking, the mixture was centrifuged at 10,000 rpm for 20 min, and the supernatants were concentrated using rotary evaporator (337 mbar, 40°C and 50 rpm), then collected and stored. Mature green guava fruits were harvested and surface sterilized with 0.01% sodium hypochlorite. They were then air-dried before being coated with solutions of carboxy methyl cellulose (CMC; 1% w/v) and gum arabic (GA; 10% w/v) solutions containing rose leaf (RL) and marigold petal (MP) extracts at concentration of 200 mg gallic acid equivalent (GAE)/100 ml total phenolic content.

Quality assessments were made daily for 4 days under ambient storage (A, 24±2°C; 75–80% RH) and after every 3 days for cold storage (C, 10±1°C; 85–90% RH). Firmness of guava fruits was determined using a stable micro systems texture analyzer by a P/2, 2 mm diameter stainless steel cylindrical probe. Maximum force during the puncture in Newton (N) was used to calculate percent firmness reduction during storage. Digital refractometer (ATAGO make; 0–50°B) was used to determine total soluble solids (TSS) of guava samples. Total antioxidant activity (TAA) was assessed by cupric reducing antioxidant capacity (CUPRAC) assay (Sethi *et al.* 2020) and results were presented as µmol trolox equivalents/g dry weight (DW). Total sugars were estimated by the method described by Lane and Eynon (1923). Colour changes occurring in guava were expressed as yellowness index using the formula given by Aguero *et al.* (2019):

$$YI = 142.86b^*/L^*$$

where YI, Yellowness index; L*, Lightness; b*, Yellowness and blueness observed by Hunter Lab colorimeter (model Labscan XE).

Method of Prasad *et al.* (2022) was followed to determine the polygalactouronase (PG) activity of guava samples and expressed as:

$$PG \text{ activity} = (288.07 \times OD) \mu\text{g galactouronic acid/g/h FW}$$

Statistical analysis: The statistical analysis was done separate for cold and ambient storage. Variables were analyzed using one-way ANOVA. All statistical analysis was carried out using SAS software package version 9.4. Tukey's significant difference test was used to compare differences among the treatments and storage intervals

at $P \leq 0.05$ significance and results of the experiments are expressed as mean.

RESULTS AND DISCUSSION

In the present study, the edible coating functionalized with rose leaf and marigold petal extracts had significant impact on firmness reduction of guava fruits stored under both ambient and cold conditions (Table 1). Percentage firmness reduction (PFR) increased throughout the storage period for both control and treated guava fruits. Among treatments CMC+RL showed minimum PFR (77.02 and 84.71%) compared to control (89.95 and 89.73%) at the end of storage periods (4th day for ambient and 18th day for cold storage, respectively). The PFR increased in the order control > GA > CMC > GA+MP > GA+RL > CMC+MP > CMC+RL in both storage conditions. Higher PFR shows the rapid loss in firmness. Increased ethylene production under ambient storage conditions may be attributed to the softening and lower firmness of the fruit (Kumar *et al.* 2021). In line with our research, Madhav *et al.* (2020) reported that vegetable wax coated fruits of cv. Allahabad Safeda and Lalit showed 35.62% and 34.00% retention of firmness at the end of storage life. Guava is rich in pectins and fibre, which play a crucial role in maintaining cell wall structure. Enzymes such as polygalacturonase, pectin methylesterase, and pectate lyases collaborate to hydrolyze the fruit cell wall as it ripens. Together, they cause depolymerization and increase the solubility of pectin polysaccharides by reducing the size of pectin molecules (Hasan *et al.* 2022). Likewise, El-Gioushy *et al.* (2022) demonstrated that using a combination of gum Arabic (10%) and moringa extract (10%) was the most effective treatment across various parameters studied, resulting in the highest levels of firmness retention. It can be explained that the main factor contributing to the enhanced firmness of coated fruit, as compared to uncoated ones, was the prevention of moisture depletion. Functionalized edible coatings containing rose leaves and marigold petal extracts significantly decreased firmness loss compared with the control, during both the storage conditions. These extracts possess antioxidant capabilities along with antimicrobial attributes owing to polyphenolic compounds. Major polyphenolics in rose leaf include quercetin, quercetin 3-O-rutinoside and kaempferol acetyl disaccharide while marigold petal possess kaempferol, epicatechin gallate and feruloyl-caffeoylquinic acid which collectively contribute to the efficient ROS (reactive oxygen species) scavenging property of the extracts and their potential in slowing down oxidative damage and enzymatic activity in guava fruit. The contributory phenolics in rose leaf have capacity to donate the most electrons owing to the greater number of –OH groups thus imparting greater antioxidant potential (Jan *et al.* 2022).

The present study revealed that, active edible coatings of both CMC and GA have significant effect on the total soluble solids (TSS) of the guava fruits (Fig. 1). In control fruits, TSS showed an increasing trend till 2nd day of storage under ambient (13.40°B) and 12th day of storage

Table 1 Effect of active edible coatings on percentage firmness reduction, CUPRAC antioxidant activity and polygalactouronase activity of guava fruits during ambient and cold storage

Treatment	Ambient storage (24±2°C) days					Cold storage (10±1°C) days							
	0	1	2	3	4	0	3	6	9	12	15	18	
<i>Per cent firmness reduction</i>													
Control	0 ^q	21.61 ^m	58.34 ^h	82.79 ^{cd}	89.95 ^a	0 ^w	29.53 ^s	42.91 ^o	63.41 ^j	78.44 ^{fg}	85.89 ^{bc}	89.73 ^a	
GA	0 ^q	19.43 ^{mn}	57.48 ^{hj}	70.28 ^f	87.47 ^{ab}	0 ^w	29.15 ^s	37.63 ^q	61.37 ^k	77.45 ^{gh}	82.93 ^{de}	87.90 ^{ab}	
CMC	0 ^q	16.80 ^{no}	54.56 ^{ij}	68.76 ^f	86.25 ^b	0 ^w	26.83 ^t	38.82 ^{pq}	60.16 ^k	76.39 ^{gh}	82.79 ^{de}	86.95 ^b	
GA+MP	0 ^q	16.19 ^{no}	52.35 ^{jk}	65.74 ^g	85.28 ^{bc}	0 ^w	22.38 ^u	39.82 ^p	55.16 ^l	76.57 ^{gh}	83.38 ^{de}	86.68 ^{bc}	
GA+RL	0 ^q	16.32 ^{no}	49.66 ^k	64.63 ^g	82.56 ^{cd}	0 ^w	22.64 ^u	39.47 ^{pq}	52.21 ^m	76.17 ^h	82.43 ^e	86.40 ^{bc}	
CMC+MP	0 ^q	15.28 ^o	45.61 ^l	63.64 ^g	80.07 ^d	0 ^w	23.12 ^u	39.98 ^p	52.30 ^m	73.17 ^{gh}	80.18 ^f	85.80 ^{bc}	
CMC+RL	0 ^q	11.72 ^p	44.30 ^l	60.55 ^h	77.02 ^e	0 ^w	14.83 ^v	34.23 ^r	47.18 ⁿ	60.88 ^k	77.49 ^{gh}	84.71 ^{cd}	
<i>CUPRAC antioxidant activity (μmol trolox/g)</i>													
Control	7.12 ^a	6.14 ^{k-o}	6.04 ^{l-o}	5.87 ^o	5.44 ^p	6.87 ^a	6.23 ^{i-o}	6.15 ^{k-o}	6.09 ^{n-q}	6.01 ^{opq}	5.86 ^{pq}	5.58 ^r	
GA	6.63 ^{b-f}	6.23 ^{h-m}	6.11 ^{k-o}	5.95 ^{mno}	5.86 ^o	6.68 ^{a-d}	6.23 ^{i-o}	6.19 ^{j-o}	6.11 ^{m-q}	6.08 ^{n-q}	6.01 ^{opq}	5.86 ^q	
CMC	6.87 ^{ab}	6.37 ^{d-h}	6.19 ⁱ⁻ⁿ	6.04 ^{l-o}	5.94 ^{no}	6.68 ^{a-d}	6.29 ^{g-n}	6.24 ^{i-o}	6.19 ^{j-o}	6.12 ^{k-p}	6.06 ^{n-q}	6.00 ^{opq}	
GA+MP	6.87 ^{ab}	6.49 ^{d-h}	6.24 ^{h-l}	6.12 ^{k-o}	6.02 ^{l-o}	6.63 ^{a-e}	6.38 ^{e-k}	6.36 ^{f-m}	6.28 ^{h-n}	6.21 ^{j-o}	6.12 ^{l-q}	6.06 ^{n-q}	
GA+RL	6.63 ^{b-f}	6.51 ^{c-h}	6.37 ^{f-j}	6.27 ^{h-i}	6.18 ^{j-n}	6.87 ^a	6.45 ^{d-j}	6.59 ^{b-f}	6.45 ^{d-j}	6.36 ^{f-m}	6.26 ^{h-o}	6.14 ^{k-o}	
CMC+MP	6.78 ^{cb}	6.67 ^{b-e}	6.42 ^{e-j}	6.36 ^{f-k}	6.29 ^{g-l}	6.78 ^{a-c}	6.55 ^{c-g}	6.61 ^{b-f}	6.51 ^{d-h}	6.42 ^{e-j}	6.38 ^{e-l}	6.29 ^{g-n}	
CMC+RL	6.87 ^{ab}	6.75 ^{bcd}	6.56 ^{c-g}	6.48 ^{d-i}	6.37 ^{f-k}	6.83 ^{ab}	6.69 ^{a-d}	6.63 ^{a-e}	6.59 ^{b-f}	6.48 ^{d-i}	6.41 ^{e-j}	6.37 ^{e-l}	
<i>Polygalactouronase activity (μg galactouronic acid/ h/g FW)</i>													
Control	83.54 ^{stu}	112.35 ^{ij}	123.87 ^{fg}	135.39 ^d	149.80 ^a	83.11 ^y	100.98 ^{pq}	110.64 ^{mn}	125.47 ^{gh}	137.52 ^{cd}	147.19 ^b	154.32 ^a	
GA	83.14 ^{stu}	101.55 ^{mn}	119.32 ^h	130.56 ^e	145.29 ^b	85.22 ^{wxy}	97.37 ^{qrs}	107.89 ^{no}	120.54 ^{ijk}	131.32 ^{ef}	140.08 ^c	149.86 ^{ab}	
CMC	85.23 ^{rst}	98.46 ^{no}	116.26 ^{hi}	126.88 ^{ef}	140.27 ^c	84.75 ^{wxy}	95.51 st	104.48 ^{op}	116.60 ^{kl}	127.45 ^{gf}	135.32 ^{de}	141.11 ^c	
GA+MP	80.66 ^u	95.18 ^{pq}	113.25 ^{ij}	120.42 ^{gh}	136.25 ^{cd}	83.89 ^{xy}	93.25 ^{stu}	100.36 ^{pqr}	111.26 ^{mn}	122.61 ^{hij}	131.15 ^{ef}	136.48 ^{cd}	
GA+RL	82.24 ^{tu}	92.82 ^{pq}	107.76 ^k	116.19 ^{hi}	129.22 ^e	85.50 ^{wxy}	89.34 ^{uvw}	96.05 ^{rst}	103.41 ^{op}	117.39 ^{kl}	124.55 ^{ghi}	131.53 ^{ef}	
CMC+MP	85.18 ^{rst}	89.34 ^{qr}	103.11 ^{lm}	110.04 ^{jk}	124.87 ^f	84.83 ^{wxy}	87.85 ^{vwx}	92.17 ^{tuv}	97.83 ^{qrs}	112.73 ^{lm}	118.37 ^{jk}	125.43 ^{gh}	
CMC+RL	84.44 ^{stu}	87.23 ^{rs}	97.24 ^o	105.94 ^{kl}	120.31 ^{gh}	83.14 ^{xy}	85.33 ^{wxy}	88.78 ^{uvw}	94.22 st	101.06 ^{pq}	110.48 ^{mn}	120.27 ^{ijk}	

Means with same superscript within a storage temperature do not vary significantly ($P \leq 0.05$) amongst each other.

Treatment details are given under Materials and Methods.

under cold conditions (12.50°B), with a decline thereafter. In CMC, GA, GA+MP treated fruits, the TSS increased up to 3rd day in ambient and 15th day in cold storage followed by a decline. Meanwhile TSS of GA+RL, CMC+MP and CMC+RL treated fruits increased gradually till the end of storage period in both ambient and cold storage conditions.

Lower TSS in treated fruits might be owing to lower rate of respiration coupled with reduced metabolism. The initial increase in TSS may be mainly due to conversion of starch into soluble forms of sugars and subsequent decrease in TSS was owing to rapid utilization of reducing sugars and other organic metabolites (Rehman *et al.* 2020). Recently,

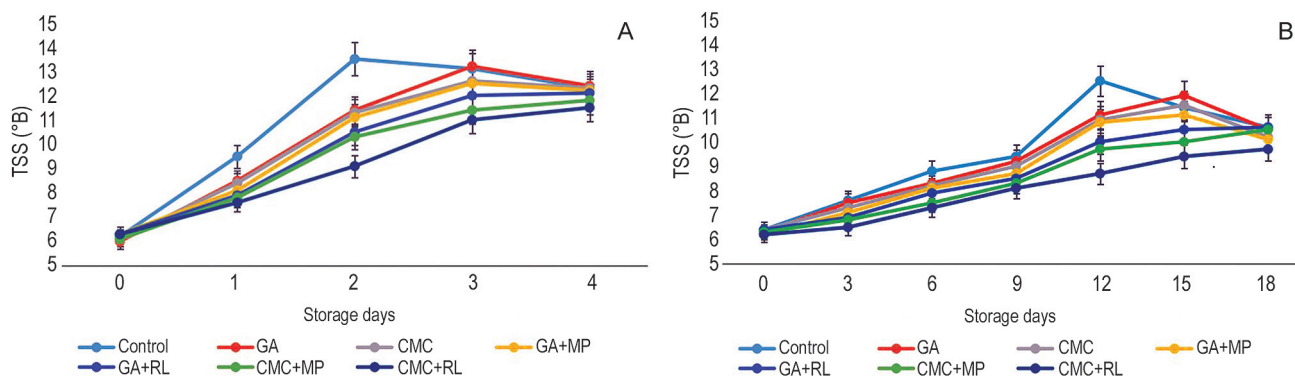


Fig. 1 Effect of active edible coatings on changes in total soluble solids (TSS) of guava fruits during A) Ambient; B) Cold storage. Bars denote the standard error. Treatment details are given under Materials and Methods.

Yadav *et al.* (2022) formulated a coating from mango kernel seed starch with varying concentrations of lemongrass essential oil and applied it to guava. Regardless of whether lemongrass essential oil was included or not, both types of coatings effectively controlled the increase in TSS content in guava fruit throughout the ambient storage period. Anjum *et al.* (2020) observed that the mixture of garlic extract and gum arabic coating significantly impeded the rise in TSS (14.66%) in guava cv. Gola after 15 days of storage in comparison to the control group (15.33%).

Total sugar content in guava fruits was significantly affected by both storage days and treatments (Fig. 2) and followed similar trend as of TSS. There was a sudden increase in the total sugar content on 2nd and 12th day of storage in control fruits in ambient and cold storage conditions, respectively. Total sugar content in control fruits increased to 14.13% from 8.02% and then decreased to 12.94% at the end of storage in ambient storage condition. GA, CMC and GA+MP coated fruits showed this sudden rise in total sugar content on 3rd and 15th days only, maybe because of delayed ripening in these treated fruits. Functionalized coatings (GA+RL, CMC+MP and CMC+RL) showed a gradual increase in total sugar content from 0th day till the end of storage period under both temperatures. Coated guava showed lower total sugar content compared to non-coated ones. Maximum total sugar content was observed in control fruits (14.13 and 13.78%) and lowest in CMC+RL coated guava (13.06% and 13.17%) under ambient and cold storage, respectively. The initial surge and subsequent reduction in total sugars in control fruits might be due to the hydrolysis of carbohydrates during fruit ripening followed by their consumption during senescence (De Bruno *et al.* 2023). The delay in reaching the climacteric peak in functionalized coated fruits can be attributed to the intricate composition of extracts, which mimics the characteristics of various additives, viz. antioxidants, nutraceuticals, pharmaceuticals, antimicrobials, nutrients, probiotics and browning inhibitors which are already in use (Avramescu *et al.* 2020). The significant slowdown in total sugar increase observed in CMC-coated fruit may be attributed to the coating's ability to slow down post-harvest ripening and prolong onset period

of senescence, consequently delaying the conversion of starch to sugar. Recently, Gupta *et al.* (2023) reported, total sugar content was uninterruptedly amplified with ripening but application of edible coatings delayed this increase. CMC coating retained significantly lower amount of total sugars (12.19%) as compared to guar gum, gum acacia and control treatments. The maximum value of total sugars was recorded in uncoated fruits (14.46%). Although, coatings themselves exhibit significant impermeability to water vapor, the crosslinking of incorporated bioactive extracts enhance their ability to act as a barrier against moisture, thus delaying ripening and consequently a suppressed conversion of starch into sugars.

The current study revealed the significant effect of active edible coating on antioxidant activity of guava fruits during storage (Table 1). CUPRAC values reduced during storage irrespective of storage conditions. At the end of storage period, maximum CUPRAC activity was observed for CMC+RL treated fruits (6.37 $\mu\text{mol TE/g}$ for both storage conditions), where the control fruits showed 5.44 $\mu\text{mol TE/g}$ and 5.58 $\mu\text{mol TE/g}$, respectively followed by CMC+MP > GA+RL > GA+MP > CMC > GA > control. The rose leaves and marigold petals have high antioxidant activity as they are rich in polyphenol content which might be a reason for higher antioxidant content in these coated fruits. Consistent with our findings, Madhav *et al.* (2021) observed enhanced preservation of overall CUPRAC antioxidant capacity in guava fruits (cv. Allahabad Safeda and Lalit) coated with 5-sulfosalicylic acid (2 mM) + vegetable wax (1:4 v/v). This effect was evident under both 5°C and 10°C storage compared to uncoated control fruits. A similar observation was made by Sood *et al.* (2021) where the fruits treated with aloe vera and papaya leaf extract displayed noticeably elevated overall antioxidant activity in comparison to the control group. In our study, the antioxidant capacity of guava fruits experienced a notable decline throughout the storage period. The fruit's antioxidant capability is influenced by presence of various bioactive compounds such as flavonoids, ascorbic acid, and phenolics. Zehiroglu *et al.* (2019) elucidated the scientific rationale for the notably elevated antioxidant activity in coated fruits as being attributed to the

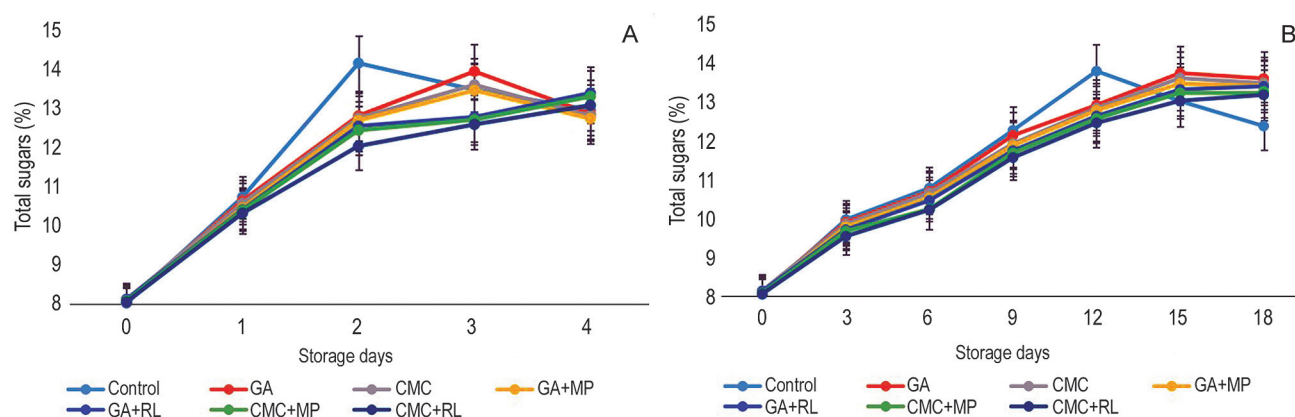


Fig. 2 Changes in total sugars of coated guava fruits during A) Ambient; B) Cold storage. Bars denote the standard error. Treatment details are given under Materials and Methods.

higher concentrations of total phenolic acids and ascorbic acid. The utilization of coatings has a beneficial effect in reducing oxidative stress and preserving the structural integrity of cellular compartments where antioxidants are situated. Higher CUPRAC values in coated fruits could be attributed to the higher concentration of phenolics, flavonoids, and ascorbic acid in the treated fruits, resulting from a delayed senescence process. Bhan *et al.* (2022) reported that despite applying various coating treatments, the overall antioxidant activity in the fruits progressively declined as the storage period extended. However, Kinnow mandarin fruits coated with guar gum + tamarind seed starch displayed notably higher total antioxidant activity at 23.43 $\mu\text{mol TE/g}$, followed by chitosan + tamarind seed starch coatings at 22.96 $\mu\text{mol TE/g}$ throughout the entire storage duration. Generally, antioxidant content decreased in stored fruit owing to their oxidation by enzymes and reactive oxygen species during senescence.

Yellowness index (YI) is a measure to assess the skin colour change of the fruit. In our study, the yellowness index of guava fruits was affected by storage days and the coating applied which indicated the effect of these on ripening of the fruits. YI increased during storage irrespective of treatment and storage condition (Fig. 3). Control fruits exhibited a rapid increase in the yellowness index in comparison to other treatments irrespective of storage conditions. Least YI at the end of storage was observed for CMC+RL coated fruits stored under ambient and cold conditions. The surface colour of guava has a crucial role in determining its marketability, as consumers often make their selection based on this characteristic. As guava ripens, the skin changes colour from green to yellow. This loss of surface green colour is a natural consequence of ripening triggered by ethylene. It is linked to the breakdown of chlorophyll molecules and a simultaneous increase in carotenoid content. During storage, the reduction of chlorophyll is associated with the transformation of chloroplasts into chromoplasts, which contain yellow and red carotenoid pigments. Further, chlorophyll degrades as ripening initiates, giving way to production of pheophytin and pheophorbide (Singh *et al.* 2022). The polyphenolic compounds present in RL and

MP extracts prevent the oxidative enzymatic reactions in the fruit and thus, result in delayed ripening and associated colour changes.

Activity of cell wall degrading polygalactouronase (PG) increased gradually during storage irrespective of treatments and storage conditions (Table 1). The PG activity recorded in fruits was in the order, control > GA > CMC > GA+MP > GA+RL > CMC+MP > CMC+RL under both storage conditions. This clearly indicates that CMC+RL shows better efficiency to prevent cell wall degradation, as also indicated by reduced percentage firmness giving longer shelf-life to the fruit. The PG activity of control guava fruits increased from 84.54, 83.11 $\mu\text{g galactouronic acid/h/g FW}$ to 149.80, 154.32 $\mu\text{g galactouronic acid/h/g FW}$ while the PG activity of CMC+RL coated fruits at end of storage was only 120.31 and 120.27 $\mu\text{g galactouronic acid/h/g FW}$ for ambient and cold stored fruits, respectively. In concurrence with our results Sharma *et al.* (2023) documented that chitosan (1 and 2%) coated guava fruits exhibited reduced PG activity in contrast to the control group on the third day of storage. Elevated levels of PG activity can result in the product becoming softer and experiencing decay. The rise in PG activity observed during storage, regardless of the applied coatings, suggests that the coatings only offered partial effectiveness in inhibiting pectin degradation in the fruits. Thus, along with coatings, low storage temperature may act synergistically to prevent quality loss of guava fruits. The edible coatings functionalized with rose leaves and marigold petal extracts showed additional inhibition of PG which might be due to the delayed ripening and senescence owing to the presence of polyphenols and antioxidants in them.

The application of an active edible coating based on CMC proved to be effective in preserving and prolonging the shelf life of mature green guava cv. Allahabad Safeda, whether stored at room temperature or in cold storage (Supplementary Fig. 1). The coated guava fruits effectively retained their firmness and turgidity for 4 days at room temperature and for 18 days in cold storage. Among the coatings, CMC combined with rose leaf extract (CMC+RL) demonstrated the best performance exhibiting the lowest

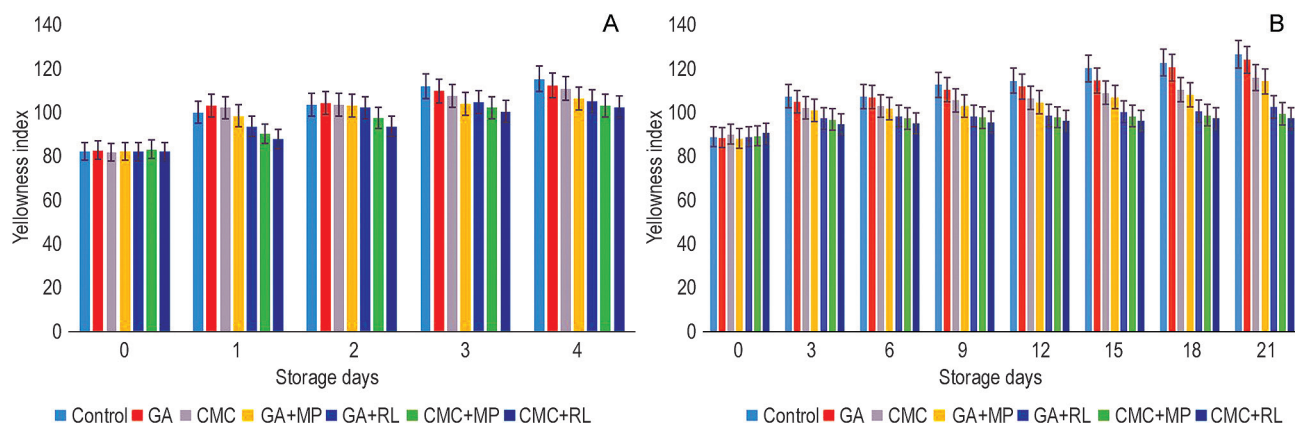


Fig. 3 Effect of active edible coatings on changes in yellowness index of guava fruits during A) Ambient; B) Cold storage. Bars denote the standard error. Treatment details are given under Materials and Methods.

reduction in firmness percentage, lowest polygalactouronase (PG) activity, highest antioxidant activity, lowest yellowness index, and the least increase in total soluble solids and total sugar content. The overall findings suggest that employing biodegradable edible coatings infused with extracts from ornamental plants holds promise as a viable substitute for synthetic preservatives. This approach demonstrates potential in maintaining fruit quality during postharvest storage. To summarize, the future of functionalized edible coatings appears promising, with the utilization of antimicrobial and antioxidant compounds derived from ornamental plant extracts poised to offer an environmentally sustainable alternative to currently used chemicals.

ACKNOWLEDGEMENT

The authors are grateful to the Indian Council of Agricultural Research, New Delhi for providing scholarship during the PhD programme of the student for smooth conduct of the research work.

REFERENCES

- Aguero A, Morcillo M D C, Quiles-Carrillo L, Balart R, Boronat T, Lascano D and Fenollar O. 2019. Study of the influence of the reprocessing cycles on the final properties of polylactide pieces obtained by injection molding. *Polymers* **11**: 1908. doi.org/10.3390/polym11121908
- Anjum M A, Akram H, Zaidi M and Ali S. 2020. Effect of gum arabic and Aloe vera gel based edible coatings in combination with plant extracts on postharvest quality and storability of Gola guava fruits. *Scientia Horticulturae* **271**: 109506. doi.org/10.1016/j.scienta.2020.109506
- Avramescu S M, Butean C, Popa C V, Ortan A, Moraru I and Temocico G. 2020. Edible and functionalized films/coatings: Performances and perspectives. *Coatings* **10**: 687. doi.org/10.3390/coatings10070687
- Bhan C, Asrey R, Meena N K, Rudra S G, Chawla G, Kumar R and Kumar R. 2022. Guar gum and chitosan-based composite edible coating extends the shelf-life and preserves the bioactive compounds in stored Kinnow fruits. *International Journal of Biological Macromolecules* **222**: 2922–35. doi.org/10.1016/j.ijbiomac.2022.10.068
- El-Gioushy S F, Abdelkader M F, Mahmoud M H, Abou El Ghit H M, Fikry M, Bahloul A M and Gawish M S. 2022. The effects of a gum arabic-based edible coating on guava fruit characteristics during storage. *Coatings* **12**: 90. doi.org/10.3390/coatings12010090
- De Bruno A, Gattuso A, Ritorto D, Piscopo A and Poiana M. 2023. Effect of edible coating enriched with natural antioxidant extract and bergamot essential oil on the shelf-life of strawberries. *Foods* **12**: 488. https://doi.org/10.3390/foods12030488
- Gupta V, Meena N K, Sharma Y K and Choudhary K. 2023. Comparative study of different polysaccharide-based edible coatings on physicochemical attributes and bioactive compounds of mango cv. Dashehari fruits. *eFood* **4**: e55. doi.org/10.1002/efd2.55
- Hasan K, Islam R, Hasan M, Sarker S H and Biswas M H. 2022. Effect of alginate edible coatings enriched with black cumin extract for improving postharvest quality characteristics of guava (*Psidium guajava* L.) fruit. *Food and Bioprocess Technology* **15**: 2050–64. https://doi.org/10.1007/s11947-022-02869-2
- Jan R, Khan M, Asaf S, Lubna Asif S and Kim K M. 2022. Bioactivity and therapeutic potential of kaempferol and quercetin: New insights for plant and human health. *Plants* **11**: 2623. doi.org/10.3390/plants11192623
- Kumar S, Baswal A K, Ramezani A, Gill K S and Mirza A A. 2021. Impact of carboxymethyl cellulose based edible coating on storage life and quality of guava fruit cv. Allahabad Safeda under ambient storage conditions. *Journal of Food Measurement and Characterization* **15**: 4805–12. doi.org/10.1007/s11694-021-01057-8
- Lane J H and Eynon L. 1923. Methods for determination of reducing and non-reducing sugars. *Journal of Science* **42**: 32–37.
- Madhav J V, Sethi S, Sharma R R, Nagaraja A and Varghese E. 2020. Influence of lipid and polysaccharide based edible coatings on quality of guava fruits during storage. *Indian Journal of Horticulture* **77**: 173–78. doi:10.5958/0974-0112.2020.00019.5
- Madhav J V, Sethi S, Sharma R R, Nagaraja A, Arora A and Varghese E. 2021. Influence of bilayer coating of salicylic acid and edible wax on chilling injury and functional attributes of guava. *Journal of Food Processing and Preservation* **45**: 15601. doi: 10.1111/jfpp.15601
- NABCONS. 2022. Study to determine post-harvest losses of agri produces in India. https://www.mofpi.gov.in/sites/default/files/study_report_of_post_harvest_losses.pdf. Accessed on 9.10.2023
- Prasad K, Sharma R R, Asrey R, Sethi S, Srivastav M, Singh D and Arora A. 2022. Hydrocolloid edible coatings extend shelf life, reduce postharvest decay, and maintain keeping quality of mango fruits (*Mangifera indica* L.) under ambient storage. *Journal of Food Biochemistry* e14481. https://doi.org/10.1111/jfbc.14481
- Rehman M A, Asi M R, Hameed A and Bourquin L D. 2020. Effect of postharvest application of aloe vera gel on shelf-life, activities of anti-oxidative enzymes, and quality of Gola guava fruit. *Foods* **9**: 1361. doi.org/10.3390/foods9101361
- Sethi S, Joshi A, Arora B, Bhowmik A, Sharma R R and Kumar P. 2020. Significance of FRAP, DPPH and CUPRAC assays for antioxidant activity determination in apple fruit extracts. *European Food Research and Technology* **246**: 591–98. doi.org/10.1007/s00217-020-03432-z
- Sharma K, Ravi K and Wani A W. 2023. Evaluation of natural edible coatings for enhancing the post-harvest quality and shelf life of guava (*Psidium guajava* L.) fruits. *Annals of Phytomedicine* **12**: 808–15. doi.org/10.54085/ap.2023.12.1.62
- Singh A, Singh B K, Barman K and Singh A K. 2022. Effect of edible coating and packaging on ripening behaviour and keeping quality of guava fruits. *The Pharma Innovation Journal* **11**: 1812–20.
- Sood M, Bandral J D and Gupta N. 2021. Influence of herbal edible coatings on phytochemical content of guava during storage. *Plant Archives* **21**: 534–39. doi.org/10.51470/plantarchives.2021.v21.no1.075
- Yadav A, Kumar N, Upadhyay A, Singh A, Anurag R K and Pandiselvam R. 2022. Effect of mango kernel seed starch-based active edible coating functionalized with lemongrass essential oil on the shelf-life of guava fruit. *Quality Assurance and Safety of Crops and Foods* **14**: 103–15. doi:10.15586/qas.v14i3.1094
- Zehiroglu C and Ozturk Sarikaya S B. 2019. The importance of antioxidants and place in today's scientific and technological studies. *Journal of Food Science and Technology* **56**: 4757–74. doi.org/10.1007/s13197-019-03952-x