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Physio-biochemical and antioxidative enzymatic changes in ambient stored 'Misribhog' mango in response to chitosan and *aloe vera* gel coatings

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ABSTRACT

Purpose: Mango shelf life has significance for both market availability and long-distance transportation. So, effective treatments of postharvest are vital for maintaining the climacteric character of mangoes by limiting postharvest losses during storage. **Research method:** A total of 96 physiologically mature mango fruits (8 fruits in each replication) were taken. This study assessed the effect of *Aloe vera* gel (1:1 AVG), chitosan (1.5% CTS), and combinations (CTS+AVG) on mango shelf life and postharvest features following 16 days at ambient storage (28±3°C and 80±5% RH). The experiment was conducted using completely randomized design. **Findings:** The results demonstrated that either CTS or AVG had a positive effect compared to control on different parameters but their combinations was considerably superior treatment equated to the control in terms of weight loss (13.09, 20.03%), reduced respiration rate (11.22, 19.89 mlCO_2/kg/h), ethylene production (0.50, 0.56 µl/kg/h), total soluble solids (17.33, 22.23 °Brix), pH (5.86, 7.40) and decay percentage (13.14, 27.64%). Fruit quality metrics were all higher when CTS+AVG was used than the control, such as titratable acidity (0.66, 0.61), fruit firmness (28.61, 21.95 N/m^2), ascorbic acid (14.52, 10.84 mg/100g), total phenolic content (112.99, 80.02 mg GAE/100g) and antioxidant activity (274.86, 196.65 µmol/g). Coated fruits exhibited a considerable reduction in polyphenol oxidase (PPO) (5.49, 7.87 U/mg FW), while higher levels of catalase (CAT) (0.54, 0.45 U/mg FW) and peroxidase (POD) (0.75, 0.70 U/mg FW) enzyme activity. During storage, coated fruit peels exhibited notably less discoloration than control fruits. **Research limitations:** In future, mechanism of CTS and AVG for prolonging shelf life of mangoes will be revealed using molecular approach. **Originality/Value:** These results suggest that chitosan (CTS) and *Aloe vera* gel (AVG) coatings combined can preserve 'Mishribhog' mango shelf life and postharvest quality for 16 days during ambient storage.

INTRODUCTION

In Bangladesh, mangoes (*Mangifera indica* L.) are popular and widely consumed fruit for their excellent eating properties, flavor, and distinctive color. Bangladesh ranks seventh in mango production worldwide. At present, the area under mango production is about 123997.70 hectares, with a production of over 1482937.04 MT (BBS, 2024). Mishribhog is a fibreless, sweet, and delicious variety with yellow color and attractive aroma. Because of mangoes climacteric fruit position, ripen promptly, turning them mushy and enabling a variety of microbes to grow in them during storage. Due to this behavior of less storage life and postharvest loss, a considerable amount of mango has become spoiled in several mango-producing countries around the world (Parvin et al., 2023). Mango fruits' postharvest life is prolonged by synthetic substances that are harmful to both the environment and human health. So, the applications of natural eatable coverings are very appealing, as they are incredibly fruitful for providing significant protection to the produce (Liu et al., 2020). Rajinith et al. (2022) reported that peptide-based edible coatings are used to reduce postharvest contaminations that impede anthocyanin synthesis and slow ripening in mangos. Chitosan applied exogenously lowers the transpiration rate, preserves firmness, boosts antioxidant activity, and promotes overall fruit quality (Wang et al., 2021). Because it is a naturally occurring chemical with antimicrobial properties, it effectively delays the deterioration of fruit by increasing mangos' durability and reducing the possibility of microbial attacks (Parvin et al., 2023; Nitu et al., 2025). The application of chitosan successfully extended the storage period of mango fruit (Cosme Silva et al., 2017).

Likewise, a naturally occurring material that's used as a fruit coating is *Aloe vera*. Its antibacterial and anti-oxidant properties, which come from the presence of many bioactive components, shelf life lengthen of various fruits (Jati et al., 2022; Alhassan & Ndomakaah, 2024). It also contains several complex polysaccharides, including glucomannans, creating a barrier against gaseous exchange. As a result, ripening and senescence are slowed down, and quality traits are improved (Aboryia et al., 2022). However, *Aloe vera* coating, useful alone or combined with other constituents, prolongs length of storage of mango (Amin et al., 2021), table grapes (Ayyub et al., 2024), apples (Kaur et al., 2024), apricots (Farooq et al., 2023), and guava (Supa et al., 2024) by slowing down respiration, cell wall softening, weight loss, and fruit decay, while also preserving other quality characteristics.

The research conducted to evaluates the length of application of chitosan and *Aloe vera* for postharvest treatment due to their biological and ecological benefits. Furthermore, fruits were kept at room temperature to test the potential of incorporating chitosan and *Aloe vera* to facilitate commercial exportation and long-term preservation. As a result, the current study was aimed toward exploring the possibility of chitosan and *Aloe vera* as an environmentally friendly preservation technique for reducing fruit softening, maintaining postharvest mango quality and extending storage time for commercial use.

MATERIALS AND METHODS

Mangoes were taken from a garden near Hajee Mohammad Danesh Science and Technology University, Bangladesh-5200 (Lat. 25°38'11.6664" N and Long. 88°38'10.9592" E). Mangoes were harvested when their skins (peels) were yellow at the bottom and green at the top. The normal harvest stages for local producers range from 75 to 82 days (Goutom et al., 2010). A total of 96 physiologically mature and healthy ripe mango fruits (8 fruits in each replication) were taken and submerged for three minutes in 1% sodium hypochlorite. Four treatments were control, 1.5% Chitosan (CTS; w/v), 1:1 Aloe vera (AVG; v/v), and CTS+AVG.

Mangoes were coated for 5 minutes and then air dried at room temperature for 2 hours. Fruit samples were analyzed every four days for 16 days. Mangoes were held at ambient condition (28±3°C and 80±5% RH) in this experiment.

Preparation of chitosan (CTS), *Aloe vera* gel (AVG) and chitosan-*Aloe vera* gel (CTS +AVG) coating

According to the method of Rahim et al. (1998) the chitosan solution was obtained. 1.5 g CTS powder was mixed with 1% lactic acid solution and 1ml glycerin. A magnetic stirrer homogenized the solution for 4 hours at 28°C. *Aloe vera* leaves were collected and separated the parenchyma layers and homogenized (Sing et al., 2013). CTS-AVG (1:1, v/v) was mixed for two hours at room temperature using a magnetic stirrer. Finally, four layers of muslin cloths filter the mixture to eliminate fibrous materials for the mucilaginous gel (Vieira et al., 2016).

Loss of weight (LW)

The loss of weight was obtained using this established method (1):

$$\text{LW (\%)} = \frac{\text{Weight of initial fruit (g)} - \text{Observation day fruit weight (g)}}{\text{Weight of initial fruit (g)}} \times 100 \qquad (1)$$

Respiration rate and ethylene production

The respiration rate and ethylene biosynthesis was measured according to the method described by Pristijono et al. (2019) with minor modification. The experiment involved storing fruits in sealed containers with septa at 28±3°C for two hours. A gas light hypodermic needle collected 1 ml of gas from the container's headspace and measured respiration rate with a CO_2/O_2 Gas Analyzer (FELIX Three, F-950, USA). The volume of CO_2 in the container was measured by inserting gas analyzer syringe through septa into container head space to measure ethylene. Lastly, fruit volume, weight of fruit, gas volume of container, and incubation time estimated respiration (2) and ethylene (3).

$$Respiration\ rate\ (ml\ CO_2 Kg^{-1}h^{-1}) = \frac{CO_2\ \%\times volume\ of\ container\ (ml)}{The\ sample\ weight\ (kg)\times 100\times Incubation\ time(h)} \qquad (2)$$

$$Ethylene\ production\ (\mu l\ C_2H_4 kg^{-1}h^{-1}) = \frac{C_2H_4\ \mu l\times volume\ of\ continer\ (ml)}{The\ sample\ weight\ (kg)\times Incubation\ time(h)} \qquad (3)$$

Fruit firmness

Fruit firmness was measured using an HP200 Force gauge (Handpi, China). After peeling, a 2 mm round stainless-steel probe was used to sample the fruit. Values were expressed in Newton (N).

Fruit decay

For fruit decay determination following equation (4) was used:

$$Decay\ (\%) = \frac{Number\ of\ decayed\ fruits}{Number\ of\ initial\ fruits} \times 100 \qquad (4)$$

Color

A color analyzer (Model, BCM-110 BCM-200, Biobase, China) was employed on opposite sides of the fruits for assessing the peel color. Peel color values were denoted as L* (‘+’ values=lightness, ‘-’ values=darkness), a* (‘-’ values=green, ‘+’ values=red), and b* (‘-’

values=blue, '+' values=yellow), saturation of color [Chroma, $(C=a^{*2}+b^{*2})^{0.5}$], and angle of hue ($h^{o}=\tan^{-1} b^{*}/a^{*}$).

Ascorbic acid (AA), Titratable acidity (TA), Total soluble solids (TSS), and pH

Parameters were described by Khatun et al. (2023) with slight modification, homogenize one gram of mango pulp with 3% metaphosphoric acid, the resultant mixture was filtered, and 2, 6-dichloroindophenol dye was employed to titrate a 5 ml sample of filtrate to pink endpoints (5).

$$\text{Ascorbic acid (mg/100g)} = \frac{Titrate \times factor\ of\ dye \times prepared\ volume}{Filtrate\ volume\ taken \times weight\ of\ sample} \quad (5)$$

The TA was obtained by taking 10 ml of mango extract with 500 microliters of phenolphthalein in volumetric flask. The solution was titrated against 0.1 N NaOH until the dye changed to pink.

TSS was measured using a refractometer (1.435-1.520 nD). Fruit pulp was meshed and filtered juice through cheese cloth. A refractometer prism was used to measure two drops of filtrate in °Brix. pH was acquired with a digital pH meter (HI 2211pH/ORP, China). First, 5 ml of mango extract was collected in a 10 ml volumetric flask. The pH meter probe was then put into the mango extract, and a reading was taken.

Total phenolic content (TPC)

Filter paper (Whatman No. 1) was used to filter 1 g of 10 ml methanol-extracted fruit pulp. Add 1 ml aliquot to 0.5 ml Folin-Ciocalteu and 7.5% diluted Na_2CO_3. This held 10 ml with distilled water. Mixing samples appropriately and centrifuging at 4,000 rpm for 10 minutes after 35 min at room temperature. The One Tech, China Elisa Microplate Reader (E-19) measured 765 nm absorbance against a blank. Total phenolic was measured in mg per 100 g fruit pulp (Singleton & Rossi, 1965).

DPPH scavenging activity

Using a mortar and pestle, 1 g mango pulp and 10 ml methanol were crushed. Samples were then sieved with Whatman No. 1 filter paper. Extract and DPPH (0.3 mM) solution were mixed in a falcon tube and left to settle in darkness for 30 minutes. The standard curve was created using Trolox values from 0 to 1 µmol/g. Spectrophotometer was used to measure absorbance at 517 nm compared to blank. The result was measured in micro mole per 100 gm fruit pulp (Hossain et al., 2021).

Enzyme extraction and activity assay

0.2 g fruit pulp was mixed with 3 ml buffer of phosphate (100 mM, pH 7) and 4% PVP using a mortar and pestle. Next, samples are centrifuged at 12,000 rpm for 15 minutes. A fraction was kept at 4°C for future use. Each enzyme activity was conveyed as U/mg FW.

Polyphenol oxidase activity (PPO)

The activity of PPO enzyme was obtained by the methods of Soliva et al. (2017). 600 µl enzyme extract, 1ml phosphate buffer (100 mM, pH 7), and 600 µl catechol (100 mM) were mixed. The spectrophotometer measured solution absorbance at 410 nm in two min.

Catalase activity (CAT)

A 700 µl solution of K_2SO_4 buffer, 100 µl H_2O_2 (200 mM), and 100 µl EDTA (2.5 mM) was prepared with 100 µl of enzyme extract. A spectrophotometer measured 240 nm absorbance after two min (Aebi, 1984).

Peroxidase activity (POD)

POD activity was measured by mixing 100 µl enzyme extract and guaiacol (20 mM), 600 µl phosphate buffer solutions, 100 µl EDTA (2.5 mM), and 100 µl H_2O_2 (100 mM). A spectrophotometer recorded 470 nm absorbance for two mins (Chance & Mahely, 1955).

Shelf life

Fruit's shelf life (in days) began when their weight declined 10% while stored. Fruits' shelf lives were measured starting on the harvest date and ending when more than 50% fruits were decayed Begum et al. (2023).

Statistical analysis

The acquired data was analyzed using a completely randomized design with three replications (each containing eight fruits) and two factorial designs. Analysis of variance was used to evaluate the experimental data (ANOVA). The various coatings and storage durations led to variations. The Statistical Tool for Agricultural Research (STAR, Version 2.0.1; IRRI, Laguna, Philippines) was used for all calculations and computations. Statistical differences between mean values ($P \leq 0.05$) were calculated using the LSD test. The R statistical software (version 4.3.1; R Core Team 2023) was utilized to determine potential correlations between variables through the principal component analysis (PCA).

RESULTS AND DISCUSSION

Weight loss, respiration rate and ethylene production

As a climacteric fruit, the quick weight loss is occurred in mango fruit which causes shelf-life reduction. The weight loss improved significantly ($p \leq 0.05$) with storage days. From the Figure 1a, observed that at the end of storage, weight loss increased progressively; however, the control fruits lost maximum weight (20.03%). Loss of weight of the CTS+AVG treated fruits was the least (13.9%) among the other treatments. CTS and AVG showed weight reduction of 18% and 17.31%, respectively, after storage. Weight loss occurs in fresh fruit. Water is lost by fruit transpiration and respiration. Temperature and humidity reduce fruit weight through respiration and transpiration. Allegra et al. (2021) observed that AVG-coated apples decreased transpiration, induced weight loss and dehydration. Begum et al. (2023) found that CTS+AVG-coated mangoes lost less weight at room temperature, validating our findings.

Figure 1b shows that respiration rates gradually increased throughout storage. Nevertheless, respiration rate rose significantly in control and declined slowly on day eight (19.89 mlCO_2/kgh). However, after 12th days of storage, the coated fruits had a higher respiratory rate. Then, a declining trend became apparent. During storage, CTS+AVG-coated fruits exhibited the lowest respiration rate (11.22 mlCO_2/kg/h) when equated to control. Coating film development reduces respiration (Formiga et al., 2022). This study confirms Chauhan et al. (2015)'s findings that *Aloe vera* and chitosan function as plasticizers, retaining CO_2 in fruit tissues and limiting oxygen availability.

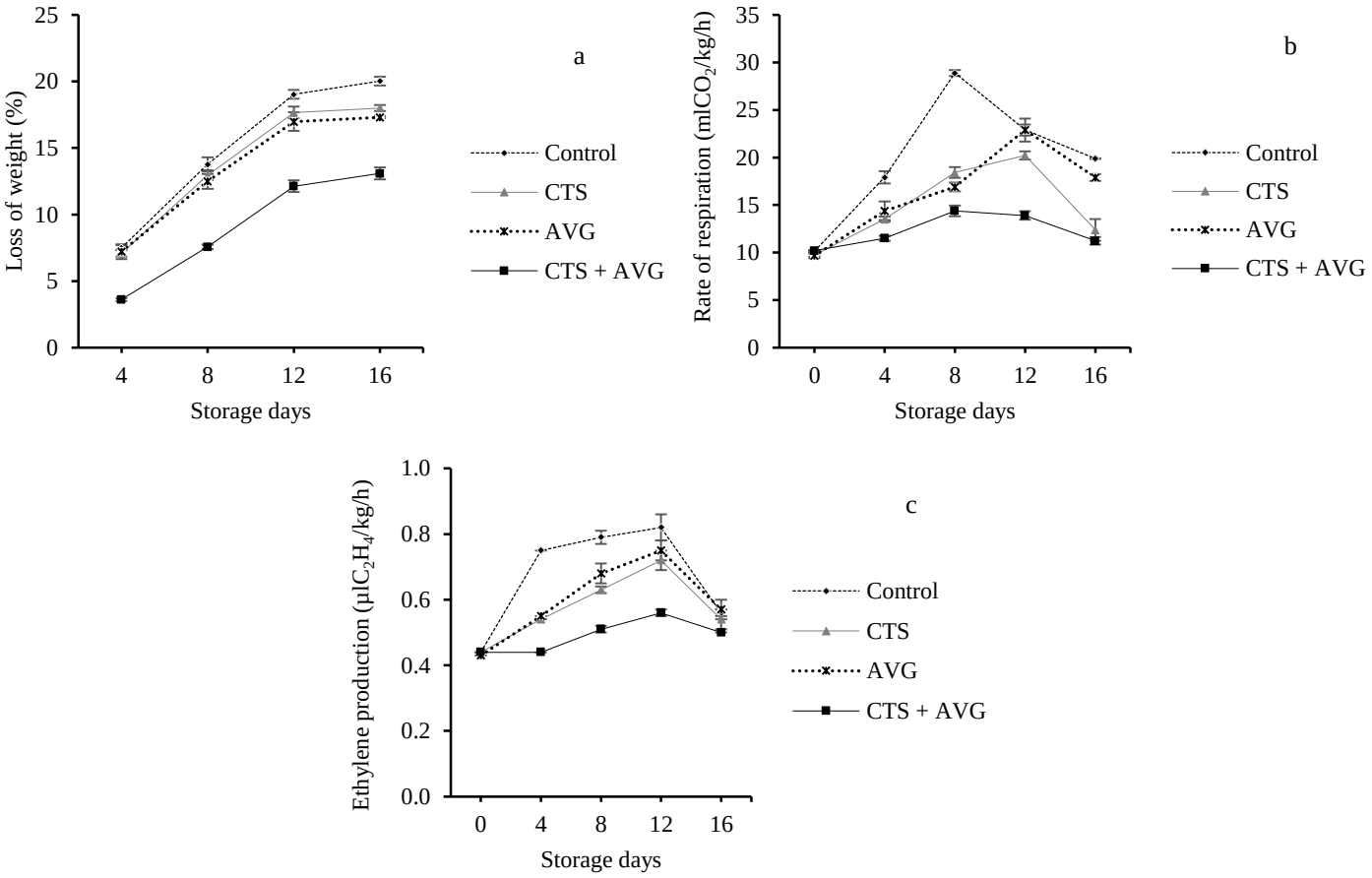

Fig. 1. Effect of different concentration of chitosan and Aloe vera gel on the weight loss (a), rate of respiration (b) and ethylene production (c) in Mishribhog mango during 16 days' storage at 25±3°C and 80–85% RH. The vertical bar shows the SE of the means (n=3). In accordance with the LSD test (P≤ 0.05), means with the same letters did not differ substantially. Control: distilled water, AVG: Aloe vera gel, CTS: 1.5% chitosan solution, CTS+AVG: 1.5% chitosan solution + Aloe vera gel, SE: Standard error

Ethylene production in mango increased gradually and then reduced as storage time increased. The initial mango ethylene production value of 0.44 µlC_2H_4/kg/h) increase dramatically up to 12th days of storage, reaching values of 0.82, 0.72, 0.75 and 0.56 µlC_2H_4/kg/h for control, CTS, and AVG and CTS+AVG, respectively. After storage, CTS+AVG-treated fruits emitted less ethylene 0.50 µlC_2H_4/kg/h compared to others treatments (Fig. 1c). Chitosan may prevent latent infection by delaying ripening and senescence. Lower internal oxygen levels may delay ethylene synthesis and respiration, causing the observed effects. Pang et al. (2024) say CTS coating is a natural covering that keeps mangoes fresh after harvest. Like our investigation, it was found that CTS and AVG reduce mango ethylene production (Shah & Hashmi, 2020).

Fruit firmness, decay incidence and color

Chitosan and *Aloe vera* gel coating had a significant impact on fruit firmness. A decreasing trend was seen throughout the time of storage. After 16 days of storing, the fruit firmness declined to 21.95 N from 58.80 N in the control group. Whereas the firmness was 21.75, 23.22 and 28.61 N in case of CTS, AVG and CTS + AVG coated fruits (Table 1). Due to metabolic breakdown of cell wall polymers such pectin, cellulose, and hemicellulose, fruits soften and lose firmness with time. Coatings prevent cell wall breakdown of fruits and may preserve fruit

firmness. Mangoes coated with CTS+AVG stayed firm during storage (Shah & Hashmi, 2020).

Table 1. Effect of different concentration of chitosan and *Aloe vera* gel on the fruit firmness (FF), decay incidence (DI) and peel color attributes (L^*, a^*, b^*, C^* and h^o) in Mishribhog mango during 16 days' storage at 25±3°C and 80–85% RH.

Treatments	Storage Periods (days) 0	4	8	12	16	Mean (Treatments)
			FF (N)			
Control	58.80±0.46^{a}	43.81±0.11^{b}	33.91±0.10^{def}	28.42±0.11^{fg}	21.95±0.22^{h}	186.89 A
CTS	57.82±0.19^{a}	46.94±0.15^{b}	34.59±0.20^{de}	28.32±0.04^{fg}	21.75±0.36^{h}	189.42 A
AVG	55.86±0.19^{a}	42.92±0.12^{bc}	37.63±0.05^{cd}	35.08±0.00^{de}	23.22±0.50^{gh}	194.71 A
CTS+AVG	52.92±0.27^{a}	44.10±0.05^{b}	41.65±0.06^{bc}	29.79±0.17^{ef}	28.61±0.34^{fg}	197.07 A
Mean (Storage periods)	225.40 A	177.77 B	147.78 C	121.61 D	95.53 E	
			DI (%)			
Control	0.00±0.00^{j}	0.00±0.00^{j}	9.64±0.31^{h}	21.31±0.13^{b}	27.64±0.27^{a}	11.72 A
CTS	0.00±0.00^{j}	0.00±0.00^{j}	0.00±0.00^{j}	13.31±0.13^{f}	17.31±0.13^{d}	6.12 C
AVG	0.00±0.00^{j}	0.00±0.00^{j}	5.31±0.13^{i}	14.64±0.31^{e}	18.31±0.13^{c}	7.65 B
CTS+AVG	0.00±0.00^{j}	0.00±0.00^{j}	0.00±0.00^{j}	12.47±0.31^{g}	13.14±0.03^{f}	5.12 D
Mean (Storage periods)	0.00 D	0.00 D	3.73 C	15.43 B	19.10 A	
			L^*			
Control	62.85±3.61^{bc}	53.24±0.52^{gh}	44.78±2.13^{j}	41.21±0.91^{kl}	37.87±0.55^{m}	47.99 C
CTS	61.28±2.99^{cd}	57.30±1.55^{ef}	50.83±1.14^{hi}	43.38±2.32^{jk}	40.78±1.34^{klm}	50.70 B
AVG	59.61±2.60^{de}	55.63±2.34^{fg}	49.82±1.15^{i}	41.72±1.84^{kl}	40.39±1.53^{lm}	49.43 C
CTS+AVG	68.97±2.16^{a}	65.26±2.96^{b}	60.81±1.93^{cd}	59.27±1.57^{de}	54.94±2.52^{fg}	61.85 A
Mean (Storage periods)	63.18 A	57.86 B	51.56 C	46.39 D	43.48 E	
			a^*			
Control	-6.62±0.84^{h}	-3.90±0.03^{f}	-1.63±0.18^{bc}	-0.28±0.14^{a}	-0.19±0.04^{a}	-2.52A
CTS	-6.62±0.83^{h}	-5.61±0.19^{g}	-3.35±0.32^{ef}	-0.97±0.06^{ab}	-1.14±0.07^{ab}	-3.54 B
AVG	-6.62±0.83^{h}	-3.95±0.17^{fghi}	-2.81±0.23^{defg}	-0.28±0.10^{ab}	-0.62±0.14^{a}	-2.96 A
CTS+AVG	-4.59±0.83^{ghij}	-3.94±0.04^{f}	-2.81±0.57^{de}	-0.83±0.04^{ab}	-0.62±0.17^{a}	-4.72 C
Mean (Storage periods)	-6.62 D	-4.86 C	-3.21 B	-1.47 A	-1.03 A	
			b^*			
Control	25.40±0.56^{gh}	29.09±0.57^{f}	28.83±1.00^{f}	24.43±1.50^{hi}	22.80±0.30^{i}	26.11 D
CTS	23.55±1.39^{hi}	23.01±0.26^{hi}	41.70±1.45^{b}	30.00±0.46^{ef}	28.33±0.59^{f}	29.32 C
AVG	24.47±0.21^{hi}	27.68±0.06^{fg}	37.54±0.36^{c}	33.14±1.43^{d}	31.81±0.16^{de}	30.92 B
CTS+AVG	23.55±1.39^{hi}	29.51±0.27^{ef}	45.75±0.33^{a}	36.03±0.46^{c}	33.36±0.97^{d}	33.64 A
Mean (Storage periods)	22.24 E	27.32 D	38.46 A	30.90 B	29.08 C	
			C^*			
Control	25.40±0.60^{gh}	29.09±0.56^{f}	28.83±1.00^{f}	24.43±0.30^{hi}	22.80±0.30^{i}	26.08 D
CTS	23.55±1.10^{hi}	23.01±0.28^{hi}	41.70±1.42^{b}	30.00±0.02^{ef}	28.33±0.59^{f}	29.59 C
AVG	24.47±0.02^{hi}	27.68±0.04^{fg}	37.54±0.35^{c}	33.14±0.14^{d}	31.81±0.15^{de}	30.92 B
CTS+AVG	23.55±1.10^{hi}	29.51±0.27^{ef}	45.75±0.33^{a}	36.03±0.02^{c}	33.36±0.98^{d}	33.97 A
Mean (Storage periods)	25.17 E	27.78 D	38.60 A	30.05 B	29.10 C	
			h^o			
Control	75.41±1.76^{a}	82.35±0.21^{c}	86.77±0.24^{efgh}	89.59±0.10^{i}	89.51±0.09^{hi}	84.72 B
CTS	74.04±2.86^{h}	76.28±0.40^{g}	85.36±0.62^{de}	88.26±0.09^{fghi}	87.68±0.15^{efghi}	82.32 A
AVG	74.86±1.99^{a}	81.88±0.37^{c}	85.71±0.39^{def}	88.52±0.17^{ghi}	88.87±0.26^{ghi}	83.97 B
CTS+AVG	74.04±2.86^{a}	78.52±0.05^{b}	83.72±0.71^{cd}	83.79±0.05^{cd}	56.30±0.22^{defg}	81.27 A
Mean (Storage periods)	74.59 A	79.76 B	85.39 C	87.54 D	88.09 D	

The mean followed by the same letter (s), is not statistically different within the columns or rows (LSD test, P ≤0.05). n=3 replications, ±SE. Control: distilled water, AVG: *Aloe vera* gel, CTS: 1.5% chitosan solution, CTS+AVG: 1.5% chitosan solution + *Aloe vera* gel.

Throughout storage, fruits covered with various coatings degraded less compared to control group. For the control and *Aloe vera* gel-treated mango fruits, the decay incidence began at 8 days of storage while chitosan alone or combination treated fruits decay incidence began at 12 days, and then increased gradually until 16 days of storing. Nonetheless, after storage, CTS+AVG coated fruits exhibited a lower mean decay incidence of 5.12% as opposed to 11.72% for the control, 6.12% for CTS, and 7.65% for AVG (Table 1). *A. vera* gel-covered hog plums resist microbial invasion and prevent fruit destruction. Nourozi and Sayyari (2020), found that AVG coatings improve storability and reduce microbial deterioration in apricots, preventing fruit decay. This study demonstrated that CTS or CTS+AVG prevented mango fruit storage deterioration.

According to the Table 1, peel brightness (L^*) showed a significant declining trend throughout storage. End of storage, fruits in the control had the lowest L^* value (32.55) out of all the treatments. Conversely, the treated fruits with CTS and AVG had lower L^* values (38.36 and 36.93), but the fruits treated with CTS+AVG coating had a higher L^* value (40.07). After the storage, the fruits coated with CTS+AVG exhibited a minor a^* value (-2.16) compared to the other treatments (-0.19, -0.62 and -1.14). The value of b^* increased during the storage period beginning on first day and reaching its maximum on the eighth day, in case of all treatments applied and then started to decline. However, fruits treated with CTS+AVG treatments had the highest b^* value (33.36) when compared to CTS (31.81), AVG (28.34), and control (22.8). The chroma value reveals 8^{th} day of storage, the color intensity was enhanced. CTS+AVG treatment had more chroma value (33.36) at the sixteenth day of storage. Following the same trend as the b* value, there are four possible angle of hue values: red (0° to 360°), yellow (90°), green (180°) and blue (270°). After initially increasing, the hue angle gradually decreased as storage progressed. The hue angle of the CTS+AVG fruits was much lower (56.30) than other treatments. As carotenoids, anthocyanins, and xanthophyll deteriorated from chlorophyll, mango turned yellow or reddish yellow after storage. The findings of the present study are consistent with the previous results by Seyed et al. (2021), who reported that the *Aloe vera* gel with chitosan coating decreased mango fruit color changes during storage, unlike the control. According to Lo'ay and Taher (2018), coating fruits prolongs their shelf life and makes them greener by preventing chlorophyll breakdown, limiting gas exchange, and lowering respiration.

Ascorbic acid (AA), Total soluble solids (TSS), Titratable acidity (TA) and pH

The AA content in Figure 2a diminished as the storage days increased, and at the conclusion of the storage, the CTS + AVG treated fruits had an advanced ascorbic acid content (14.52 mg/100g) than the other treatments (10.84, 10.71 and 11.08 mg/100g, respectively). Fruit loses ascorbic acid, a vitamin-like characteristic, as storage days' escalation. In this work, chitosan and *Aloe vera's* ability to restrict carbon dioxide and oxygen permeability on fruit surfaces was linked to its ability to reduce ascorbic acid losses. Khatri et al. (2020) found that chitosan and *Aloe vera* gel preserved tomato fruit ascorbic acid during storage.

In the Figure 2b an increasing trend was detected in case of TSS. Compared to other treatments, fruits coated with CTS+AVG had the least TSS value (17.73%), while the control had the most TSS value (22.23%). Moisture loss, starch degradation into simple sugar, and cell wall polysaccharide hydrolysis increased TSS substantially during storage (Seyed et al., 2021). Coating closes stomata and inhibits respiration, decreasing gaseous exchange, metabolic activity, and TSS content (Chavan et al., 2023). Our findings are consistent with Sree et al. (2022), who reported that CTS and AVG delayed the increase of tomato TSS during storage.

Figure 2c shows that the mean acidity 0.60%, 0.61% and 0.61% were observed in control, CTS and AVG treatments while the highest mean acidity (0.66%) was observed in case of CTS+AVG treated fruits after 16 days of storing. It was shown that acidity depends critically on the interactions between storage times and treatments. Treatment-related TA remained high. Previous studies found that CTS+AVG coatings boosted mango TA (Begum et al., 2023) supporting our findings.

The treated fruits showed considerable pH changes during storage. CTS+AVG coated fruits had the lowest pH compared to control (5.86; 7.40). On the other hand, the value of pH in case of CTS and AVG were 6.90 and 6.78 (Fig. 2d). The pH value may increase during storage because organic acid works as a component of the respiration process during fruit maturity or ripening. According to our research, CTS+AVG-coated fruit has the lowest pH. Amin et al. (2021) found that CTS+ AVG lowers mango pH, supporting our findings.

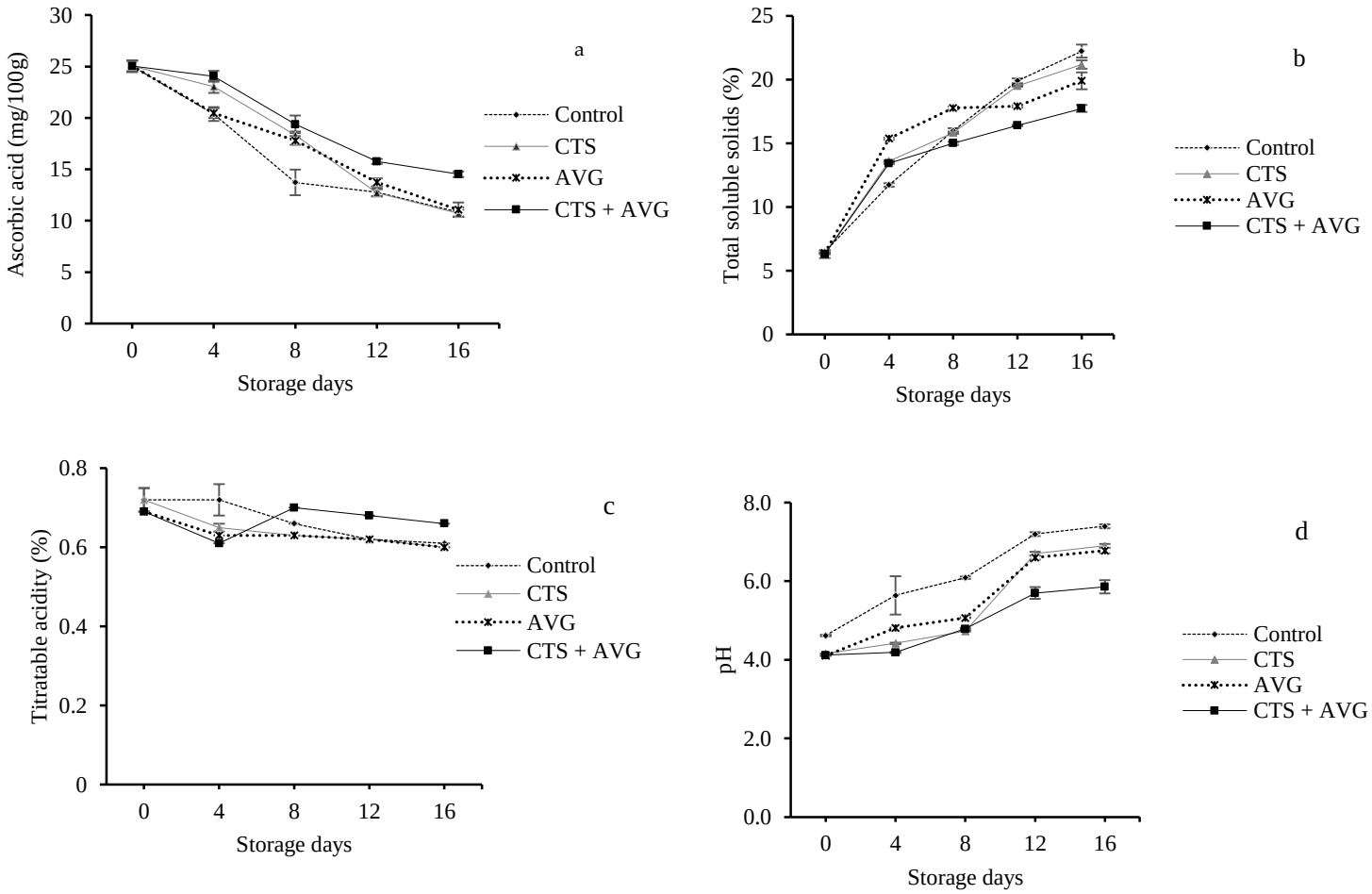

Fig. 2. Effect of different concentration of chitosan and *Aloe vera* gel on the ascorbic acid (a), total soluble solids (b), titratable acidity (c) and pH (d) in Mishribhog mango during 16 days' storage at 25±3°C and 80–85% RH.
Note: See Fig. 1.

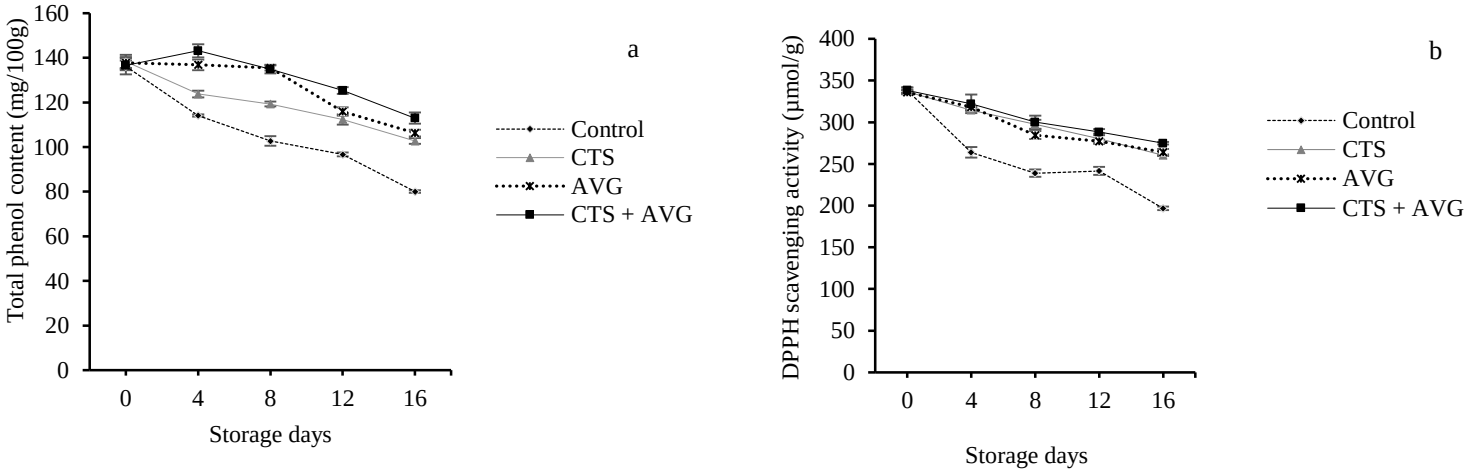

Fig. 3. Effect of different concentration of chitosan and *Aloe vera* gel on the total phenolic content (a) and DPPH scavenging activity (b) in Mishribhog mango during 16 days' storage at 25±3°C and 80–85% RH. Note: See Fig. 1.

Total phenolic content and DPPH scavenging activity

For every treatment, there was a discernible drop in the total phenolic concentration as the storage days rose (Fig. 3a). The fruits coated with CTS+AVG had the most total phenolic content of 112.99 mg/100g, whereas the lowest phenol level of 80.02 mg/100g was substantially detected in the control group. Mango phenolic compounds decreased with storage (Khaliq et al., 2019). PAL enzyme activity may increase phenolic chemical synthesis. Romanazzi et al. (2002) reported that chitosan treatment increased the activity of the grape fruit PAL enzyme, which synthesizes phenolic compounds. The current investigation found that chitosan and *Aloe vera* gel coatings improve mango phenolic retention over time, like Seyed et al. (2021).

In Figure 3b, the DPPH activity was decreased more quickly in the fruits of control compared to the fruits coated with CTS, AVG and CTS+AVG. While the fruits coated with CTS+AVG had higher DPPH scavenging activity (274.86 µmol/g) than the fruits of control (196.65 µmol/g) after the storage. All treated and control fruits lost DPPH scavenging activity during storage, and controls shriveled faster. At ripening and storage, fruits and vegetables naturally produce more reactive oxygen species (ROS), which induces oxidative stress and reduces antioxidant capacity (Rabeh et al., 2021). Coatings prevent fruit oxidation and antioxidant depletion by reducing gas permeability (Rabeh et al., 2021). Shah and Hashmi (2020) claimed that postharvest *Aloe vera* and chitosan-treated mangoes increased DPPH scavenging.

Enzyme activity

Activity of PPO was raised dramatically with the increase of storage period. As demonstrated in the figure, the fruits coated with CTS+AVG showed the lowest value of PPO activity (5.49 U/mg FW). Conversely, fruits covered with AVG and CTS also showed lower PPO activity 5.72 U/mg FW and 5.61 U/mg FW contrary to control 7.87 U/mg FW (Fig. 4a). POD (Peroxidase) activity was increased in all coated fruits. The lower POD activity was noticed in fruits of control (0.70 U/mg FW) while the coated fruits showed higher POD activity. However, AVG-coated fruits had the least POD activity (0.70 U/mg FW) after storage. Fruits treated with CTS+AVG had maximum POD activity (0.75 U/mg FW) (Fig. 4b). Increasing of

storage period shows increased CAT activity. Compared to CTS, AVG, and control (0.54, 0.54 and 0.45 U/mg FW), CTS+AVG had higher CAT activity (0.54 U/mg FW) (Fig. 4c). During ripening, genes encoding fruit antioxidant system enzymes like PPO, POD, and CAT increased, and endogenous defenses prevented ROS formation (Lo'ay & EL-Ezz, 2021). According to Adiletta et al. (2019), coatings reduced PPO activity, activated defense-related enzymes, inhibited mango browning, and extended storage. Fruit surface chitosan coating may have reduced PPO activity and enzymatic browning (Rehman et al., 2022). Edible coatings lowered PPO activity, possibly activating defense enzymes and protecting fruit. According to Zheng et al. (2024), adding CTS to sweet cherries inhibited PPO activity to varying degrees. Shah and Hashmi (2020) found that mango chitosan coating increases CAT activity by removing O_2 and H_2O. The fruits contain POD, a unique oxyradical detoxifying enzyme that reduces oxidation damage (Xing et al., 2015). Seyed et al. (2021) found that chitosan with *Aloe vera* gel preserves fruit quality and increases CAT with POD while lowering PPO activity.

The study indicated that CTS+AVG-coated fruit stored longest (16 days) and lost the least weight. However, AVG and CTS fruits lasted 16 days. Controlled fruits lasted 12 days. Chitosan coating mango fruits may improve their shelf life and maintain nutritional concentration during room temperature storage, according to Begum et al. (2023).

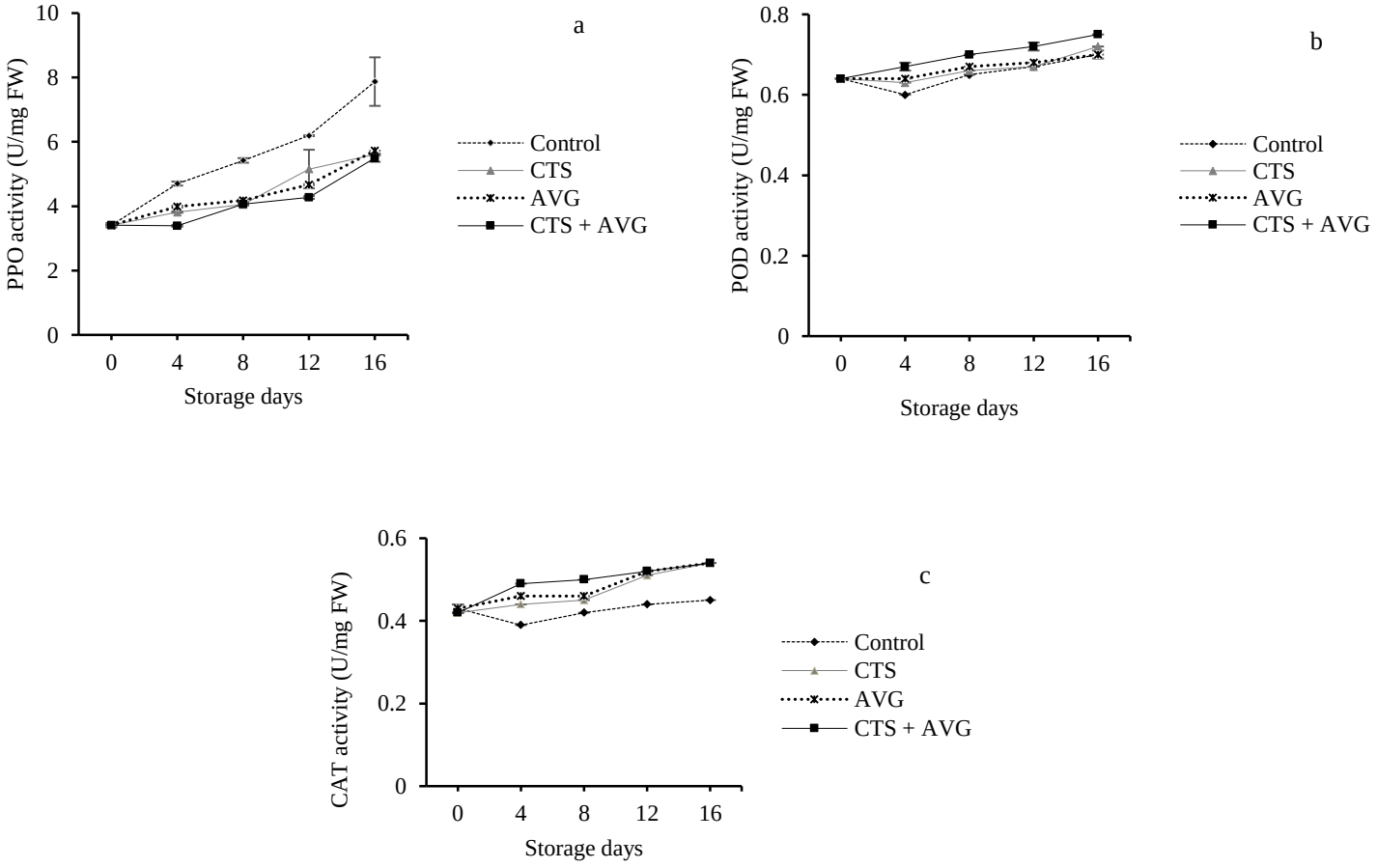

Fig. 4. Effect of different concentration of chitosan and *Aloe vera* gel on the polyphenol oxidase (PPO) (a), peroxidase (POD) (b) and catalase (CAT) (c) in Mishribhog mango during 16 days' storage at 25±3°C and 80–85% RH. Note: See Fig. 1.

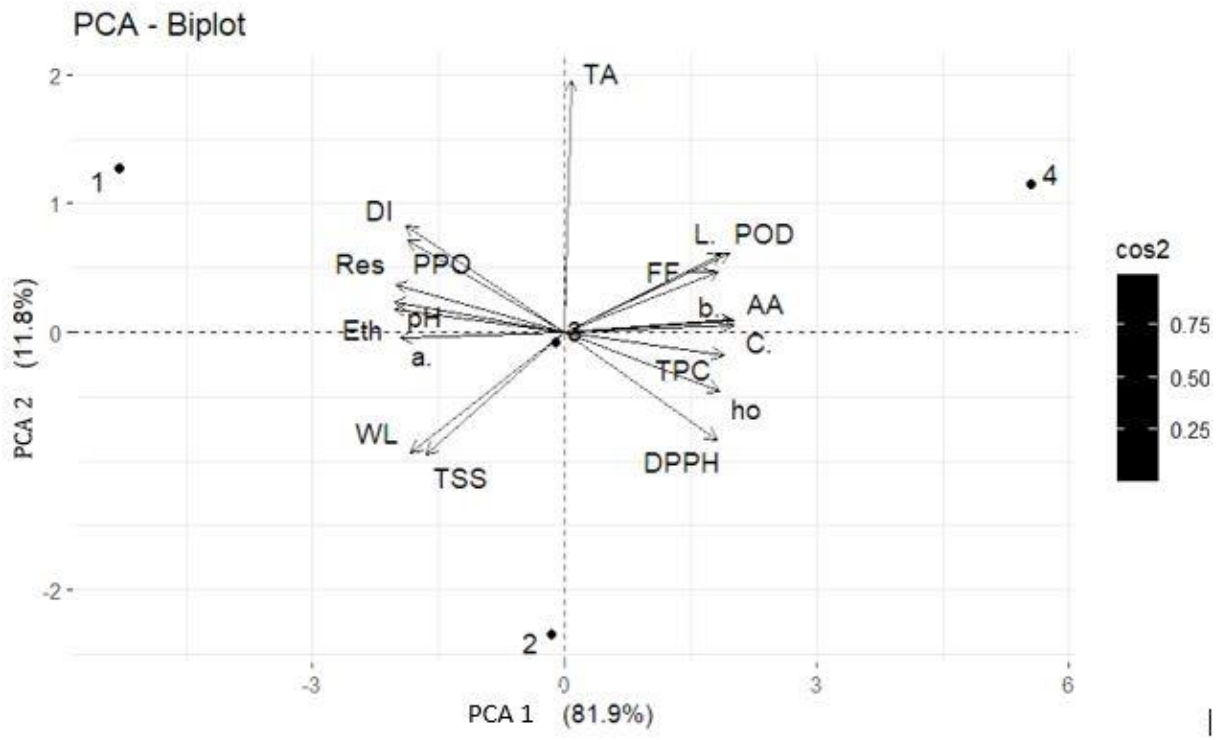

Fig. 5. Principal component loading plot of physiochemical and antioxidant enzymes activities of Mishribhog mango during storage. Here, DPPH: DPPH scavenging activity, ho: hue, TPC: Total phenol content, C: Chroma, AA: Ascorbic acid, b: b* (yellowness), FF: Fruit firmness, L: L* (Lightness), POD: Peroxidase, TA: Titratable acidity, DI: Decay incidence, PPO: Polyphenol oxidase, Res: Respiration rate, Eth: Ethylene production, a: a* (greenness to redness), WL: Weight loss, TSS: Total soluble solids.

Principal Component Analysis (PCA)

To evaluate mango fruit quality following harvest with various treatments, PCA was utilized to examine a number of biochemical limitations and antioxidant enzymes (Fig. 5). Two primary components, PC1 and PC2, represented 93.7% of variance. In the dataset, PC1 represented 82.5% of variations, whereas PC2 explained 11.2%. The antioxidant activity, color, CAT, total phenolics, chroma, ascorbic acid, firmness of fruit, POD enzymes, L*, and b* values were all found to positively correlate with PC1. Decay incidence, PPO enzyme, respiration, ethylene, pH, peel's a* value, weight loss, and TSS negatively linked with PC1. PC2 correlated negatively with TSS and antioxidant activity, while only TA showed a strong positive correlation. AVG and CTS treatments showed a substantial link with DPPH, hue, TSS, and weight loss, while CTS+AVG showed a strong correlation with L* values, POD, and hardness of fruit. Contrary to this, the control was more strongly associated with respiration, PPO, and decay.

CONCLUSION

The chitosan and *Aloe vera* coating reduced weight loss and TSS changes, improving "Mishribhog" mango fruit postharvest value and shelf life. Chitosan-infused *Aloe vera* gel preserves fruit quality such skin color, firmness, titratable acidity, and ascorbic acid after 16 days at room temperature. The coating decreases PPO and increases CAT and POD activity during storage. Compared to uncoated control, *Aloe vera* and chitosan increase bioactive substances such total phenolic and antioxidant activity. Chitosan and *Aloe vera* coatings also

greatly inhibit ethylene production and respiration, delaying fruit ripening. Given health concerns, edible coverings like chitosan and *Aloe vera* may improve mango storage quality. To commercialize mango fruit and increase storability using edible coatings, more research is required.

Conflict of interest

It is declared by the authors that there is no conflict of interest.

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