JOURNAL OF HORTICULTURE AND POSTHARVEST RESEARCH
2024, VOL. 7(SPECIAL ISSUE: POSTHARVEST TECHNOLOGIES), 15-34

Journal of Horticulture and Postharvest Research

Journal homepage: www.jhpr.birjand.ac.ir

University of Birjand

Edible coatings maintained postharvest quality and increased shelf life of guava fruits

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ARTICLE INFO

Original Article

Article history:
Received 28 June 2023
Revised 25 August 2023
Accepted 28 August 2023
Available online 12 October 2023

Keywords:
Aloe vera gel
Chitosan
Quality
Storage

DOI: 10.22077/jhpr.2023.6531.1324
P-ISSN: 2588-4883
E-ISSN: 2588-6169

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ABSTRACT

Purpose: Guava is believed to be the most important commercial fruit crop in Bangladesh. Guava fruit exhibit very short storage life mainly due to high respiration rate, susceptibility to various pathogens and mechanical damages which can rapidly reduce the quality. However, the experiment was conducted to study the edible coatings effects on postharvest quality and shelf life of guava. **Research Method:** Commercially mature guava fruits (Swarupkathi and Thai) were treated with six edible coatings viz., (i) T_1 : Control, (ii) T_2 : Aloe vera gel (25%), (iii) T_3: Carboxy methyl cellulose (CMC) (1%), (iv) T_4: Chitosan(1%), (v) T_5: Aloe vera gel (25%) + Chitosan (1%) and (vi) T_6: Green tea leaf extract. The two-factor experiment was designed with a Completely Randomized Design and three replications. **Findings:** The results showed that, Thai Piara with Chitosan 1% treatment recorded the minimum weight loss (6.28%), the highest vitamin C content (191.44 mg/100gFW), the lowest pH (5.30), the maximum total soluble solids content (6.77 °Brix) and the highest titratable acidity (2.04%) at 10 days after storage compare to untreated Swarupkathi piara. Thai Piara treated with Aloe vera gel 25 % + Chitosan 1% exhibited the highest shelf life (13.00 days) followed by (12.67) in Chitosan (1%) treatment. **Research Limitations:** The study did not focus on ethylene and respiration rate determination. **Originality/Value:** The study demonstrated that Thai Piara, treated with Chitosan 1% solution showed better performance followed by Aloe vera gel 25% + Chitosan 1% solution for maintaining postharvest quality and shelf life of guava.

INTRODUCTION

Guava (*Psidium guajava* L.) belongs to the family Myrtaceae, is believed to be the most important commercial fruit crop in Bangladesh. It is one of the most popular fruit in Bangladesh due to its comparative low price, high nutrient value, good taste and high health benefit than some other fruits (Bose, Ahmed, Howlader, & Ali, 2019). Guava is the major source of vitamin C and Pectin. Guava contains moisture 80-83%, acid 2.45%, reducing sugar 3.5-4.45%, non-reducing sugar 3.97-5.23%, TSS 9.73-14.23, Potassium 0.48%, vitamin C 260mg per 100 g of edible' potion (F. Islam, Islam, Al Munsur, & Rahim, 2008). It is an excellent source of dietary fibers and minerals such as potassium, manganese, magnesium and phosphorus (Soares, Pereira, Marques, & Monteiro, 2007). Guava is consumed along with its seeds which are rich in omega fatty acids and fiber (Meena et al., 2021).

The per capita availability of fruits is reduced due to high level of postharvest losses. Approximately 40% fruit goes waste during postharvest handling, storage and ripening (FAO, 2018). At harvesting stage high respiration and quick ripening of the guava fruits leads to perishable during storage interval. To supply fresh and quality fruits to the consumers during the entire year, it is important to develop postharvest technologies related to quality maintenance and shelf life extension of guava varieties (Chien, Sheu, & Yang, 2007; Qiuping, Wenshui, & Jiang, 2006). To control postharvest decay and increase shelf life of fruits, different synthetic chemicals are used but, consumers prefer more natural, eco-friendly minimally processed products without considerable changes in their fresh characteristics with high nutritional quality and longer shelf life (Bose, Howlader, Jia, Wang, & Yin, 2019). Guava is climacteric fruit higher rate of respiration and ethylene production, very susceptible to mechanical injury that limits its postharvest shelf-life at room temperature (Azam et al. 2020). Various postharvest treatments were used to enhance the storage life and quality of guava such as fruits treated with edible coatings (Silva et al., 2018), gamma-irradiation and calcium chloride (Javed, Randhawa, Butt, & Nawaz, 2016; Pandey, Joshua, Bisen, & Abhay, 2010), ascorbic acid (Azam et al., 2020), 1-MCP (Phebe & Ong, 2010), control atmosphere storage (Teixeira, Júnior, Ferraudo, & Durigan, 2016), low temperature storage (Mahajan, Gill, & Dhaliwal, 2017) and packaging types (Rana & Siddiqui, 2018).

Recently edible coatings are used as novel food preserving compounds which help to maintain food quality (Ergun & Satici, 2012). These compounds do not have side effects and due to presence of antimicrobial compounds, increases the food quality and storage period (Ashwini & Desai, 2018). A number of edible coatings have been used and discussed by the scientists and efforts are still going on to find the best one (Abbasi, Iqbal, Maqbool, & Hafiz, 2009; Zhu, Wang, Cao, & Jiang, 2008). Application of edible coating is one of the low cost and proven technologies which have attained wide popularity among the researchers. They prevent the entry and exit of moisture and gases, controls the growth of microorganisms, retain the original color of the fruits, and effectively extend the shelf-life of the product (Vania, 2011). So, edible coating might be the alternative of chemical preservative and one of the best solutions for preserving guava fruit quality and shelf life.

However, in Bangladesh, there is limited information and experience to use edible coatings as postharvest treatment to extend the shelf life of guavas. Therefore, the present experiment was undertaken to study the effect of edible coating in maintaining the postharvest quality of guava.

MATERIALS AND METHODS

Experimental chemicals and materials

Two varieties of guava, namely Swarupkathi and Thai piara was used as experimental materials for the experiment. Swarupkathi guava is oval to round shape, upper surface rough, green and yellowish green in mature and ripe stage respectively. Flesh is whitish, very sweet, juicy and pleasant aroma. Fruits were harvested at turning stage and immediately after harvest fruits were transferred in the laboratory. Thai piara is ovate shape; flesh is white, yellowish green in mature and ripe stage. The guavas were collected from farmer's field at Swarupkathi in Pirojpur district, Bangladesh. Commercially mature fruits of guava with uniform size, shape and maturity were harvested and used for the experiment. The fruits were cured just after harvesting to make sure the temperature of the fruits was stable. Then the skin of the fruits was cleaned with soft cloth and water. The different treatments were selected on the basis of previous studies. The experiments consist of six treatments viz., T_1 = control; T_2 = aloe vera gel (25%); T_3 = carboxy methyl cellulose (CMC) (1%); T_4 = chitosan (1%); T_5 = aloe vera gel (25%) + chitosan (1%); T_6 = tea leaf extract (green tea leaf extract).

Coating application

The 25% aloe vera gel was prepared from collected fresh aloe vera leaves. The colorless hydro parenchyma was mixing with distilled water with a ratio of (1:3), then homogenized in a blender machine. The gel was then filtered by sieve to remove all unwanted lump and to get 25 percent fresh aloe gel. CMC (1%, w/v) was prepared by solubilizing 1 g of CMC powder in 100 mL of water–ethyl alcohol mixture (3:1 L/L) at 75 ˚C under magnetic stirring for 15 min. For preparation of 1% chitosan solution, 10g of chitosan was taken and slowly added to the beaker with 50 ml glacial acetic acid and 1L water placed on magnetic stirrer which was already stirring and gradually heating up. After adding full amount of chitosan powder to the beaker, 1L chitosan solution was prepared. Green tea leaves are heated with distilled water at 90 ˚C for 10 minutes at a ratio of 1gm to 5ml and filtered using Whitman No.1 filter paper. glycerol (10%) was used as additive.

A total of 360 fresh guava fruits of two varieties were used for this experiment. Ten fruits from each variety were selected for individual treatment. Then the selected fruits were individually dipped into each solution for 2 minutes and allowed to air dry for a period of 10 min and then kept on brown paper for observation at 22±2 ˚C and 70-85% relative humidity. During the entire storage period, the fruits used for experiment will be keenly observed everyday but data will be recorded on physico-chemical changes during 2, 4, 6, 8 and 10 DAS influenced by different edible coatings.

Color, firmness and weight loss analyses

Changes in skin color were recorded during storage by matching the pericarp colors with a standard color chart. Digital penetrometer along with a measuring probe (5 mm diameter stainless steel) was used for firmness determination. Fruit firmness was measured from two opposite sides of each fruit by penetrating the probe at a distance of 5 mm into the fruit with pre- and post-test speed 1mms^{-1}. The firmness was calculated as maximum penetration force reached during tissue breakage and expressed as Newton (N).

The percent weight loss was calculated by the following formula (1) by Ranganna (1979):

$$\text{Total weight loss (\%)} = \frac{IW - FW}{IW} \times 100 \qquad (1)$$

[Here, IW= Initial/Fresh weight (g), FW= Final weight (g)]

Titratable acidity (TA) and pH determination

Titratable acidity was determined according to the method by Ranganna (1977) with minor modification. Ten grams of guava pulp tissues were homogenized with 40 ml of distilled water by using a Kitchen blender for two minutes and filtered through a Whatman filter paper No.2. Five milliliters of the guava juice extract solution were taken in a 100ml conical flask. Two to three drops of phenolphthalein indicator solution were added and then the conical flask was shaken vigorously. The sample was titrated with 0.1 M sodium hydroxide (NaOH) solution until the color changed to pink and persistent for at least 15 seconds. The titer volume was recorded and the result was expressed as percentage citric acid, which was calculated using the following formula (2):

$$\text{Citric acid (\%)} = \frac{\text{Titre (mL)} \times \text{NaOH normality (0.1N)} \times \text{vol.made up (50 mL)} \times \text{citric acid eq.weight (64 g)} \times 100}{\text{Vol.of sample for titrate (5 mL)} \times \text{wt.of sample taken (10 g)} \times 1000} \quad (2)$$

The remaining juice extract from TA measurement was used to measure the pH of the fruit pulp. The pH was determined by using a glass electrode pH meter.

Total soluble solids (TSS) (°Brix) analysis

The total soluble solids of the thoroughly mixed guava fruit pulp was directly recorded by using hand refractometer (Model BS Eclipse 3-45) at room temperature (Nanda, Sarkar, Sharma, & Bawa, 2003). Fruits were homogenized in a kitchen blender for two minutes and filtrated through four layers of muslin cloth. A drop of fruit extract was placed on the prism of refractometer and reading was observed. The results were expressed as percent soluble solids (°Brix).

Determination of total sugar content of guava pulp

Sugar content was estimated by determining the volume of unknown sugar solution of guava pulp required for complete reduction of standard Fehling's solution. Fifty gram of fruits was used to calculate percent reducing, non-reducing and total sugar content using the following formulae (3, 4):

$$\text{\% Reducing sugar} = \frac{I \times D \times 100}{T \times D \times 1000} \quad (3)$$

(Where, I = mg of invert sugar required to reduce to known volume of Fehling's solution, D = Dilution, T = Titre and W = wt. of the sample)

% Non-reducing sugar = (% Total invert sugars - % reducing sugars originally present) × 0.95 (conversion factor) (4)

3. % Total sugars = % reducing sugar + % non-reducing sugar

Estimation of vitamin C content

Ascorbic acid content of guava was estimated by titration method using 2, 6-dichlorophenol indophenol dye solution described by Ranganna (1986). The method of estimation involves the reduction of 2, 6-dichlorophenol indophenol dye to a colorless form by ascorbic acid in an alkaline solution. The reaction is quantitative and particularly specific for ascorbic acid in solution in the pH range of 1-3.5. Then the ascorbic acid content of the sample calculated by the following formula (5):

$$\text{Vitamin C (mg/100g fruit)} = \frac{T \times D \times V1}{V2 \times W} \times 100 \quad (5)$$

(Here, T= Titre, D= Dye factor, V_2= Volume made up, V_1= Volume taken for titration, W= Weight of the sample taken for estimation)

Shelf life

Shelf life of guava fruits as influenced by different storage treatments and variety was calculated by counting the days required to ripe fully as to retaining optimum marketing and eating qualities**.**

Statistical analysis

The experiment was carried out in a Completely Randomized Design (CRD) with three replications. The collected data were significantly analyzed by Analysis of variance method using SPSS software. The significance of difference between pair of means will be tested by the Least Significant Difference (LSD) test at 5% and 1% levels of probability (Gomez & Gomez, 1984).

RESULTS AND DISCUSSION

Color

Guava is a green fruit that does not change color much during storage. Instead, it loses water and turns slightly brown, followed by skin softening. This is common under control conditions.

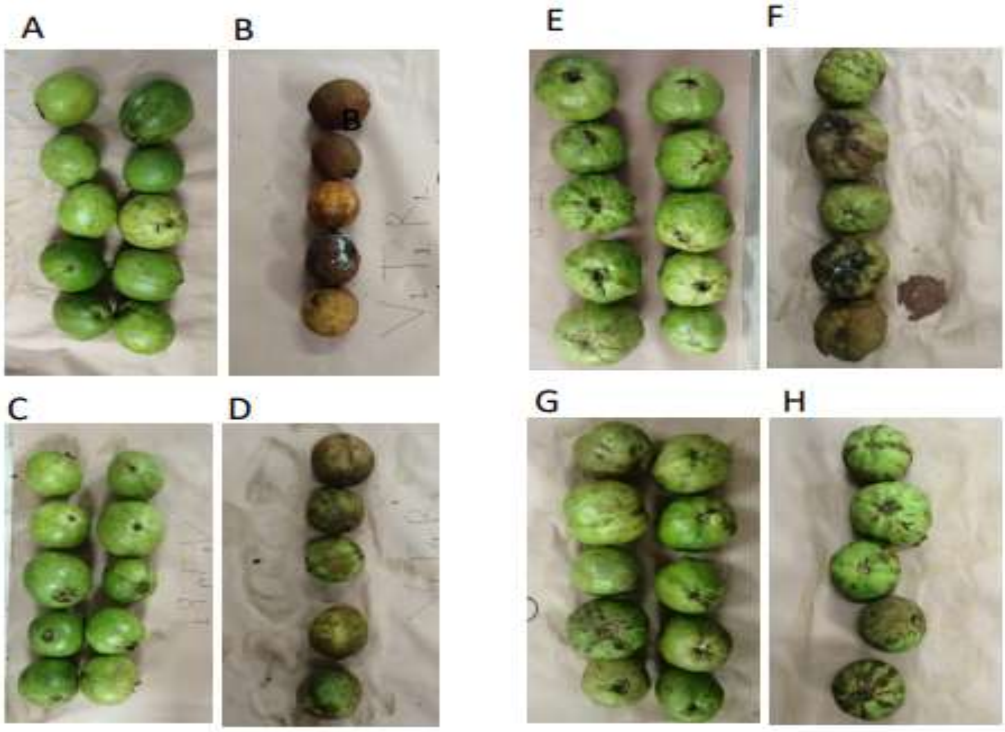

Fig. 1. Color changes of guava fruits during storage. Here, (A & B): Uncoated Swarupkathi piara after 2 and 10 days of storage, (C & D): Swarupkathi piara coated with chitosan (1%) after 2 and 10 days of storage, (E & F): Uncoated Thai piara after 2 and 10 days of storage, (G & H): Thai piara coated with chitosan (1%) after 2 and 10 days of storage.

However, when different postharvest treatments were used, a noticeable difference was observed in each case. In terms of color change, when two varieties of guava were combined with edible coatings, all of the treatments showed better results than control. The best result was found when Thai piara treated with chitosan (1%) and the lowest was noted from Swarupkathi piara without edible coating (Fig. 1). The color changed into brown in Swarupkathi piara after 6 days of storage when fruits were uncoated whereas Thai piara treated with chitosan (1%) able to retain its color up to 12 days followed by aloe vera gel (25%) + chitosan (1%) (11 days).

Firmness and weight loss

In respect of firmness, there was a significant variation was observed between two varieties. However, decreasing trend in firmness was found during storage. At 2 DAS, the highest firmness was 4.30 N which decreased to 3.60 N at 10 DAS in Swarupkathi while in Thai piara, at 2 DAS and 10 DAS, the firmness was 4.40 and 3.76 N, respectively (Fig. 2a). The results on firmness showed that there was a significant variation among the postharvest treatments of guava in relation to storage duration. Higher rate of decreasing trend in firmness was recorded only on control treatment while slow decreased rate on firmness was recorded for other treatments especially in case of carboxy methyl cellulose (1%) (Fig. 2b). The combined effect of varieties and treatments on firmness was non-significant at 2, 4 and 6 DAS but it was significant in 8 and 10 DAS. Decreasing trend of firmness was recorded for increasing of storage duration for all the treatment combinations. At 2 DAS, the highest firmness (4.68 N) was noted from Thai piara coated with carboxy methyl cellulose (1%) whereas the lowest firmness (3.81 N) was recorded from uncoated Swarupkathi piara which was significantly different from other treatment combinations (Table 1). Similar results were observed and they demonstrated that treatment with 2.0 percent chitosan greatly slowed weight loss and firmness loss over the course of a 12-day storage period. (Hong, Xie, Zhang, Sun, & Gong, 2012).

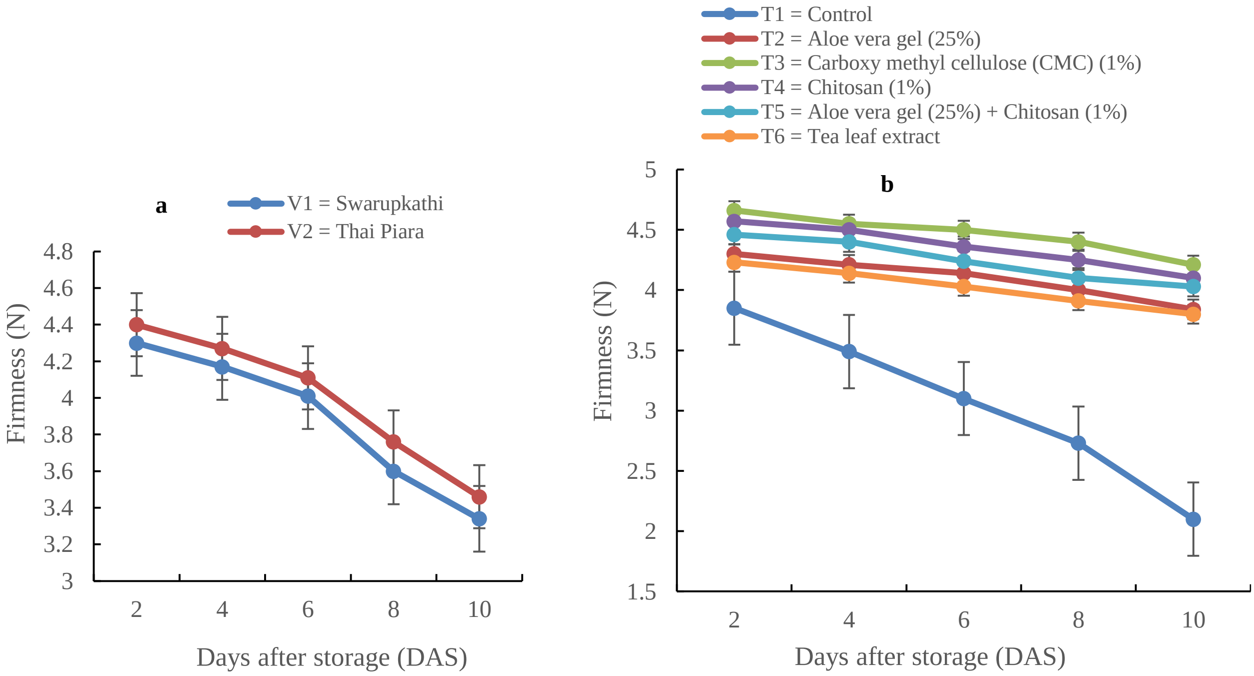

Fig. 2. Effect of variety (a) and treatments (b) on firmness of guava at different days after storage. Vertical bars represent standard error.

During ripening of fruit, softening appears mainly due to middle lamella and cell wall degradation, that mostly occurs in the last stages of the ripening process (He et al., 2019). At the time of ripening of fruit, depolymerization of pectin substances occurs and at the same time increase activities of softening related enzymes such as pectin-esterase and polygalacturonase (Desai & Park, 2006).

Edible coatings restrict the loss of moisture from the fruit to the external environment and to lessen the absorption of the oxygen by the fruit. Its preserve the texture of the fruit by reducing the respiration rate and providing physical protection to the food product. Less availability of oxygen to the coated fruit may be responsible for reduction in the activities of these enzymes and hence retention of the firmness of fruits during storage (Salunkhe, Bolin, & Reddy, 1991).

There was a significant difference between the two varieties in terms of total weight loss. However, it was shown that in both varieties, the rate of weight loss increased as the storage duration lengthened. The weight loss was greater in Swarupkathi (8.12%) compared to Thai Piara (7.63%) at 10th days after storage (Fig. 3a). The current study demonstrated that postharvest treatments greatly showed significant effects in respect of weight loss. The total weight loss was found to be the highest (6.99, 7.69, 8.17, 9.07 and 9.89%) in case of uncoated fruits where the fruit treated with chitosan 1% represented the lowest weight loss (4.32, 4.75, 5.41, 5.98 and 6.32%) at 2, 4, 6, 8 and 10 days after storage, respectively (Fig. 3b). Combined effect of treatments and fruit varieties showed non-significant variation in 2 and 4 DAS. But in case of 6, 8 and 10 DAS, significant variation was observed on overall weight loss.

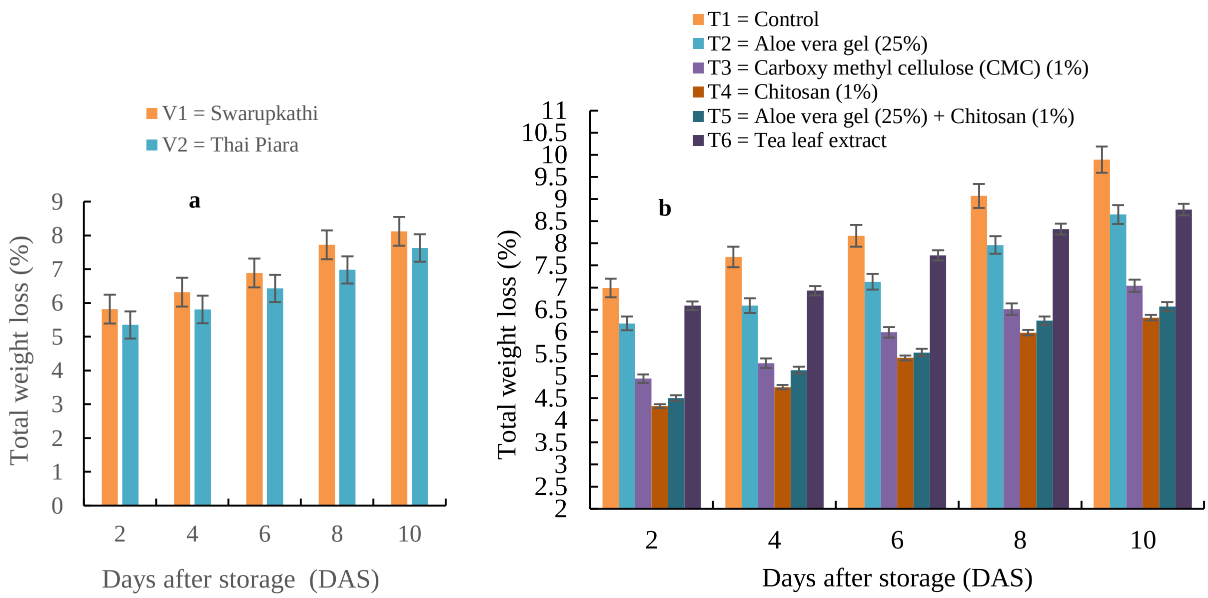

Fig. 3. Effect of variety (a) and treatments (b) on total weight loss of guava at different days after storage. Vertical bars represent standard error**.**

The variety, Swarupkathi under control treatment gave the highest weight loss (6.79, 7.24, 7.80, 8.03 and 8.32% at 2, 4, 6, 8 and 10 DAS, respectively) whereas the lowest weight loss (4.21. 4.63, 5.47, 5.93 and 6.28 % at 2, 4, 6, 8 and 10 DAS, respectively) was found in Thai Piara treated with Chitosan (1%) (Table 2). The present result was similar to the findings of Krishna and Rao (2014), they found that the total weight loss increased gradually in all the treatments with advancement of storage period. Islam et al. (2018) also found that the application of 2% chitosan showed the lowest weight loss 6.58% in banana compared to the control samples. Edible coating closed the opening of stomata and lenticels thereby, reducing the rate of transpiration and respiration, which increases retention of moisture in the fruit. During storage period, weight loss increased with the advancement of storage which might be due to increase in respiration rate of fruits (Azam et al., 2020).

pH

Significant variation between two varieties was seen in cases of fruits pulp pH during total storage period except 6 DAS. However, from 2 DAS to 10 DAS, an increasing pH trend was seen. At 2 DAS, the highest pH was 3.78 which increased to 6.13 at 10 DAS in Swarupkathi while in Thai Piara, at 2 DAS and 10 DAS, the pH was 3.52 and 5.70, respectively. At 4, 6, 8 and 10 DAS, the higher pH (4.29, 4.63, 5.58 and 6.13 respectively) was recorded in Swarupkathi whereas the lower pH was recorded (3.96, 4.60, 5.58, and 5.70) respectively in Thai Piara (Fig. 4a).

Significant difference among the postharvest guava treatments in respect pH of fruit pulp was recorded during storage. Only the control treatment showed a higher rate of pH increment, while other treatments, particularly chitosan (1%), showed a slower rate of pH increment. At 2 DAS, the highest pH (4.02) was found in control treatment and the lowest pH (3.38) was marked in the fruits in chitosan (1%) treatment followed by 3.45 in aloe vera gel (25%) + chitosan (1%), 3.60 in carboxy methyl cellulose (Fig. 4b).

The combined effect of varieties and edible coating on pH was significant at 2 and 10 DAS but non-significant at 4, 6, and 8 DAS (Table 3). At 2 DAS, Uncoated Thai piara exhibited the greatest pH (4.23) and Swarupkathi piara coated with chitosan (1%) showed the lowest pH (3.34). For all treatment combinations, an increasing trend in pH was observed as storage duration increased. At 4, 6, 8 and 10 DAS, the maximum pH (4.56, 5.10, 6.27, and 6.74, respectively) was observed in uncoated Thai piara, whereas the minimum pH (4.09, 4.77, 5.10, and 5.30, respectively) was recorded in Swarupkathi piara treated with chitosan (1%). Similar results were also observed by Azam et al. (2020). They found that pH values increased slightly during storage periods. With the progression of the storage period, pH was found to be higher in untreated fruits and lower in acetic acid treated fruits (He et al., 2018).

Table 1. Effect of variety and postharvest treatments on firmness of guava during storage.

Variety × Treatments	Firmness at different DAS				
	2	4	6	8	10
V_1T_1	3.81	3.43	3.06	2.61e	2.01 e
V_1T_2	4.25	4.16	4.08	3.95 de	3.81 cd
V_1T_3	4.65	4.50	4.45	4.35 ab	4.15 a-c
V_1T_4	4.51	4.46	4.30	4.18 b-d	4.00 a-d
V_1T_5	4.40	4.38	4.20	4.05 c-e	3.91 b-d
V_1T_6	4.20	4.10	4.00	3.90 e	3.75 d
V_2T_1	3.90	3.55	3.15	2.85 f	2.20 e
V_2T_2	4.36	4.26	4.20	4.05 c-e	3.86 b-d
V_2T_3	4.68	4.61	4.56	4.46 a	4.28 a
V_2T_4	4.63	4.55	4.43	4.33 ab	4.2 ab
V_2T_5	4.53	4.41	4.28	4.21 a-c	4.15 a-c
V_2T_6	4.26	4.18	4.06	3.93 de	3.85 cd
Level of significance	NS	NS	NS	*	*
LSD at 1%	0.22	0.2	0.19	0.21	0.27
CV (%)	2.2	3.08	2.13	2.28	3.19

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.01 level of probability. * & ** Significant at 5 & 1% level of provability, NS = Non-significant, CV = Coefficient of variation, DAS = Days after storage, V_1: Swarupkathi, V_2: Thai Piara, T_1: Control, T_2: Aloe vera gel (25%), T_3: Carboxy methyl cellulose (CMC) (1%), T_4: Chitosan (1%), T_5: Aloe vera gel (25%) + Chitosan (1%), T_6: Tea leaf extract.

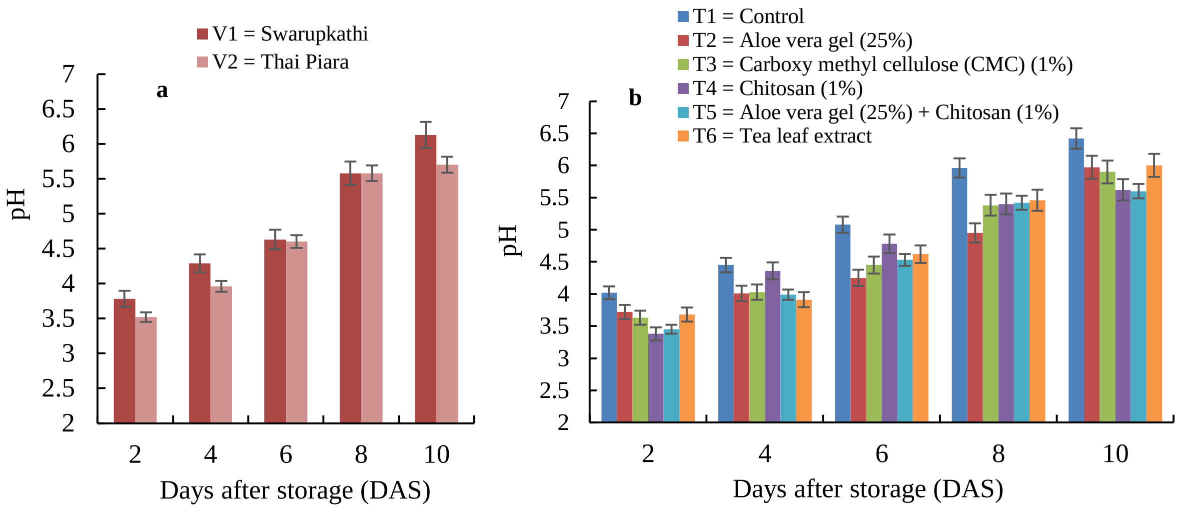

Fig. 4. Effect of variety (a) and treatments (b) on pH of guava at different days after storage. Vertical bars represent standard error.

Table 2. Combined effect of variety and postharvest treatments on total weight loss of guava during storage.

Variety × Treatments	Total weight loss (%) at different DAS				
	2	4	6	8	10
V_1T_1	7.18	8.13	8.55 a	9.48 a	10.16 a
V_1T_2	6.65	6.91	7.53 b	8.69 b	9.02 c
V_1T_3	5.03	5.29	6.25 cd	6.73 e	7.07 e
V_1T_4	4.42	4.87	5.35 e	6.03 fg	6.37 fg
V_1T_5	4.72	5.47	5.78 de	6.74 e	6.88 ef
V_1T_6	6.91	7.25	7.86 b	8.62 b	9.20 bc
V_2T_1	6.79	7.24	7.80 b	8.67 b	9.26 b
V_2T_2	5.74	6.28	6.72 c	7.23 d	8.27 d
V_2T_3	4.84	5.28	5.73 de	6.29 f	7.01 e
V_2T_4	4.21	4.63	5.47 e	5.93 g	6.28 g
V_2T_5	4.28	4.81	5.29 e	5.76 g	6.27 g
V_2T_6	6.26	6.61	7.60 b	8.03 c	8.32 d
Level of significance	NS	NS	*	**	*
LSD at 1%	0.7	0.56	0.57	0.29	0.51
CV (%)	5.46	4.06	3.73	1.7	2.82

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.01 level of probability.

Table 3. Combined effect of variety and postharvest treatments on pH of guava during storage.

Variety × Treatment	pH at different DAS				
	2	4	6	8	10
V_1T_1	3.82 bc	4.34	5.10	6.27	6.1 bc
V_1T_2	3.46 e	3.77	4.12	4.74	5.61 d-f
V_1T_3	3.40 e	3.84	4.52	5.20	5.76 de
V_1T_4	3.34 e	4.09	4.77	5.10	5.30 f
V_1T_5	3.43 e	3.93	4.43	5.07	5.48 ef
V_1T_6	3.67 cd	3.78	4.67	5.25	5.97 c
V_2T_1	4.23 a	4.56	5.06	5.66	6.74 a
V_2T_2	3.98 b	4.25	4.40	5.16	6.34 b
V_2T_3	3.86 bc	4.23	4.37	5.57	6.04 bc
V_2T_4	3.43 e	4.63	4.78	5.68	5.77 c-e
V_2T_5	3.48 de	4.06	4.64	5.74	5.91 cd
V_2T_6	3.69 c	4.03	4.57	5.68	6.04 bc
Level of significance	**	NS	NS	NS	**
LSD at 1%	0.15	0.48	0.52	0.83	0.28
CV (%)	1.86	5.14	4.86	6.63	2.02

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.01 level of probability.

Titratable acidity (TA)

In respect of titratable acidity, there was a non-significant variation between two varieties was seen in case of titratable acidity. However, decreasing trend in titratable acidity was found from 2 DAS to 10 DAS. At 2 DAS, the highest titratable acidity was 1.99% which decreased to 1.43% at 10 DAS (DAS) in Swarupkathi while in Thai Piara, at 2 DAS and 10 DAS, the titratable acidity were 1.92% and 1.42% respectively which was lowest compared to Swarupkathi (Fig. 5a). At 4, 6, and 8 DAS, the highest titratable acidity (1.90, 1.68 and 1.50%, respectively) was recorded in Swarupkathi whereas the lowest titratable acidity (1.81, 1.58 and 1.50 %, respectively) was measured in Thai Piara.

The results on titratable acidity of guava showed that there was a highly significant variation among the postharvest treatments in relation to storage duration (Fig. 5b). Higher rate of decreasing trend in titratable acidity was recorded only on control treatment while slow decreased rate on titratable acidity was recorded for other treatments especially in case of chitosan (1%). At 2 DAS, the highest titratable acidity 2.49% was found in chitosan (1%) treatment followed by 2.23 in carboxy methyl cellulose (1%) and the lowest 1.4% in the fruits under control treatment (Fig. 5b). At 4, 6, 8 and 10 DAS, the maximum titratable acidity (2.38, 2.20, 2.04 and 1.98%, respectively) was recorded in chitosan (1%) treatment and the minimum (1.34, 1.08, 1.02 and 0.91%, respectively) was marked in control treatment (Fig. 5b).

The combined effect of varieties and treatments on titratable acidity was significant during storage (Table 4). At 2 DAS, the highest titratable acidity 2.56% was recorded in Thai piara treated with chitosan (1%) followed by 2.43 and 2.31% in Swarupkathi piara treated with chitosan (1%) and carboxy methyl cellulose (1%) respectively whereas the lowest titratable acidity 1.53% was recorded in untreated Swarupkathi piara. Decreasing trend of titratable acidity was recorded for increasing of storage duration for all the treatment combinations. At 4, 6, 8 and 10 DAS, the maximum titratable acidity (2.30, 2.24, 2.17 and 2.04%, respectively) was also recorded in Chitosan (1%) treated Thai piara whereas the minimum titratable acidity (1.27, 1.02, 1.02 and 0.77 %, respectively) was found in untreated Swarupkathi piara (Table 4). That is similar to the findings of (Silva et al., 2018), they demonstrated that in the treatment with 2% and 3% of chitosan in the solid soluble content and ascorbic acid were reduced; retarded the loss of titratable acidity during 96 h after treatment. The maximum utilization of acid in the metabolism of organic acid during respiratory process might be the reason for minimum acidity in control and in advancement of storage period (Silva et al., 2018).

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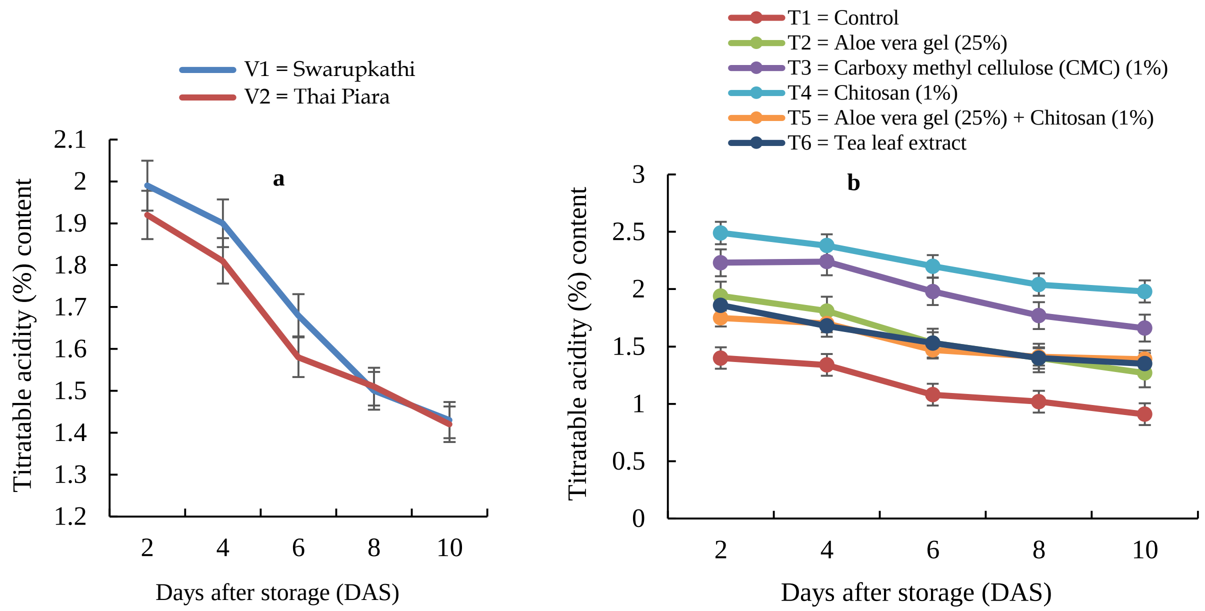

Fig. 5. Effect of variety (a) and treatments (b) on titratable acidity of guava at different days after storage. Vertical bars represent standard error.

Table 4. Combined effect of variety and postharvest treatments on titratable acidity of guava during storage.

Variety× Treatments	Titratable acidity (%) at different DAS				
	2	4	6	8	10
V_1T_1	1.40 e	1.27 g	1.02 h	1.02 g	0.77 g
V_1T_2	2.26 a-c	2.04 c	1.79 b-e	1.66 b-d	1.4 cd
V_1T_3	2.31 a-d	2.21 b	2.04 a-c	1.74 b-d	1.79 b
V_1T_4	2.43 ab	2.46 a	2.17 ab	1.91 ab	1.92 ab
V_1T_5	1.58 de	1.53 ef	1.40 e-h	1.27 e-g	1.29 de
V_1T_6	1.91 a-e	1.79 d	1.66 c-f	1.40 d-f	1.41 cd
V_2T_1	1.53 e	1.40 fg	1.15 gh	1.02 g	1.05 f
V_2T_2	1.62 c-e	1.57 e	1.27 f-h	1.15 fg	1.15 ef
V_2T_3	2.25 a-c	2.17 bc	1.91 a-d	1.79 bc	1.53 c
V_2T_4	2.56 a	2.3 b	2.24 a	2.17 a	2.04 a
V_2T_5	1.92 a-e	1.87 d	1.53 d-g	1.53 c-e	1.49 cd
V_2T_6	1.79 b-e	1.57 e	1.40 e-h	1.40 d-f	1.28 def
Level of significance	*	*	**	**	**
LSD at 1%	0.52	0.12	0.32	0.29	0.18
CV (%)	11.47	2.89	8.40	8.37	5.50

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.01 & 0.05 level of probability.

Total soluble solids (TSS)

The different varieties used in the investigation showed statistically significant variation in case of total soluble solid content of guava at 2, 4, and 10 DAS but non-significant variation at 6 and 8 DAS. At 2, 4, 6, 8 and 10 DAS, Thai Piara had higher TSS content (5.32, 5.92, 6.73, 7.79 and 8.66%) and the variety Swarupkathi had lower TSS content (4.93, 5.86, 6.70 7.70 8.55 % at 2, 4, 6, 8 and 10 DAS, respectively) (Fig. 6a).

The different treatments used in the investigation showed statistically significant variation in relation to TSS during storage period. Control treatment showed the highest TSS content 6.36, 6.93, 7.76, 9.05 and 9.76% at 2, 4, 6, 8 and 10 DAS, respectively. But under the treated terms, aloe vera gel (25%) showed the highest TSS content followed by tea leaf extract where the lowest TSS content was achieved by chitosan (1%) treatment (3.60, 4.37, 5.05, 5.73 and

6.60%) at 2, 4, 6, 8 and 10 DAS, respectively followed by aloe vera gel (25%) + chitosan (1%) (Fig. 6b).

It was found that the combined effects of variety and postharvest treatments were statistically significant during entire storage period (Table 5). It was found that untreated Thai piara (6.80, 7.23, 7.87, 9.10 and 9.81%) showed the highest TSS content compared to Swarupkathi piara (6.60, 6.90, 7.80, 8.87 and 9.73%) and at 2, 4, 6, 8 and 10 DAS, respectively. Results also revealed that the lowest TSS content was noted from chitosan (1%) treated Swarupkathi (3.50, 4.30, 4.96, 5.53 and 6.43%) followed by Thai piara treated with same treatment (3.70, 4.41, 5.13, 5.93 and 6.77%) at 2, 4, 6, 8 and 10 DAS, respectively. (Table 5). This observation is somewhat similar to Kumar et al. (2017). Kumar et al. (2020), reported that that fruits treated with chitosan (0.25% and 0.50%) were better in maintaining all physico-chemical characteristics (pH-4.60, TSS-9.40, Acidity-0.34, Ascorbic acid-208, Weight loss-14.87 and Moisture-73.37) than control throughout the storage period. The highest TSS in aloe vera gel coated fruits might be due to more concentration of juice resulting higher content of sugars, while minimum acidity may be due to more utilization of acids in biochemical activities leading to depletion of organic acids. The increasing trend of percent total soluble solids contents of fruit during storage could be attributed mainly to the breakdown of starch into simple sugars Mondal et al. (2023).

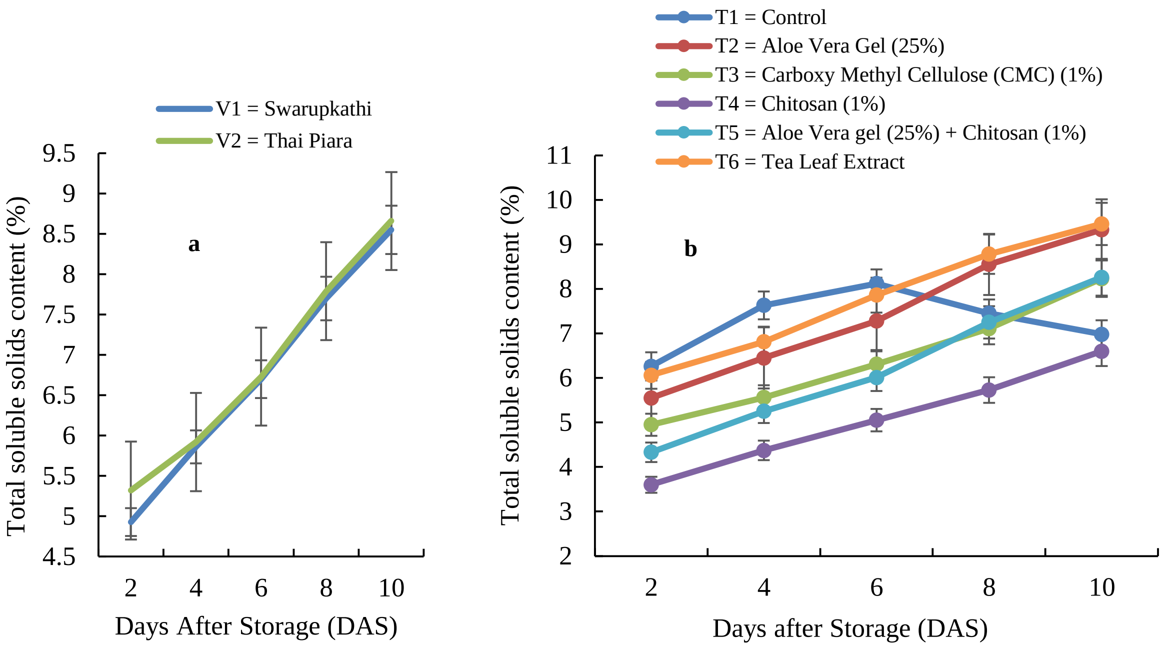

Fig. 6. Effect of variety (a) and treatments (b) on TSS of guava at different days after storage. Vertical bars represent standard error.

Table 5. Combined effect of variety and postharvest treatments on TSS of guava during storage.

	TSS (° Brix) at different DAS				
Variety × Treatments	2	4	6	8	10
V_1T_1	6.60 a	6.9 ab	7.80 a	6.62 de	6.43 e
V_1T_2	5.40 cd	6.36 c	7.06 b	8.60 c	9.26 b
V_1T_3	4.60 e	5.30 e	6.20 cd	7.13 d	8.16 c
V_1T_4	3.50 g	4.30 f	4.96 e	5.53 f	6.43 e
V_1T_5	4.20 f	5.33 e	6.13 cd	7.26 d	8.2 c
V_1T_6	5.70 b	6.53 bc	7.50 ab	8.51 c	9.40 b
V_2T_1	6.80 a	7.23 a	7.87 a	6.69 de	6.51 de
V_2T_2	5.70 b	6.73 bc	7.86 a	9.00 ab	9.53 ab
V_2T_3	5.23 d	5.83 d	6.43 c	7.10 d	8.31 c
V_2T_4	3.70 g	4.41 f	5.13 e	5.93 e	6.77 d
V_2T_5	4.46 ef	5.16 e	5.91 d	7.23 d	8.33 c
$V T_6$	5.53 bc	6.63 bc	7.73 a	8.70 bc	9.41 b
Level of significance	**	**	**	*	*
LSD at 1%	0.21	0.38	0.39	0.29	0.26
CV (%)	1.81	2.84	2.54	1.65	1.29

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.01 & 0.05 level of probability.

Total Sugar

There was a significant difference between the two varieties in terms of total sugar content. The highest total sugar content (8.26%) was recorded in Thai Piara, whereas it was the lowest (7.85%) in Swarupkathi at 10 DAS. However, increasing trend in percent total sugar content was found from 2 DAS to 10 DAS (Fig. 7a).

The results on percent total sugar content showed that there was a highly significant variation among the postharvest treatments of guava pulp in relation to storage duration. Higher rate of increasing trend in percent total sugar content was recorded only on control treatment while lower increased rate on percent total sugar content was recorded for other treatments especially in case of T_5 (25% aloe-vera gel + 1% Chitosan) (Fig. 7b).

The combined effect of varieties and treatments on percent total sugar content was highly significant during entire storage period. At 10 DAS, the maximum percent total sugar content (9.79%) was recorded in untreated Thai piara whereas the minimum percent total sugar content (5.78%) was found in Swarupkathi piara treated with aloe vera gel (25%) + chitosan (1%) (Table 6).

Under the present study total sugar content increased during storage period which is similar to the observation of (Augustin & Osman, 1988) and he reported that storing guava at ambient temperature showed significant increase in total sugar content. Total sugars of fruits are considered one of the basic criteria to evaluate the fruit ripening. From our results it was observed that total sugars were very low at initial stage but it was gradually increased with advancement of storage period. The increase in sugars during storage period might be due to rapid conservation of polysaccharides into sugars. The result is also similar to the findings of Bose et al. (2019).

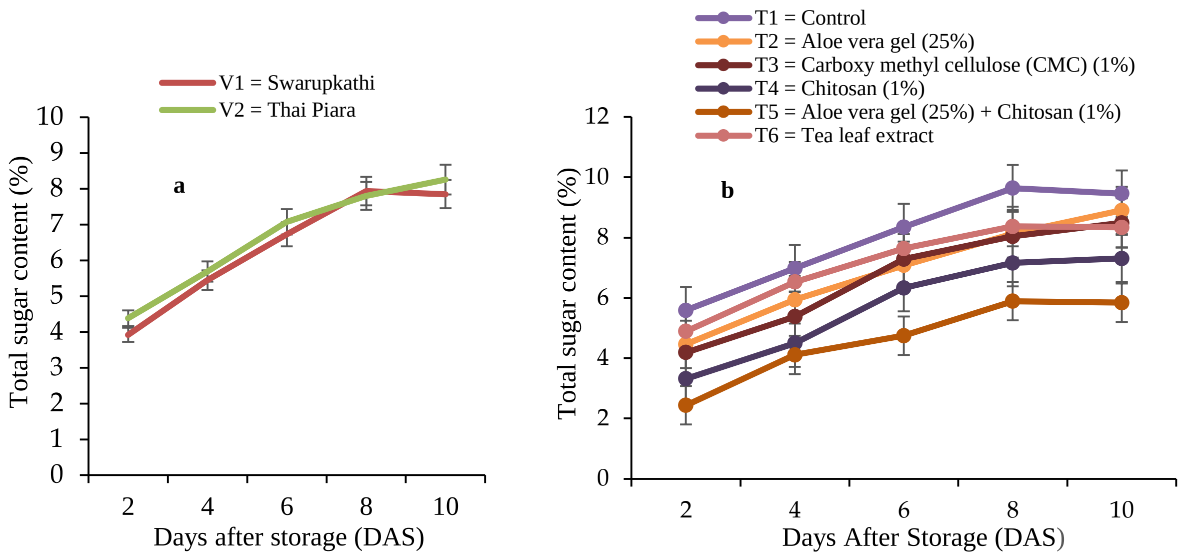

Fig. 7. Effect of variety (a) and treatments (b) on total sugar content of guava at different days after storage. Vertical bars represent standard error.

Table 6. Combined effect of variety and postharvest treatments on total sugar content of guava during storage.

Variety × Treatments	Total sugar content (%) at different DAS				
	2	4	6	8	10
V_1T_1	5.62 a	6.79 b	8.17 b	9.94 a	9.16 b
V_1T_2	4.01 c	5.68 d	6.27 f	7.91 e	9.07 bc
V_1T_3	3.97 c	5.32 e	7.72 cd	8.07 de	8.3 e3
V_1T_4	2.84 d	4.26 g	5.92 g	7.08 f	7 g
V_1T_5	2.34 d	3.77 h	4.49 i	5.96 g	5.78 h
V_1T_6	5.09 b	6.98 ab	7.82 c	8.7 c	7.84 f
V_2T_1	5.67 a	7.19 a	8.52 a	9.28 b	9.79 a
V_2T_2	4.88 ab	6.28 c	7.82 bc	8.3 d	8.83 cd
V_2T_3	4.41 bc	5.42 de	6.86 e	8.06 de	8.64 d
V_2T_4	3.81 c	4.73 f	6.74 e	7.24 f	7.61 f
V_2T_5	2.65 d	4.47 fg	5.02 h	5.81 g	5.9 h
V_2T_6	5.05 ab	6.11 c	7.47 d	7.99 e	8.44 cd
Level of significance	**	**	**	**	**
LSD at 1%	0.51	0.24	0.26	0.25	0.23
CV (%)	5.34	1.88	1.47	1.34	1.22

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.01 level of probability.

Vitamin C content

Vitamin C content of guava pulp was significantly influenced between two varieties of guava during storage period. The higher vitamin C content (199.32, 194.00, 187.59, 181.58 and 177.19 mg/100g) was found in Thai Piara and the lower vitamin C content (194.42, 191.49, 184.87, 178.24 and 171.79 mg/100g) was observed in Swarupkathi at 2, 4, 6, 8 and 10 DAS, respectively (Fig. 8a).

Effects of different postharvest treatments in respect of vitamin C content were statistically significant at different days of storage. There was a decreasing trend in relation to vitamin C content of fruit pulp during storage. The higher vitamin C content (191.18 mg/100g) was recorded in chitosan (1%) treatment followed by treatment aloe vera gel (25%) + chitosan (1%) and lower vitamin C content (159.64 mg/100g) was found in control followed by aloe vera gel (25%) at 10 DAS (Fig. 8b).

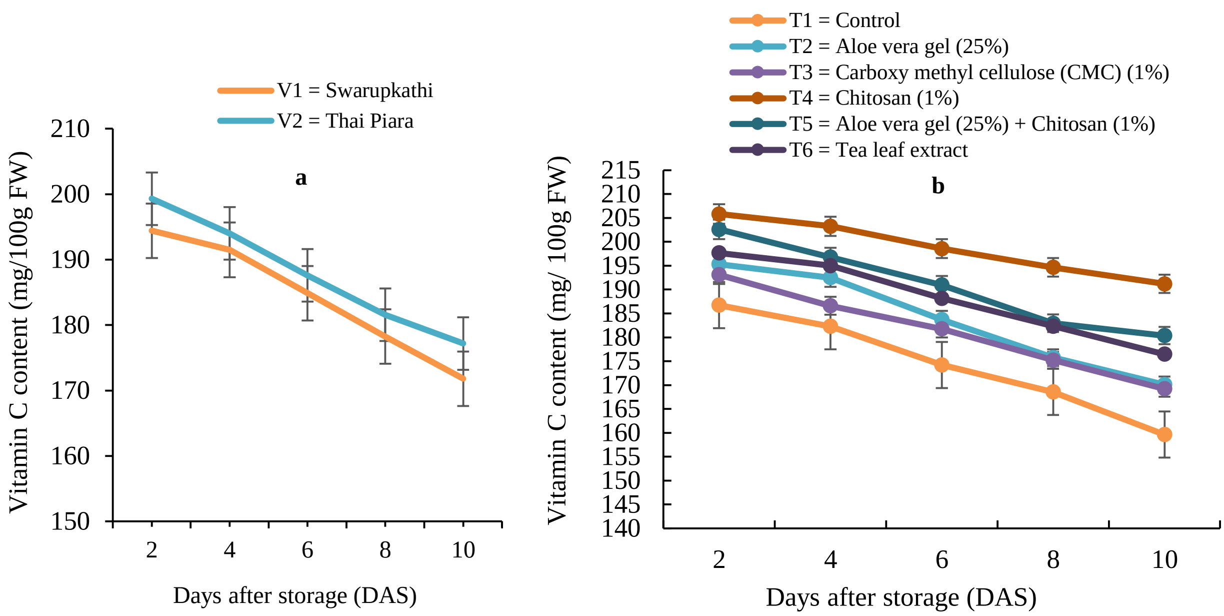

Fig. 8. Effect of variety (a) and treatments (b) on vitamin C content of guava at different days after storage. Vertical bars represent standard error.

Table 7. Combined effect of variety and postharvest treatments on vitamin C content of guava during storage.

	Vitamin C content (mg/100g FW) at different DAS				
Variety × Treatments	2	4	6	8	10
V_1T_1	185.21 j	180.97 k	172.60 k	168.99 de	157.3 h
V_1T_2	193.27 g	190.45 g	182.65 h	175.81 c	168.59 ef
V_1T_3	191.60 h	187.64 h	185.26 fg	174.17 cd	167.55 f
V_1T_4	201.52 c	200.94 b	196.78 b	194.08 a	190.92 ab
V_1T_5	198.41 de	195.36 de	186.29 e	177.67 c	173.43 d
V_1T_6	196.52 f	193.58 f	185.62 ef	178.67 c	172.41 de
V_2T_1	188.23 i	183.63 j	175.83 j	168.13 e	161.98 g
V_2T_2	197.38 ef	194.55 ef	184.77 g	175.67 c	171. 58 d-f
V_2T_3	194.58 g	185.56 i	178.26 i	176.25 c	170.90 d-f
V_2T_4	210.12 a	205.58 a	200.38 a	195.17 a	191.44 a
V_2T_5	206.79 b	198.20 c	195.64 c	188.22 b	187.26 b
V_2T_6	198.84 d	196.46 d	190.68 d	186.02 b	180.50 c
Level of significance	**	**	**	**	**
LSD at 1%	1.04	0.95	0.6	4.2	3.19
CV (%)	0.23	0.21	0.14	1.01	0.8

In a column, means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.01 level of probability.

Combined effects of variety and postharvest treatments on vitamin C content were significant during storage period. The higher vitamin C content (210.12, 205.58, 200.38, 195.17 and 190.92 mg/100g) was found in chitosan (1%) treated Thai piara followed by Swarupkathi piara treated with same treatment at 2, 4, 6, 8 and 10 DAS, respectively. The lower vitamin C content (185.21, 180.97, 172.60, 168.99 and 157.3 mg/100g) was observed in untreated Swarupkathi piara followed by untreated Thai piara at 2, 4, 6, 8 and 10 DAS, respectively (Table 7).

The result is also similar to the findings of Silva et al. (2018). They demonstrated that in the treatment with 2% and 3% of chitosan in the solid soluble content and ascorbic acid were reduced; retarded the loss of titratable acidity during 96 h after treatment. Vitamin C is one of the powerful antioxidant and scavenger of the reactive oxygen species (ROS) produced in the body thus helps to save the human from many serious diseases (Patel, Naik, & Arbat, 2011). The fruits coated with 1% chitosan maintained the higher levels of vitamin C compared to other coated materials. It might possibly be due to retardation of oxidation process and consequently slow rate of conversion of L-ascorbic acid into dehydroascorbic acid by ascorbic acid oxidase. Similar observation have also been recorded in mango (Jain & Mukherjee, 2011) and mandarin orange (Yadav, Kumar, Singh, & Singh, 2010).

Shelf life

In the current investigation, a highly significant difference in shelf life between the two guava varieties was found. Thai Piara had longer shelf life (9.94 days) than Swarupkathi's (7.94 days) (Fig. 9a).

The shelf life of guava was significantly varied by postharvest treatments (Fig. 9b). The study's findings showed that guava fruits had a shelf life of between 6 and 11.67 days. The longest shelf life (11.67 days) was found in aloe vera gel (25%) + chitosan (1%) followed by (11.6 days) in chitosan (1%), whereas the shortest shelf life (6.00 days) was recorded in Control (Fig. 9b).

The combined effects of variety and postharvest treatments were significant in extending shelf life (Table 8). The longest shelf life (13.00 days) was observed in Thai piara treated with aloe vera gel 25% + chitosan 1% followed by chitosan (1%) (12.67 days). On the other hand, the shortest shelf life (5.00 days) was observed in untreated Swarupkathi piara followed by untreated Thai piara (6.67 days), (Table 8). Fruits degrade to the simpler inorganic compound (CO_2, HO_2, and NH_3), decreased in free energy and increase in respiration, consequently reduce the shelf life as well as other qualities of fruits (Mondal et al., 2023).

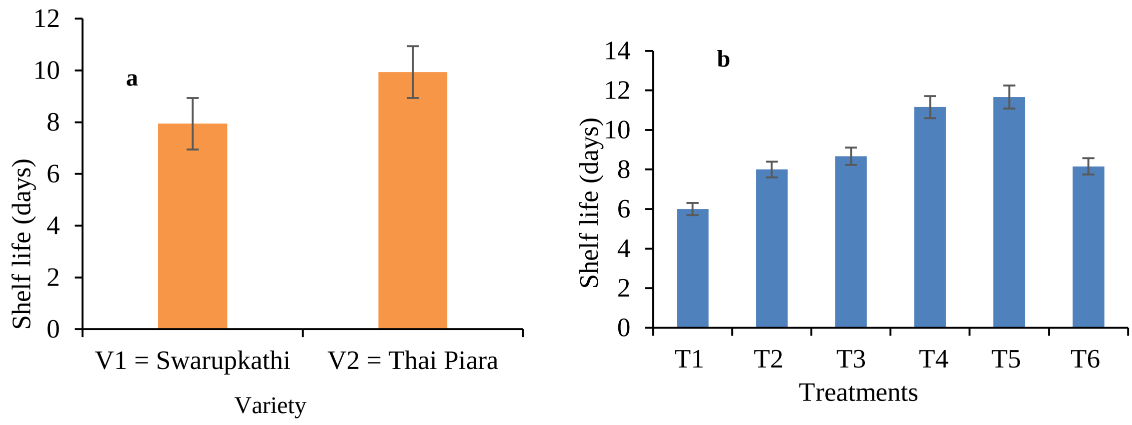

Fig. 9. Effect of variety (a) and treatments (b) on shelf life of guava at different days after storage. Vertical bars represent standard error.

Table 8. Combined effect of variety and postharvest treatments on shelf life of two variety of guava.

Variety × Treatments	Shelf life (days)
V_1T_1	5.33 g
V_1T_2	7.33 def
V_1T_3	7.67 e
V_1T_4	10.33 b
V_1T_5	9.67 bc
V_1T_6	7.00 ef
V_2T_1	6.67 f
V_2T_2	8.67 d
V_2T_3	9.67 bc
V_2T_4	12.67 a
V_2T_5	13.00 a
V_2T_6	9.00 cd
Level of significance	*
LSD at 1%	1.19
CV (%)	5.81

Means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

CONCLUSION

It can be concluded that between the two tested variety, Thai Piara performed better than Swarupkathi. Thai Piara with edible coating aloe vera gel 25% + chitosan 1% exhibited longest shelf life (13 days) compare to control with Swarupkathi. chitosan 1% with Thai Piara also showed promising results. Finally, this study recommends that guava treated with chitosan 1%, followed by aloe vera gel 25% + chitosan 1% solution as edible coating is promising for long term storage and maintaining overall quality of guava fruits.

This study recommends chitosan as the best edible coating material that is very effective in improving the overall quality of mango fruits.

Conflict of interest

Author declared no conflict of interests.

Acknowledgments

I am grateful to the Ministry of Science and Technology of Bangladesh for financial support to conduct the research work.

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