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Chitosan oligosaccharides maintained postharvest quality and increased shelf life of mango

Nishat Jahan Nitu[1], Md. Sefat Ullah[1], Prianka Howlader[1], Md. Nazmul Hasan Mehedi[1], Habiba Zannat Meem[1] and Santosh Kumar Bose[1*]

1, Department of Horticulture, Patuakhali Science and Technology University (PSTU), Dumki, Patuakhali-8602, Bangladesh

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***Corresponding author:**
Department of Horticulture, Patuakhali Science and Technology University (PSTU), Dumki, Patuakhali-8602, Bangladesh.

Email: santosh@pstu.ac.bd

ABSTRACT

Purpose: Mango is one of the most important and widely cultivated climacteric fruit which ripens rapidly after harvesting. It exhibits very short shelf life mainly due to high respiration rate, susceptible to various storage pathogens and mechanical injuries at the time of postharvest management which lead to reduce the quality. However, the experiment was carried out to investigate the chitosan oligosaccharides (COS) coating effects on postharvest quality and shelf life of mango varieties. **Research Method:** Mango fruits of two selected varieties (Langra and Amropali) were collected at mature stage. Changes in different physico-chemical characteristics were studied at different days of storage under ordinary room condition through different COS concentration viz., control, COS 25 mg/L, COS 50 mg/L, COS 100 mg/L, COS 250 mg/L and COS 500 mg/L. The two factor-experiments were laid out in a completely randomized design with three replications. **Findings:** Results demonstrated that COS had a positive effect on retaining higher amount of anthocyanin content, total sugar and total soluble solid content. Moreover, COS treated fruits exhibited significant delays of firmness, weight loss percentage, titratable acidity, pH and vitamin C content compared to untreated fruits. In addition, between two varieties of mango, Langra exhibited better performance compared to Amropali when treated with COS 100 mg/L. **Research Limitations:** The study did not focus on ethylene biosynthesis and respiration rate determination. **Originality/Value:** COS 100mg/L have great potentiality to maintain postharvest quality and increase shelf life of mango which could be applied commercially for preservation of mango in an ecofriendly manner.

INTRODUCTION

Mango (*Mangifera indica*) belongs to the family Anacardiaceae, is one of the most delicious, attractive and extensively cultured tropical fruit in the world. It is known as king of fruits among all the fruits cultivated in the world (Kobra et al., 2012). In Bangladesh mango found to be grow in all districts and one of the most popular fruits. It has also strong economic impact on the economy of Bangladesh. Mango occupied an area of 121075 ha with production of 1948583 metric tons which contribute 28.22% of the area and 26.38% production of total fruit crops in Bangladesh (BBS, 2022). Nutritionally, mango is a great source of carbohydrates, nutritional fiber, vitamins (vit A, beta-carotene, vit C, vit K etc), minerals arid (iron, calcium, magnesium, manganese etc.) protein, low fats and it play vital role to save many human diseases (Sogi et al., 2013).

Mangoes, one of the climacteric fruits, ripen rapidly after harvest and are easily infected by several postharvest diseases, susceptible to mechanical injury which lead to considerable postharvest losses, and limits the storage, handling and transport. Post-harvest losses occur due to various factors such as the usage of inappropriate harvesting tools, inefficient handling and lack of suitable transport equipment, usage of inappropriate packaging materials, poor temperature management and rough handling of fresh fruits as well as substandard road infrastructure (Kefas et al., 2024). There are a number of fungi *(Colletotrium gloeosporoides, Botryodiplodia theobromae* etc.) attack mango fruits at maturity after collection from tree. These fungi cause infection during storage and transfer. Short shelf-life and lack of proper postharvest management has restricted mango export to distant markets. Therefore, various techniques such as use of a plant growth regulator, ionizing radiation, plant extracts, modified atmosphere, controlled atmosphere, and edible coatings were used to extend the postharvest life of mango (Perumal et al., 2017). The use of synthetic chemicals and different storage techniques may be leave residue to the fruit which have detrimental effect on both human and environment (Bose et al., 2021a). Nowadays, globally consumers prefer more natural, eco-friendly process product with high nutritional quality and long shelf life. Regarding this issue, the use of bio-preservatives is of growing interest for preserving quality and increasing shelf life of mango.

Nowadays the use of natural non-toxic substance including chitosan (Chaiprasart et al., 2006), chitosan oligosaccharides (He et al., 2019), alginate oligosaccharides for fruit storage and preservation, showing great attention. Chitosan oligosaccharide, degraded from chitosan, has been established as an effective plant elicitor, water soluble non-toxic compounds which influenced several secondary metabolites to improve fruit qualities. Considering the above scheme in mind, the present research work was undertaken in order to assess the effects of chitosan oligosaccharides as postharvest treatment on storage quality and shelf life of mango fruits.

MATERIALS AND METHODS

Experimental chemicals and materials

Fully mature uniform size and free from defects mango fruits cv. Langra and Amropali were harvested from commercial orchard (Chapai Nawabgonj, Bangladesh) and quickly transferred to the research laboratory. Chitosan oligosaccharide (degree of polymerization = 2~10; degree of deacetylation> 95 %) were collected from Dalian GlycoBio Co., Ltd. (Dalian, China). Two factor (Factor A: Variety- Langra (V_1) and Amrapali (V_2); Factor B: Postharvest treatments (6) T_0 = Control (no treatment); T_1= 25 mg/L COS; T_2= 50 mg/L COS; T_3 = 100 mg/L COS; T_4 =250 mg/L COS and T_5 =500 mg/L COS) experiment were carried out at Postharvest

laboratory, Department of Horticulture, Patuakhali Science and Technology University following completely Randomized Design (CRD) with three replications.

Preparation and application of postharvest treatment

For preparation of different concentration of COS, certain amount of COS powder was dissolved in 1000 ml distilled water and stored in a glass jar. Twenty-four fruits for each treatment were then individually dipped in prepared COS solution and the fruits were kept on brown paper of the laboratory table at ambient condition arranging at random by replication. For control, twenty-four fruits of each variety (Eight fruits were in each replication) were selected randomly from the mango lot and kept without treating COS solution.

Methods of studying physico-chemical properties

Firmness

Fruit firmness was determined by using digital penetrometer along with a measuring probe (5 mm diameter stainless steel). Fruit firmness was measured from two opposite side of each fruit by penetrating the probe at a depth of 5 mm into the fruit with pre- and post– test speed 1 mms- 1. The firmness was calculated as maximum penetration force reached during tissue breakage and expressed as Newton (N).

Weight loss

The fruits of each treatment were weighted with the help of electric balance at 2 days' interval and then weight loss percentage was calculated by using the following formula (1):

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

Here IW= Initial (g); FW= Final weight (g)

Titratable acidity (TA) and pH determination

Titratable acidity was measured according to the method described by Ranganna (1977) with minor modification. Briefly, ten grams of mango pulp were homogenized for two minutes with 40 ml of distilled water by using a Kitchen blender (Vision, Bangladesh) and filtered through a Whatman filter paper No.2. Consequently, 5 ml of the extracted juice were taken in a 100 ml conical flask and two to three drops of phenolphthalein indicator solution were added and then the conical flask was shaken vigorously. The sample was titrated with 0.1M NaOH solution until the color turned into pink and insistent for 15 seconds. The titer volume was recorded and the result was expressed as percentage citric acid, which was calculated using the following formula (2):

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

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.

Determination of vitamin C

Vitamin C content of mango was determined by titration method using 2, 6-dichlorophenol indophenol dye solution as described by Ranganna (1986). The method of determination involves the reduction of 2, 6-dichlorophenol indophenol dye to a colorless form by ascorbic acid in an alkaline solution. Then the vitamin C content of the sample was calculated by the following formula (3):

$$\text{Vitamin C (mg/100g fruit)} = \frac{T \times D \times V1}{V2 \times W} \times 100 \quad (3)$$

(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)

Estimation of total anthocyanin content

Total anthocyanin content of mango peel was estimated according to the method described by Sims and Gamon (2002). Briefly, 5g pulp of mango were properly homogenized with 10ml (1:2) 80% cold acetone (80:20 vol:vol, pH = 7.8) and centrifuged for 4 minutes at 800 rpm maintaining 4^0C. The clear supernatant was diluted to a final volume of 5 ml by adding acetone and was used for the estimation of total anthocyanin content. The absorbance of the extract solutions was recorded at 665nm, 649nm, 646nm, 663nm, 470 nm, and 529nm and 650nm wave length by using double beam spectrophotometer (Dynamica HALO-DB-20S UV-VIS Double Beam Spectrophotometer). Content of chlorophyll-a and chlorophyll-b as well as anthocyanin was calculated by using the following formulae (4, 5, and 6):

$$\text{Chlorophyll a-a } (\mu g/ml) = 12.21\ A_{665} - 6.88\ A_{649} \quad (4)$$

$$\text{Chlorophyll a-b } (\mu g/ml) = 20.13\ A_{646} - 5.03\ A_{663} \quad (5)$$

$$\text{Anthocyanin } (\mu mol/ml) = A_{529} - 0.288\ A_{650}$$

$$\text{Anthocyanin } (\mu mol/g \times 207.247 = \mu g/g) = A_{529} - 0.288\ A_{650} \quad (6)$$

Where, A is the absorbance of the extract solution in a 1-cm path length cuvette at wave length.

Total soluble solids (°Brix)

The total soluble solids of mango fruit pulp were determined by using hand refractometer (Model BS Eclipse 3-45) at room temperature. Fruit pulp was homogenized in a kitchen blender for two minutes and filtrated through four layers of muslin cloth. A drop of fruit juice was placed on the prism of refractometer and direct reading was noted. The results were expressed as percent soluble solids (°Brix).

Estimation of total sugar content

Total sugar content of mango pulp was estimated by using standard Fehling's solution. Fifty gram of fruits were used to calculate percent reducing, non-reducing and total sugar content using the following formulae (7, 8, and 9):

$$\% \text{ Reducing sugar} = \frac{F \times D \times 100}{T \times W \times 100} \quad (7)$$

(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)

$$\% \text{ Non-reducing sugar} = (\% \text{ Total invert sugars} - \% \text{ reducing sugars originally present}) \times 0.95 \text{ (Conversion factor)} \quad (8)$$

$$\% \text{ Total sugars} = \% \text{ reducing sugar} + \% \text{ non-reducing sugar} \quad (9)$$

Shelf life

Shelf life of mango fruits was calculated by counting the days required to ripe fully as to retaining optimum marketing and eating qualities.

Statistical analysis

The collected data on different parameters under the study were statistically analyzed using SPSS software (IBM, New York, USA). The significant different among treatment means were separated and analysis of variance for all the parameters were performed by F-test followed by Duncan's Multiple Range Test (DMRT) at 1% level of probability (Gomez & Gomez, 1984).

RESULTS AND DISCUSSION

Changes of fruit firmness

Effect of varieties

The firmness fruit is one of the most important indices that govern the quality of fruit during storage. The firmness reduced with the advancement of storage period (Fig. 1). Changes of fruit firmness between mango varieties were significant at different days after storage. The changes of fruit firmness had higher in 'Langra' (9.39, 7.39, 5.85) at 3, 6, and 9 DAS, respectively than that of the variety 'Amropali' (7.26, 6.43, 5.13 respectively).

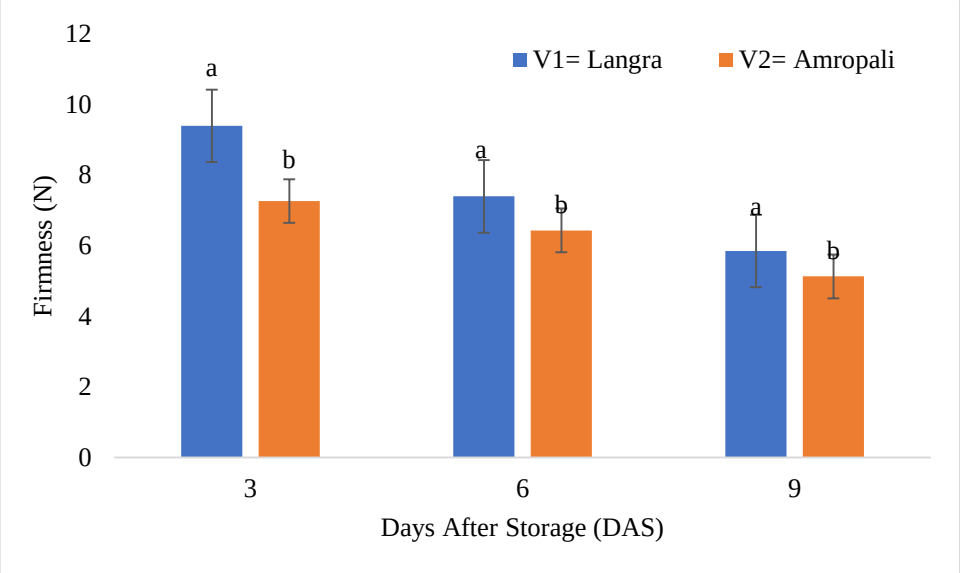

Fig. 1. Effect of variety on firmness of mango at different days after storage. Vertical bars represent standard error.

These results revealed that the changes of fruit firmness gradually decrease in increasing of storage period as well as the higher changes of firmness were obtained at 9 DAS. The fruits firmness declined due to the degradation of cell wall components and reduced the cell wall integrity. The finding of the present study is almost similar to Mustari et al. (2020) and Mondal et al. (2023), they reported that mango fruit firmness drastically reduced with advancement of storage period.

Effect of postharvest treatments

Firmness changes showed significant in case of different postharvest treatments during storage. It was observed that the firmness changes occurred at faster rate in control, whereas the rates were slower in those fruits are treated with COS 100 mg/L Fruit firmness was maximum (9.26) in COS 50 mg/L treated fruits and minimum (7.7) in control which was statistically similar with COS 100 mg/L treated fruits. Also at 6 and 9 DAS, the maximum firmness was observed in COS 50 mg/L and COS 100 mg/L (7.77 and 6.51) and the minimum firmness was shown in control (5.74 and 4.21) treated fruits, respectively (Fig. 2).

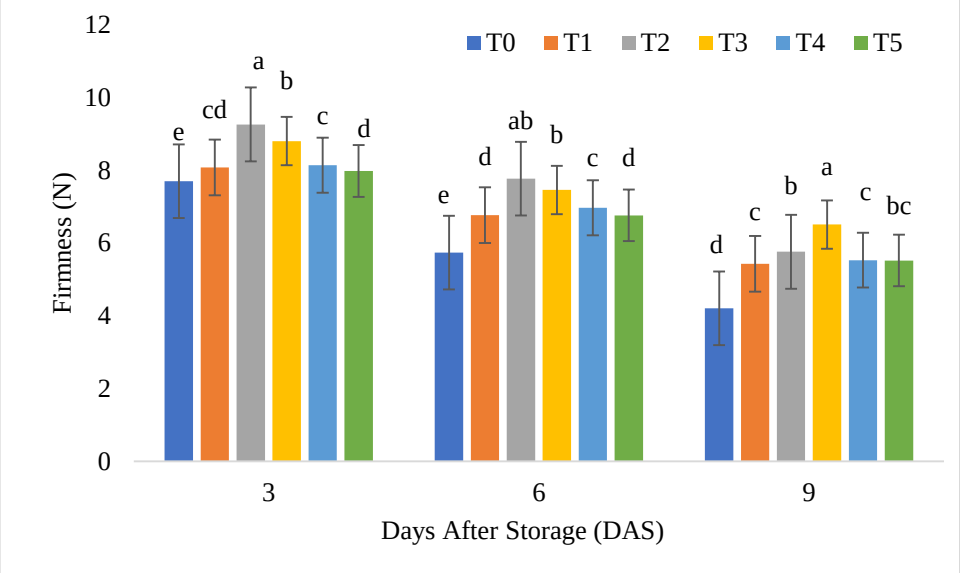

Fig. 2. Effect of treatments on firmness of mango at different days after storage. Vertical bars represent standard error. Here, T_0: Control, T_1: 25mg/L COS, T_2: 50 mg/L COS, T_3: 100 mg/L COS, T_4: 250 mg/L COS, T_5: 500 mg/L COS.

These results revealed that changes of fruit firmness significantly decreased among the all postharvest treatments in increasing of storage periods. Bose et al. (2021b) also found similar results when strawberry fruits treated with alginate oligosaccharides (AOS), they reported that postharvest application of AOS delayed the loss of firmness and suppressed the activity of N-glycan processing enzymes (a-Man and b-Hex) along with N-glycan processing enzymes associated genes expression resulting in delayed fruit softening.

Combined effect of variety and postharvest treatments

Significant variation was also obtained by the combined effect of studied mango varieties and different postharvest treatment during storage (Table 1). At 3, 6 and 9 days after storage, the highest firmness (10.03, 8.45 and 6.93 N) was recorded from treatment V_1T_3 and the lowest (6.65, 5.23 and 3.94 N) was recorded from treatment V_2T_0, respectively. The firmness decreased both in treated and untreated fruits during entire storage period. 100 mgL^{-1} COS treated fruit significantly delayed the loss of firmness compared to control fruits. Losses in firmness with the progress of storage period of mango fruits due to increased activities of cell wall hydrolysis enzymes such as pectinesterase, polygalacturonase pectin methylesterase and pectatelyases (Ali et al., 2004).

Table 1. Effect of varieties and postharvest treatments on firmness of mango during storage.

Variety × Treatment	Firmness (N)		
	3 DAS	6 DAS	9 DAS
V_1T_0	8.74e	6.25e	4.48f
V_1T_1	9.11d	7.27d	5.6cd
V_1T_2	9.76b	7.65bc	5.76bcd
V_1T_3	10.03a	8.45a	6.93a
V_1T_4	9.33cd	7.47cd	6.14b
V_1T_5	9.36c	7.24d	6.21b
V_2T_0	6.65h	5.23f	3.94g
V_2T_1	7.06g	6.26e	5.27de
V_2T_2	8.76e	7.9b	5.76bcd
V_2T_3	7.56f	6.46e	6.1bc
V_2T_4	6.96g	6.47e	4.91ef
V_2T_5	6.6h	6.29e	4.83ef
Level of Significance	**	**	**
LSD at 5%	0.15	0.27	0.27
LAD at 1%	0.23	0.37	0.52
CV (%)	1.21	2.35	4.13

** Significant at 1% level of probability, DAS = Days after Storage, V_1: Langra, V_2: Amropali, T_0: Control, T_1: 25mg/L COS, T_2: 50 mg/L COS, T_3: 100mg/L COS, T_4: 250 mg/L COS, T_5: 500 mg/L COS.

Weight loss (%)

Effect of varieties

In case of total weight loss, highly significant variation was observed between two mango varieties at different days after storage (Fig. 3). The variety 'Langra' showed the minimum weight loss (1.62%, 2.77%, 3.56%) compare to 'Amropali (1.83%, 2.70%, 3.5%) at 3, 6 and 9 days after storage, respectively. However, percentage of total weight loss of storage fruits showed significant increase with the advancement of storage period but it was lower in 'Langra' than 'Amropali' due to the keeping ability of moisture had higher. Weight loss is one of the most important indicators for maintaining the quality of any fruits during storage. The weight loss reduction is unsurprising to the physiological loss in weight due to water respiration and transpiration through peel tissue, and other organic changes taking place in the fruit (Atlaw, 2018).

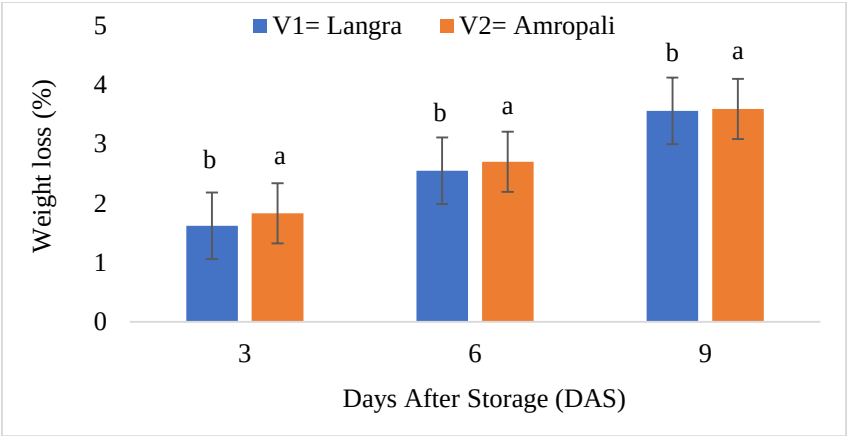

Fig. 3. Effect of variety on total weight loss of mango at different days after storage. Vertical bars represent standard error.

Effect of postharvest treatments

Significant variation was also recorded among the effect of postharvest treatments regarding to weight loss percentage at different days after storage (Fig. 4). The weight loss was lower (1.44%, 2.18%, 3.01%) in those fruits which were treated by COS 100 mg/L at 3, 6 and 9 days after storage, respectively while it was statistically differed from other treatments. In contrast, the higher weight loss (1.93%, 2.91%, 4.04%) was recorded in untreated fruits at 3, 6 and 9 days, respectively. These results appeared that all the treatments showed significant variation among them COS 100 mg/L recorded the greater performance. Similar results were also obtained by Bose et al. (2019), they reported that 100 mg/L AOS treated strawberry exhibited lower weight loss compared to untreated fruits and which may possibly be due to slow respiration and metamorphic activity of fruits. Natural elicitor postharvest treatment also delayed weight loss compared to control treatments (Rastgoo et al., 2024).

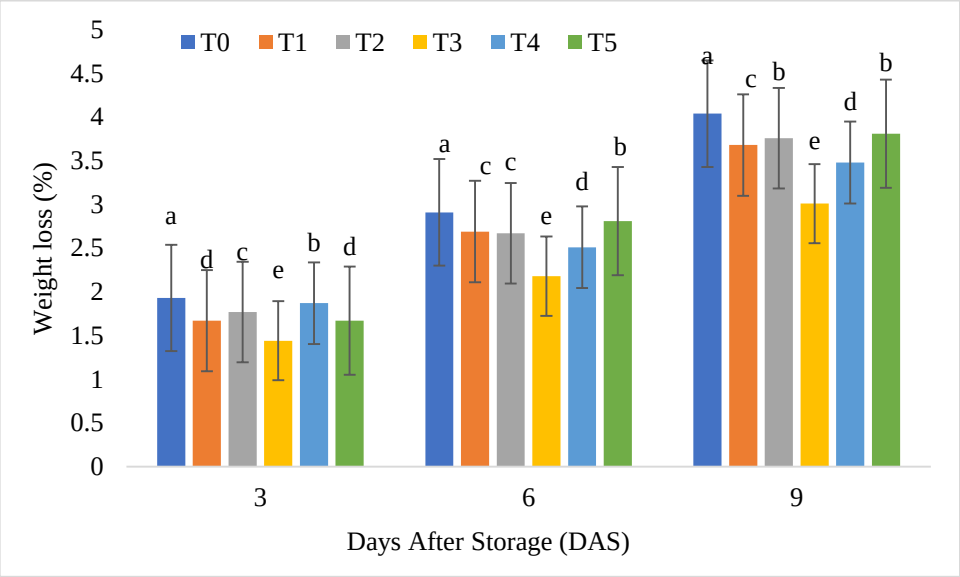

Fig. 4. Effect of treatments on total weight loss of mango at different days after storage. Vertical bars represent standard error. Here, T_0: Control, T_1: 25mg/L COS, T_2: 50 mg/L COS, T_3: 100 mg/L COS, T_4: 250 mg/L COS, T_5: 500 mg/L COS.

Combined effect of variety and postharvest treatments

A significant variation was also observed by the combined effect of studied mango varieties and different postharvest treatment during storage (Table 2). Among the treatment combinations, the minimum weight loss in (1.24%, 1.94%, 2.85%) was noted from the 'Langra' fruits treated by COS 100mg/L (V_1T_3) at 3, 6 and 9 DAS, respectively (Table 2) and the maximum weight loss (1.96%, 2.94%, 4.05%) was recorded from 'Amropali' (V_2T_0) fruits which was not subjected to any postharvest treatments. The main cause of weight loss of fruits and vegetables is the loss of water by transpiration and respiration processes (Elsabee & Abdou, 2013). The mango fruit weight loss increased during storage possibly due to the increased of the respiratory metabolism and exacerbate the loss of water absorbed by the chitosan coating on the fruit surface (Abbasi et al., 2009). Our results are in agreement with previous studies that postharvest treatments delayed the loss of fruit weight compared to untreated fruits during storage.

Table 2. Effect of varieties and postharvest treatments on weight loss of mango during storage.

Variety × Treatment	Weight loss (%)		
	3 DAS	6 DAS	9 DAS
V_1T_0	1.90ab	2.88b	4.02a
V_1T_1	1.60d	2.63d	3.72bc
V_1T_2	1.65d	2.56e	3.77b
V_1T_3	1.24f	1.93g	2.86g
V_1T_4	1.86b	2.46f	3.55d
V_1T_5	1.49e	2.78c	3.81b
V_2T_0	1.96a	2.95a	4.05a
V_2T_1	1.75c	2.76c	3.65cd
V_2T_2	1.9ab	2.78c	3.76b
V_2T_3	1.65d	2.43f	3.16f
V_2T_4	1.88b	2.56e	3.41e
V_2T_5	1.85b	2.81c	3.81b
Level of Significance	**	**	**
LSD at 5%	0.06	0.05	0.06
LSD at 1%	0.09	0.06	0.13
CV (%)	2.32	1.13	1.66

** Significant at 1% level of probability, DAS = Days after Storage, V_1: Langra, V_2: Amropali, T_0: Control, T_1: 25mg/L COS, T_2: 50 mg/L COS, T_3: 100mg/L COS, T_4: 250 mg/L COS, T_5: 500 mg/L COS. Values having same letters within the column do not differ significant at 5% level of probability.

Titratable acidity (%)

Effect of varieties

Varietals effect showed significant differences in respect of titratable acidity at different days after storage (Fig. 5). Between the varieties, 'Amropali' gave the maximum titratable acidity (0.37, 0.30 and 0.24%) to compare 'Langra' (0.36, 0.29 and 0.21%) at 3,6 and 9 DAS, respectively.

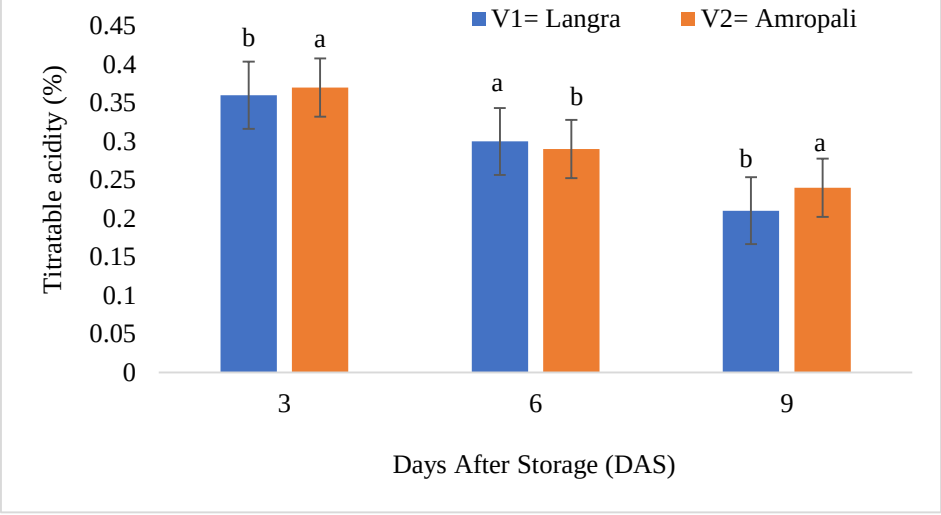

Fig. 5. Effect of variety on titratable acidity of mango at different days after storage. Vertical bars represent standard error.

Effect of postharvest treatments

Highly significant variation was observed among different postharvest treatments during storage (Fig. 6). COS 100 mg/L treated fruits had higher (0.4917, 0.361, 0.28 %) at 3, 6 and 9 DAS, respectively which was closely followed by COS 25 mg/L treated fruits of mango (0.42, 0.31 and 0.26 %) at 3, 6 and 9 DAS respectively. However, the lowest titratable acidity content (0.26, 0.21 and 0.117%) was obtained in those fruits which were untreated at 3,6 and 9 DAS respectively. The TA content decrease with increasing days after storage. Similar findings were reported by Supa et al. (2024), they noted that edible coating treatment retained higher TA content compared to control.

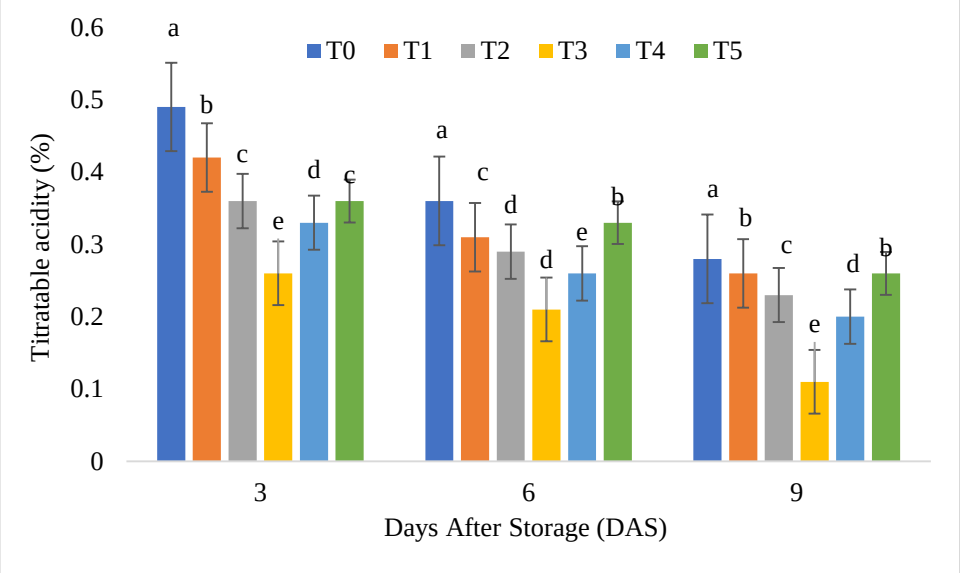

Fig. 6. Effect of treatments on titratable acidity of mango at different days after storage. Vertical bars represent standard error. Here, T_0: Control, T_1: 25mg/L COS, T_2: 50 mg/L COS, T_3: 100 mg/L COS, T_4: 250 mg/L COS, T_5: 500 mg/L COS.

Combined effect of variety and postharvest treatments

A highly significant variation was noted among the combined effect of varieties and various postharvest treatments in respect of titratable acidity at different days after storage (Table 3). The highest TA content (0.50, 0.37 and 0.28 %) was found in those fruits of 'Langra' which was treated by COS 100mg/L at 3, 6 and 9 DAS, respectively which was statistically differed forms other treatment combinations. The lowest TA content (0.24, 0.22 and 0.11%) was found from the untreated fruits of the variety 'Langra' at 3, 6 and 9 DAS. These results revealed that the TA content decrease gradually with the advancement of storage time among the all treatment combinations. The titratable acidity gradually declined with the increase in storage duration that is due to the consumption of organic acids in respiratory metabolism and conversion of citric acid into sugars (Rab et al., 2011; Rathore et al., 2007). Titratable acidity is the indicator of acidity of fleshy fruit and it is directly related to the amount of organic acid present in the fruit. During ripening of fruit, the devaluation of acidity may be due to the metabolic changes in fruit and use of organic acid in the respiratory process of fruit.

Table 3. Effect of varieties and postharvest treatments on titratable acidity of mango during storage.

Variety × Treatment	Titratable acidity (%)		
	3 DAS	6 DAS	9 DAS
V_1T_0	0.24g	0.22h	0.12f
V_1T_1	0.42c	0.31cd	0.24c
V_1T_2	0.36d	0.28f	0.22d
V_1T_3	0.47b	0.35b	0.28a
V_1T_4	0.35d	0.26g	0.16e
V_1T_5	0.35d	0.37a	0.25b
V_2T_0	0.28f	0.21h	0.12f
V_2T_1	0.42c	0.32c	0.28a
V_2T_2	0.37d	0.30de	0.25b
V_2T_3	0.50a	0.37a	0.28a
V_2T_4	0.32e	0.25g	0.25b
V_2T_5	0.36d	0.29ef	0.28a
Level of Sig.	**	**	**
LSD at 5%	0.02	0.01	9.74
LSD at 1%	0.03	0.01	0.01
CV (%)	3.90	2.05	2.52

** Significant at 1% level of probability, DAS = Days after Storage, V_1: Langra, V_2: Amropali, T_0: Control, T_1: 25mg/L COS, T_2: 50 mg/L COS, T_3: 100mg/L COS, T_4: 250 mg/L COS, T_5: 500 mg/L COS.
Values having same letters within the column do not differ significant at 5% level of probability.

pH

Effect of varieties

pH value gradually increased with the advancement of storage period and observed significantly different between the varieties of mango. Initially the pH value of 4.67 and 4.75 were found from the variety Langra and Amrapali, respectively. The highest (5.02, 6.19 and 6.86) pH was noted from 'Langra' than 'Amrapali' (4.94, 5.99 and 6.73) at 3, 6 and 12 DAS, respectively (Fig. 7). These results revealed that the 'Langra' took the more pH than 'Amrapali' due to the adaptability range and their genetic variation between two varieties in storage condition.

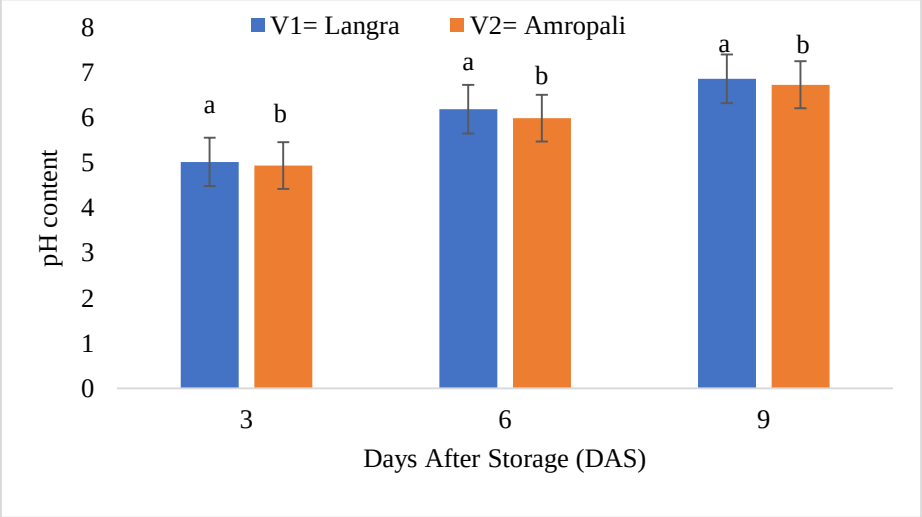

Fig. 7. Effect of variety on pH of mango at different days after storage. Vertical bars represent standard error.

Effect of postharvest treatments

Significant variation was found due to the effect of various postharvest treatments in respect of pH content at 3 to 12 DAS (Fig. 8).

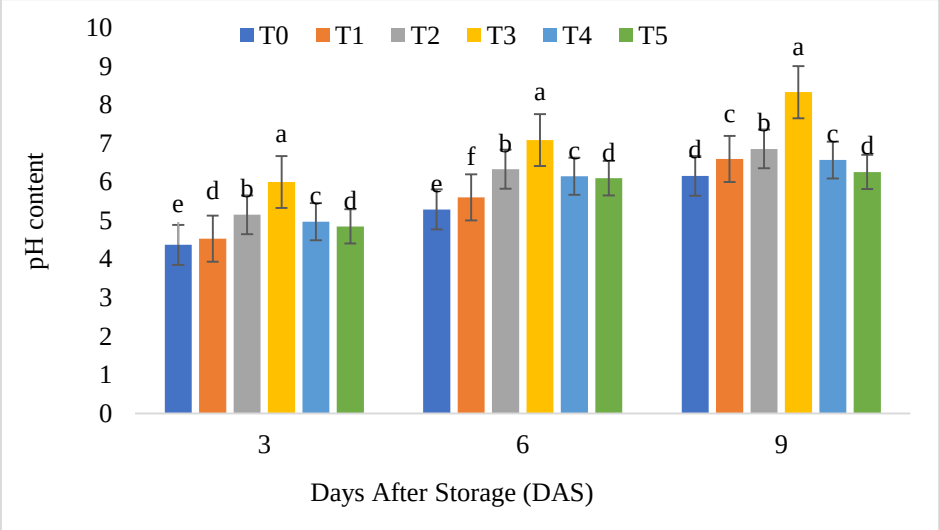

Fig. 8. Effect of treatments on pH of mango at different days after storage. Vertical bars represent standard error. Here, T_0: Control, T_1: 25mg/L COS, T_2: 50 mg/L COS, T_3: 100 mg/L COS, T_4: 250 mg/L COS, T_5: 500 mg/L COS.

Among the postharvest treatments, the higher values of pH content (6.00, 7.09 and 8.33) were recorded from the fruits treated with COS 100 mg/L at 3, 6 and 9 DAS, respectively which was statistically differed from other postharvest treatments. In contrast, the lowest values of pH content (4.37, 5.29, 6.16) were recorded while the fruits were not subjected to any postharvest treatments at 3, 9 DAS, respectively. Nasrin et al. (2008) also found significant variation among the postharvest treatments regarding to pH content of the storage fruits. These findings are closely related to He et al. (2018), they found that pH was higher in untreated fruits and lower in COS treated fruits.

Combined effect of variety and postharvest treatments

Combined effect of varieties and postharvest treatments were significantly different during entire storage period (Table 4). Among the treatment combinations, COS 100 mg/L treated fruit of 'Langra' (V_1T_3) record highest pH value (6.53, 7.55 and 8.8) at 3, 6 and 9 DAS, respectively while it was statistically differed from other treatment combinations. The lowest pH value (4.35, 5.26 and 6.16) was noted from the variety' Langra' (V_1T_0) while it was untreated at 3, 6, and 9 DAS, respectively. These results indicated that the values of pH increase with the advancement of storage time. These results are in agreement with those of Maftoonazad et al. (2008), who reported that a higher increase in pH was found in the control samples as compared to coated peaches.

Table 4. Effect of varieties and postharvest treatments on pH of mango during storage.

Varieties × Treatments	pH at different DAS		
	3	6	9
V_1T_0	4.35f	5.26h	6.16f
V_1T_1	4.40f	5.77f	6.57d
V_1T_2	5.14c	6.32c	6.85c
V_1T_3	6.53a	7.55a	8.80a
V_1T_4	4.88d	6.18d	6.51dc
V_1T_5	4.83d	6.09e	6.28ef
V_2T_0	4.38f	5.32h	6.16f
V_2T_1	4.67e	5.43g	6.64cd
V_2T_2	5.16c	6.34c	6.867c
V_2T_3	5.47b	6.64b	7.86b
V_2T_4	5.07c	6.13de	6.63cd
V_2T_5	4.88d	6.10e	6.24f
Level of Significance	**	**	*
LSD at 1%	0.20	0.09	0.32
CV (%)	1.77	0.63	2.02

*&** Significant at 5% & 1% level of probability, DAS = Days after Storage, V_1: Langra, V_2: Amropali, T_0: Control, T_1: 25mg/L COS, T_2: 50 mg/L COS, T_3: 100mg/L COS, T_4: 250 mg/L COS, T_5: 500 mg/L COS. Values having same letters within the column do not differ significant at 5% level of probability.

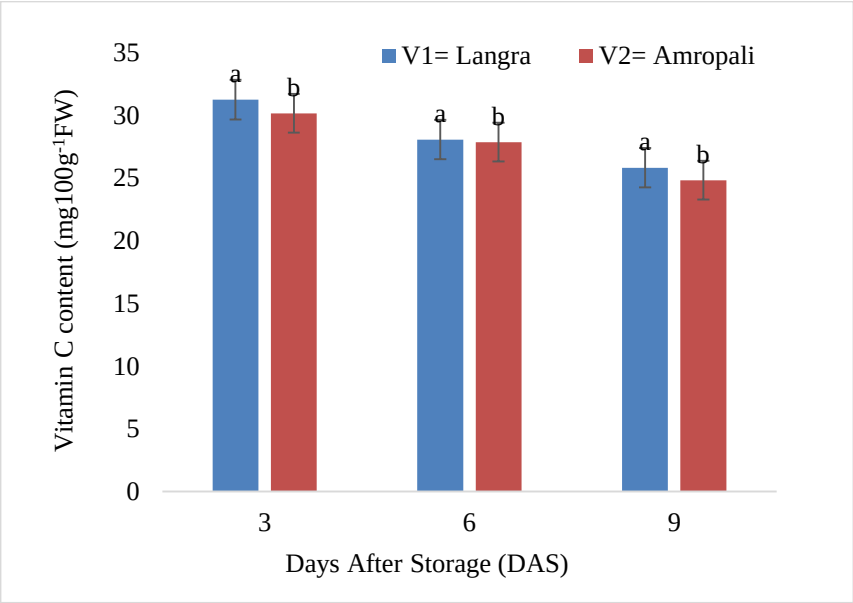

Fig. 9. Effect of variety on vitamin C content of guava at different days after storage. Vertical bars represent standard error.

Vitamin C content

Effect of varieties

Varietal effects were highly significant in relation to vitamin C content during storage of mango (Fig 9). Between two varieties, the variety 'Langra' produced significantly the maximum vitamin C content (31.24, 28.06 and 25.81 mg 100 g¹ FW) compared to 'Amropali' (30.16, 27.85 and 24.82 mg 100 g^{-1} FW) at 3,6 and 9 DAS, respectively. These results indicated that the vitamin C content significantly decreased with the advancement of storage period. Similar findings were also obtained by Supa et al. (2024), they observed varietal difference in respect of vitamin C content during storage, this may possibly due to genetical differences.

Effect of postharvest treatments

Vitamin C content was significantly influenced by the effect of various postharvest treatments at different days after storage. It was recorded that the maximum vitamin C content (38.41, 36.96 and 35.12 mg 100 g^{-1} FW) was found from the mango fruits stored in ambient temperature while it was treated by COS 100 mg/L at 3, 6 and 9 DAS, respectively. In contrast, the lowest vitamin C content (24.25, 21 and 18.96 mg 100 g^{-1} FW) was noted from untreated storage mango fruits which were statistically different from other treatments at 3,6 and 9 DAS, respectively (Fig. 10). These results revealed that the vitamin C content was significantly decreased with the advancement of storage period due to the conversion of acid to sugar with the activity of ascorbic dehydrogenase which results was fully agreed by Caron et al. (2013).

Combined effect of variety and postharvest treatments

Maximum vitamin C content (33.67, 31.16 and 35.62 mg 100 g^{-1}FW) was obtained by the variety 'Langra' while it was treated by COS 100 mg/L at 3, 6 and 9 DAS and whereas the lowest vitamin C content (23.21, 21 and 17.26 mg 100 g^{-1} FW) was found in untreated fruits of 'Amropali' (V_2T_0) which was statistically different from other at the 3, 6 and 9 DAS, respectively (Table 5). The results revealed that vitamin C content of mango were gradually decreased with advancement of storage period and reached the lowest values at the end of storage period. The findings of this study are similar to the findings obtained by Supa et al. (2024). The reduction of vitamin C content during storage of fruits might possibly 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 has also been recorded in mango (Jain & Mukherjee, 2011).

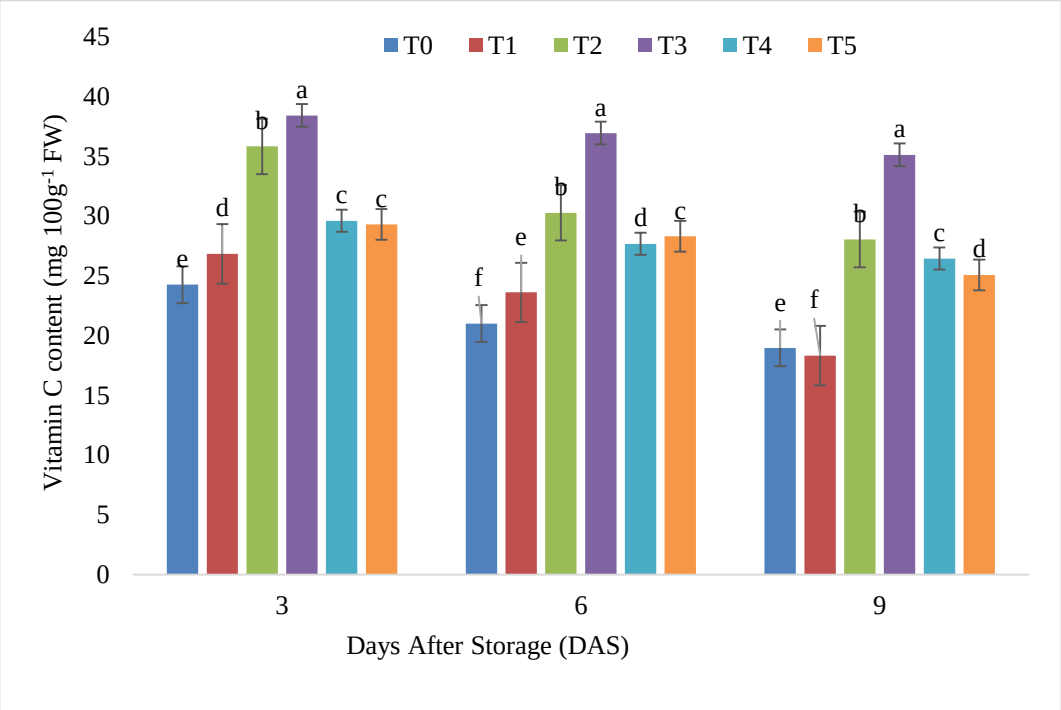

Fig. 10. Effect of treatments on vitamin C content of guava at different days after storage. Vertical bars represent standard error. Here, T_0: Control, T_1: 25mg/L COS, T_2: 50 mg/L COS, T_3: 100 mg/L COS, T_4: 250 mg/L COS, T_5: 500 mg/L COS.

Table 5. Effect of varieties and postharvest treatments on vitamin C content of mango during storage.

Variety × Treatment	Vitamin C (mg100g^{-1} FW)		
	3 DAS	6 DAS	9 DAS
V_1T_0	25.16g	21.0h	19.73f
V_1T_1	25.47g	23.6g	19.37f
V_1T_2	33.67c	31.17c	29.77c
V_1T_3	39.25a	37.47a	34.6b
V_1T_4	29.18e	28.13e	26.33d
V_1T_5	28.2f	27.03f	25.1e
V_2T_0	23.3h	21.0h	18.2g
V_2T_1	28.2f	23.6g	17.27h
V_2T_2	37.99b	29.37d	26.3d
V_2T_3	37.57b	36.4b	35.63a
V_2T_4	30.0d	27.2f	26.53d
V_2T_5	30.37d	29.57d	25.03e
Level of Significance	*	**	*
LSD at 5%	0.72	0.38	0.67
LSD at 1%	0.97	0.51	0.91
CV (%)	1.38	0.08	1.56

*&** Significant at 5% & 1% level of probability, DAS = Days after Storage, V_1: Langra, V_2: Amropali, T_0: Control, T_1: 25mg/L COS, T_2: 50 mg/L COS, T_3: 100mg/L COS, T_4: 250 mg/L COS, T_5: 500 mg/L COS. Values having same letters within the column do not differ significant at 5% level of probability.

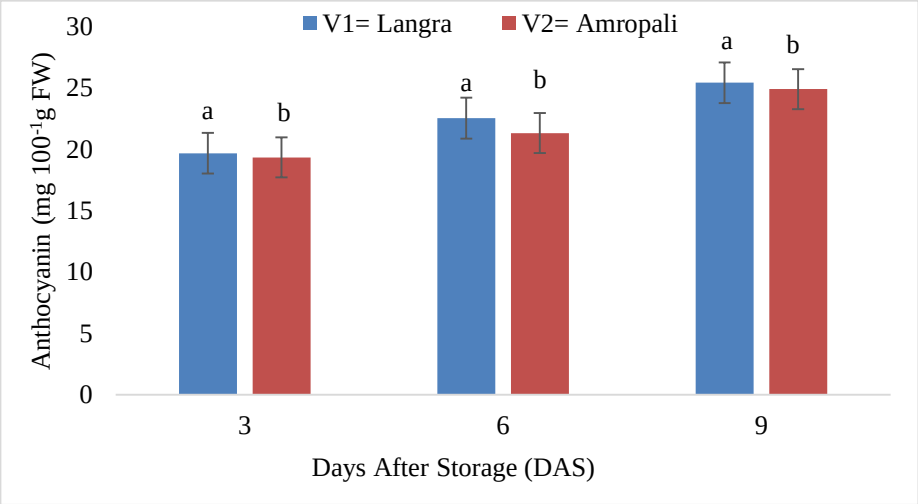

Fig. 11. Effect of variety on anthocyanin content of mango at different days after storage. Vertical bars represent standard error.

Anthocyanin Content

Effect of varieties

A highly significant variation was observed due to the effect of mango varieties in respect of anthocyanin content at different days after storage (Fig. 11).

The maximum anthocyanin content was recorded in 'Langra' (19.67. 22.53 and 25.42 ml) compared to 'Amrapali' (19.33, 21.31 and 24.89 ml) after 3, 6 and 9 DAS. These results indicated that the anthocyanin content significantly increased with the advancement of storage period.

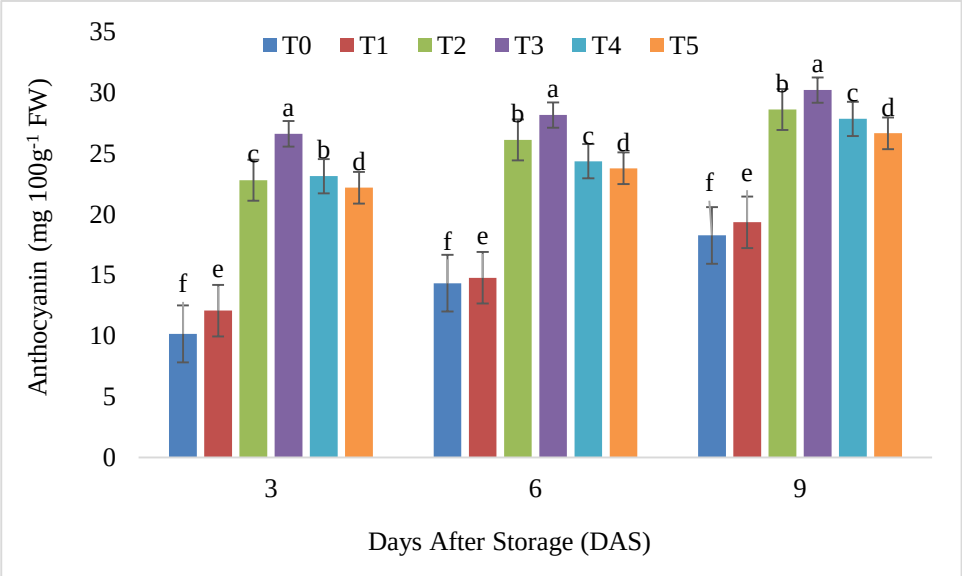

Fig. 12. Effect of treatments on anthocyanin content of mango at different days after storage. Vertical bars represent standard error. Here, T_0: Control, T_1: 25mg/L COS, T_2: 50 mg/L COS, T_3: 100 mg/L COS, T_4: 250 mg/L COS, T_5: 500 mg/L COS.

Effect of postharvest treatments

Anthocyanin content was significantly influenced by the effect of various postharvest treatments at different days after storage (Fig. 12). Maximum anthocyanin content (26.62, 28.18 and 30.223 mg/100 g FW) was found from the mango fruits stored in ambient temperature while it was treated with COS 100 mg/L at 3, 6 and 9 DAS. In contrast, the lowest anthocyanin content (10.17, 14.33 and 18.27 mg/100 g FW) was found from untreated storage mango fruits which were statistically different from other treatments at 3, 6 and 9 DAS, respectively. These results revealed that the anthocyanin content was significantly increased. Similar results were observed in case of strawberry fruit that AOS treated fruit retained higher anthocyanin content compared to control treatment (Bose et al., 2019).

Combined effect of variety and postharvest treatments

Combined effect of the mango varieties and various postharvest treatments were significantly significant in case of anthocyanin content at different days after storage (Table 6). It was found that the maximum anthocyanin content (27.53, 28.56 and 30.9 mg/100 g FW) was obtained by the variety 'Langra' while it was treated with COS 100 mg/L at 3, 6 and 9 DAS and whereas the lowest anthocyanin content (9.76, 12.43 and 18.75 mg/100 g FW) was found in untreated fruits of 'Amrapali' which was statistically different from other treatments at the 3, 6 and 9 DAS respectively. These results are supported by the findings of Bose et al. (2019), who reported AOS 100 mg/L treated strawberry fruit demonstrated higher anthocyanin content compared to untreated fruit at the end of storage.

Total soluble solids

Effect of varieties

Significant variation was observed between two varieties of mango in respect of total soluble solid (TSS) content during storage (Fig. 13). Between the varieties, 'Langra' recorded the maximum TSS (10.42, 12.24 and 13.94 % Brix) than 'Amrapali' (9.11, 10.45 and 12.60 % Brix) at 3, 6 and 9 DAS, respectively. These results revealed that the TSS content significantly increased with the increasing of storage time.

Table 6. Effect of varieties and postharvest treatments on anthocyanin content of mango during storage.

Varieties × Treatments	Anthocyanin (mg100g^{-1} FW) at different DAS		
	3	6	9
V_1T_0	10.56i	16.23f	17.75h
V_1T_1	12.40g	15.76f	19.93f
V_1T_2	23.09d	26.12c	28.61c
V_1T_3	27.53a	28.56a	30.90a
V_1T_4	22.72e	24.78d	27.90d
V_1T_5	21.73f	23.73e	26.49e
V_2T_0	9.76j	12.43h	17.80h
V_2T_1	11.76h	13.77g	18.75g
V_2T_2	22.53e	26.09c	28.64c
V_2T_3	25.70b	27.79b	29.54b
V_2T_4	23.57c	23.95e	27.80d
V_2T_5	22.65e	23.82e	26.84e
Level of Significance	*	**	**
LSD at 1%	0.44	0.81	0.55
CV (%)	0.98	1.60	0.94

*&** Significant at 5% & 1% level of probability, DAS = Days after Storage, V_1: Langra, V_2: Amropali, T_0: Control, T_1: 25mg/L COS, T_2: 50 mg/L COS, T_3: 100mg/L COS, T_4: 250 mg/L COS, T_5: 500 mg/L COS.
Values having same letters within the column do not differ significant at 5% level of probability.

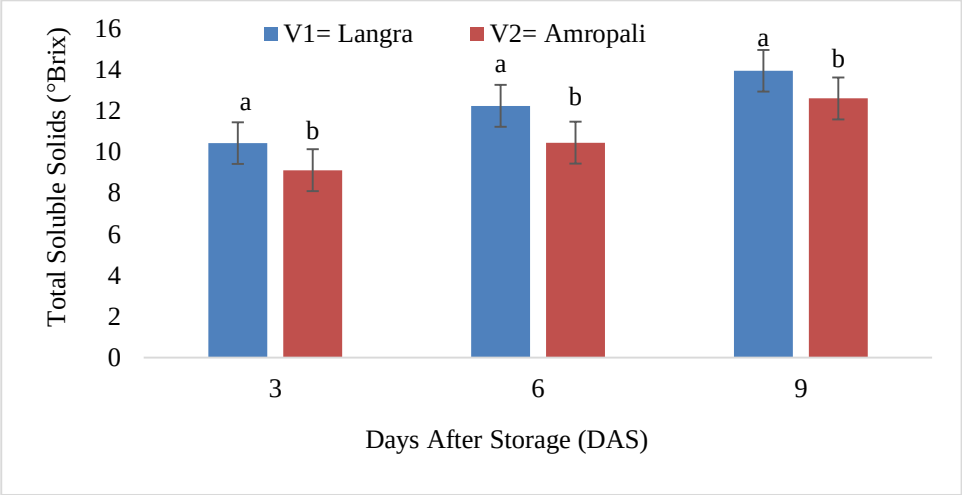

Fig. 13. Effect of variety on TSS of mango at different days after storage. Vertical bars represent standard error.

Effect of postharvest treatments

Highly significant variation was found due to the effect of various postharvest treatments in respect of TSS content at different days after storage (Fig. 14). The fruits treated with COS 100 mg/L was found the lowest TSS (8.7, 10.45 and 11.9 % Brix), and untreated fruits recorded highest TSS (10.93, 13.26 and 15.73 % Brix) at 3, 6 and 9 DAS, respectively. Present studied results supported the findings of Alhassan and Ndomakaah (Alhassan & Ndomakaah, 2024), they reported that postharvest treatment of aloe vera significantly delayed the TSS production compared to untreated banana during storage,

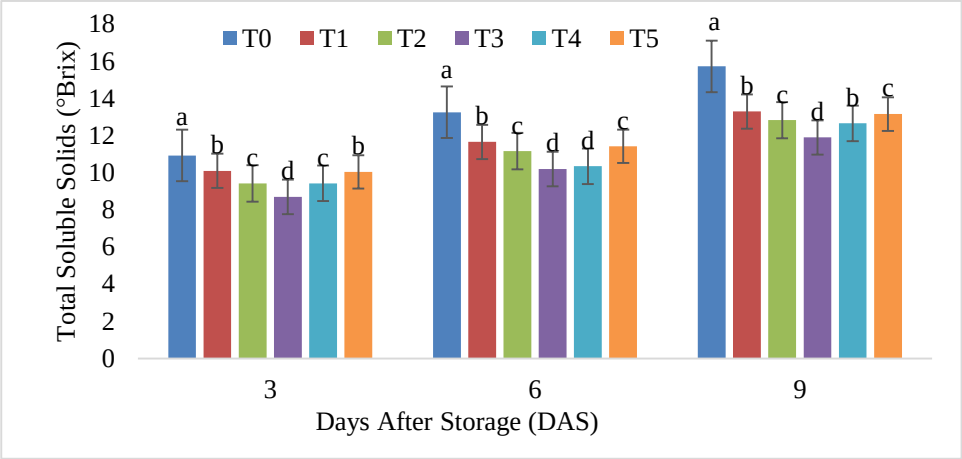

Fig. 14. Effect of treatments on TSS of mango at different days after storage. Vertical bars represent standard error. Here, T_0: Control, T_1: 25mg/L COS, T_2: 50 mg/L COS, T_3: 100 mg/L COS, T_4: 250 mg/L COS, T_5: 500 mg/L COS.

Table 7. Effect of varieties and postharvest treatments on TSS content of mango during storage

Varieties × Treatments	TSS (° Brix) at different DAS		
	3	6	9
V_1T_0	11.3a	14.73a	17.46a
V_1T_1	10.93ab	12.96b	14.3b
V_1T_2	9.83d	12.03c	12.8ef
V_1T_3	9.0ef	10.36ef	11.9g
V_1T_4	10.23cd	11.13d	13.56d
V_1T_5	11.3a	12.23c	13.63cd
V_2T_0	10.56bc	11.8c	14.0bc
V_2T_1	9.26e	10.36ef	12.4f
V_2T_2	9.03ef	10.3ef	12.86e
V_2T_3	8.4g	10.03f	11.9g
V_2T_4	8.63fg	9.56g	11.76g
V_2T_5	8.8fg	10.63e	12.7ef
Level of Significance	*	**	**
LSD at 1%	0.56	0.62	0.58
CV (%)	2.47	2.37	1.89

*&** Significant at 5% & 1% level of probability, DAS = Days after Storage, V_1: Langra, V_2: Amropali, T_0: Control, T_1: 25mg/L COS, T_2: 50 mg/L COS, T_3: 100mg/L COS, T_4: 250 mg/L COS, T_5: 500 mg/L COS.
Values having same letters within the column do not differ significant at 5% level of probability.

Combined effect of variety and postharvest treatments

Combined effect of the mango varieties and various postharvest treatments were significantly varied in case of TSS (%Brix) content during entire storage period. The TSS contents were observed in COS 100 mg/L treated fruits of 'Amrapali' (7.4, 9.03 and 11.9 % Brix) at 3, 6 and 9 DAS, respectively whereas the highest TSS (11.31, 14.73 and 17.46% Brix) was recorded from untreated fruits of 'Langra' at 3, 6 and 9 DAS (Table 7). The observation indicate that the total soluble solids contents increased significantly during storage period and it was the minimum in both varieties of 'langra' and 'Amropali' were treated with COS 100 mg /L. However, this increasing TSS is due to the conversion of complex carbohydrates into simple sugars and it was also correlated with hydrolytic changes in starch and conversion of starch to sugar being an important index of ripening process in mango and other climacteric fruits. These results are also in line with the results reported by Ali et al. (2011) and Gol and Rao (2011), who assigned the probable reasons for the reducing levels of TSS accumulation in the

chitosan alone coated fruit to the slowing down of respiration and metabolic activity, hence retarding the ripening process.

Total sugar (%)

Effect of varieties

Changes of total sugar were significantly affected by the effect of studied mango varieties at 9 DAS while it did not vary at 3 and 6 DAS (Fig. 15). Between two varieties, the variety 'Langra' had higher total sugar content (11.98%) than 'Amropali' (11.92%) at 9 DAS. At 3 and 6 DAS, both varieties were statistically identical in case of total sugar content.

Effect of postharvest treatments

Various postharvest treatments were varied significantly in respect of total sugar content of mangoes during the storage (Fig. 16). Among the postharvest treatments, COS 100 mg/L treated storage fruits recorded the lowest total sugar content (2.63 and 6.15 and 10.21%) at 3, 6 and 9 DAS, respectively whereas it was statistically differed from other postharvest treatments. On the other hand, untreated fruits showed the highest total sugar content (4.7, 9.14 and 14.13%) at these stages, respectively. From the above results, it was observed that the total sugar content gradually increased with the increasing storage period which might be due to rapid conversion of polysaccharides into sugars. The result is also similar to the findings obtained by Bose et al. (2019) and Mondal et al. (2023).

Combined effect of variety and postharvest treatments

Combined effect of the studied mango varieties and various postharvest treatments were significant in respect of total sugar content at different days after storage (Table 8). It was found that COS 100 mg/L treated fruits of 'Amrapali' recorded the lowest total sugar content (5.6 and 10.20%) at 6 and 9 DAS, and at 3 DAS the lowest total sugar content (2.6%) was recorded in 'Langra', respectively which was statistically differed from other treatment combinations. Similarly, the highest total sugar content (9.2 and 14.36%) was noted in those fruits of 'Amrapali' at 6 and 9 DAS and (5.20%) was found in those fruits of 'Langra' at 3 DAS which was not subjected to any postharvest treatments. Results demonstrated that, total sugar of mango gradually increased with the prolonged of storage period. This remarkable increase in total sugars might be attributed to the conversion of organic acid to starch during ripening and storage of fruits. Our results are in agreement with Islam et al. (2018) they reported that postharvest treated fruit exhibited higher total sugar content than untreated strawberry fruit.

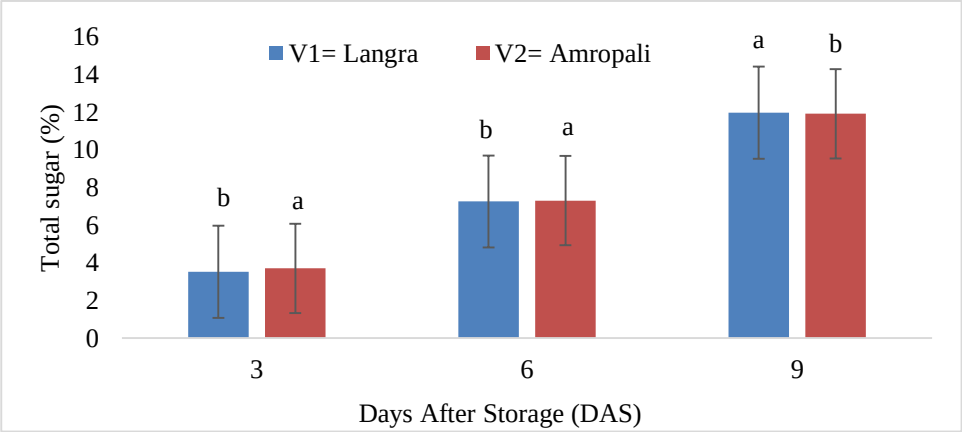

Fig. 15. Effect of variety on total sugar content of mango at different days after storage. Vertical bars represent standard error.

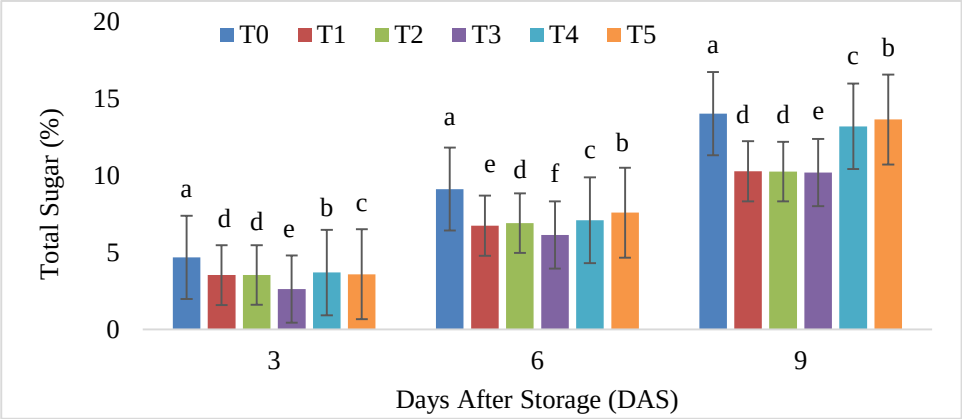

Fig. 16. Effect of treatments on total sugar content of mango at different days after storage. Vertical bars represent standard error. Here, T_0: Control, T_1: 25mg/L COS, T_2: 50 mg/L COS, T_3: 100 mg/L COS, T_4: 250 mg/L COS, T_5: 500 mg/L COS.

Shelf life

Effect of varieties

Significant variation was observed between two varieties of mango during storage period (Fig 17). Longest shelf life (12.56 days) was observed in the variety 'Langra' compare to 'Amrapali' (11.98 days).

Effect of postharvest treatments

Shelf life extension of mango has been one of the most important concerns of the researchers. These results revealed that the longest shelf life (17.66 days) of mango was recorded form COS 100 mg/L treated whereas the shortest shelf life of mango (8.5 days) was recorded from the untreated fruits (Fig. 18). Among other postharvest treatments, the shelf life 11.33, 12.83 days were noted form COS 25 mg/L, COS 50 mg/L treated fruits respectively. Islam et al. (2018) reported that shelf life of mango was higher in treated fruits and lower in untreated fruits during storage.

Table 8. Effect of varieties and postharvest treatments on total sugar content of mango during storage

Variety × Treatment	Total sugar (%) content (DAS)		
	3	6	9
V_1T_0	4.18b	9.23a	14.37a
V_1T_1	3.52fg	6.67h	10.21i
V_1T_2	3.63dc	7.05f	10.23i
V_1T_3	2.6i	5.66j	10.21i
V_1T_4	3.65d	7.01f	13.08f
V_1T_5	3.64d	7.87c	13.81b
V_2T_0	5.21a	9.06b	13.73c
V_2T_1	3.58ef	6.77h	10.4g
V_2T_2	3.48g	6.82g	10.31h
V_2T_3	2.67h	6.65i	10.21i
V_2T_4	3.78c	7.22e	13.37e
V_2T_5	3.57f	7.36d	13.54d
Level of significance	**	**	*
LSD at 5%	0.058	0.052	0.059
LSD at 1%	0.079	0.071	0.080
CV (%)	0.95	1.12	1.19

*&** Significant at 5% & 1% level of probability, DAS = Days after Storage, V_1: Langra, V_2: Amropali, T_0: Control, T_1: 25mg/L COS, T_2: 50 mg/L COS, T_3: 100mg/L COS, T_4: 250 mg/L COS, T_5: 500 mg/L COS.
Values having same letters within the column do not differ significant at 5% level of probability.

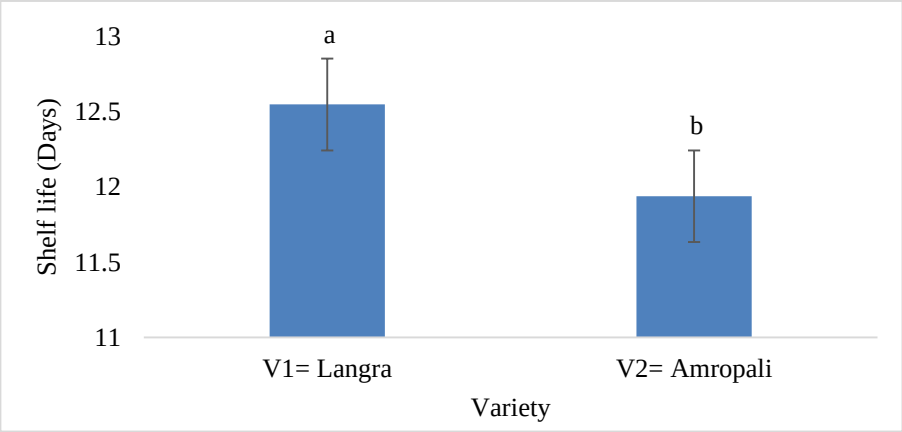

Fig. 17. Effect of variety on shelf life of mango at different days after storage. Vertical bars represent standard error.

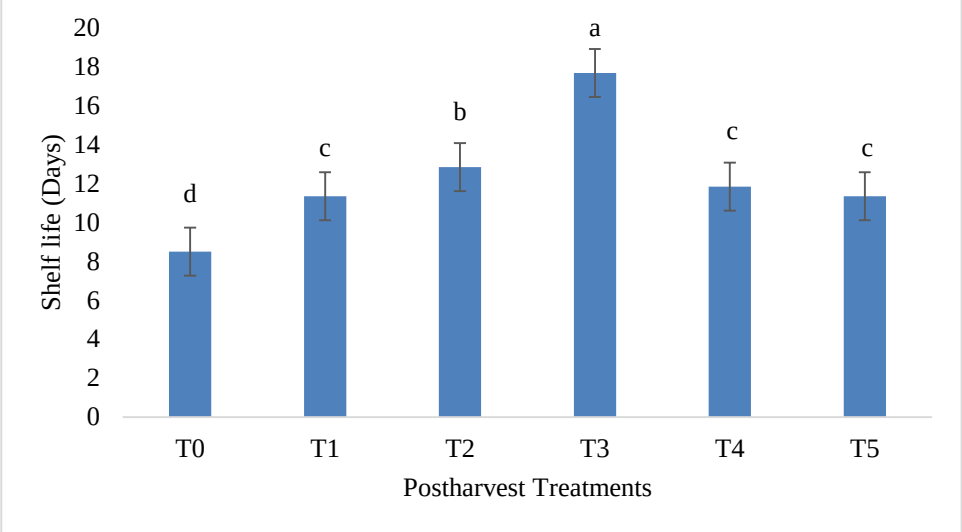

Fig. 18. Effect of treatments on shelf life of mango at different days after storage. Vertical bars represent standard error. Here, T_0: Control, T_1: 25mg/L COS, T_2: 50 mg/L COS, T_3: 100 mg/L COS, T_4: 250 mg/L COS, T_5: 500 mg/L COS.

Combined effect of variety and postharvest treatments

The longest shelf life (18.67 days) was observed in those fruits of 'Langra' treated by COS 100mg/L, which was statistically differed from other treatment combinations. In contrast, the shortest shelf life (8.33 days) was observed in those fruits of 'Langra' and 'Amrapali' which was not subjected to any postharvest treatment (Table 9) which was also statistically differed from other treatment combinations. The maximum shelf life of mango was obtained from the fruits of 'Langra' which was treated by COS 100 mg/L due to the lower weight loss, less disease incidence, disease severity, higher titratable acidity and vitamin C content were recorded under this treatment combination. From the above investigation, it was revealed that the variety 'Langra' had highly efficient than 'Amrapali' among the whole studied characteristics while COS 100mg/L treated fruits obtained the similar results. Their combined effect had also more effective to extend the more shelf life. So, the variety 'Langra' and postharvest treatment of COS 100 mg/L alone or their combination would be highly effective for extend the shelf life of mango.

Table 9. Effect of varieties and postharvest treatments on shelf life of mango during storage.

Varieties × Treatments	Shelf life (DAS)
V_1T_0	8.33f
V_1T_1	12.33cd
V_1T_2	13.33c
V_1T_3	18.66a
V_1T_4	11.33de
V_1T_5	11.33de
V_2T_0	8.66f
V_2T_1	10.33e
V_2T_2	12.33cd
V_2T_3	16.66b
V_2T_4	12.33cd
V_2T_5	11.33de
Level of Significance	**
LSD at 1%	1.373
CV (%)	4.87

*&** Significant at 5% & 1% level of probability, DAS = Days after Storage, V_1: Langra, V_2: Amropali, T_0: Control, T_1: 25mg/L COS, T_2: 50 mg/L COS, T_3: 100mg/L COS, T_4: 250 mg/L COS, T_5: 500 mg/L COS. Values having same letters within the column do not differ significant at 5% level of probability.

CONCLUSION

The present study illustrated that, postharvest coating of chitosan oligosaccharide applications is the promising strategy for the management postharvest fruit quality of mangoes cv. "Langra and Amropali" during storage. Between two varieties, the variety 'Langra' had highly efficient than 'Amrapali' among the whole studied characteristics while COS 100 mg/L treated fruits obtained the similar results. Their combined effect had also more effective as well as the more shelf life were recorded. So, therefore, the variety 'Langra' and postharvest treatment COS 100 mg/L alone or their combination would be highly effective to the physico-chemical properties and extend shelf life of mango. Further studies with other variety are needed in this regard before confirmation and recommendation.

Conflict of interest

Author declared no conflict of interests.

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