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Original Research Paper

Impact of *Aloe vera* gel with chitosan and coconut oil coatings on postharvest nutritional quality and antioxidant enzymes in 'Mishribhog' mango during storage

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ABSTRACT

The present study sought to assess the effects of *Aloe vera* gel (AV; 1:1 v/v), 1.5% chitosan solution (CH; w/v), coconut oil (CoO; 1:1 v/v), A. vera gel+1.5% chitosan solution (AV+CH; 1:1 v/v) and *Aloe vera* gel+coconut oil (AV+CoO; 1:1 v/v) on postharvest quality at 16 days of storage with ambient condition (25±2°C and 80-85% relative humidity). The results revealed that AV+CH coatings considerably reduced weight loss, respiration, and ethylene generation, as well as the decay percentage, when compared to the control. AV+CH also preserve fruit quality signs such as acidity, TSS, pH, fruit firmness, peel color, and ascorbic acid. Furthermore, phenolic content decreased modestly after storage, whereas control fruits displayed rapid oxidation of phenolic and antioxidant activity. PPO activity was significantly decreased in coated fruits, but CAT and POD enzyme activity increased throughout the storage period. The yellowing tendency of coated fruit peels during storage was significantly decreased when compared to control fruits. These findings showed that the AV+CH coating, at the appropriate dose with time, might be helpful in retaining bioactive components and post-harvest quality of 'Mishribhog' mango.

Keywords: Antioxidant enzymes, coatings, mango, nutritional quality, storage

INTRODUCTION

Mango (*Mangifera indica* L.) is a fruit is popular due to high nutritional value, eye-catching color, and delectable flavor. Bangladesh ranks 9th globally in terms of mango production, cultivating 0.124 million hectares of land and yielding more than 1.48 million tons (BBS 2024). **'**Mishribhog' mango 'is solely fiberless, extremely meaty, and delicious. Normally weighs 300 to 400 g. It is a climacteric fruit that rotten quickly (Cardenas-Coronel et al., 2012). Mango exports to distant markets have been impeded by lack of shelf life and postharvest oversight. Application of chemical compounds used to lengthen mango postharvest life but harmful to humans and the environment. Consequently, naturally occurring substances, particularly edible coatings, are appealing due to their eco-friendly nature (Liu et al., 2020).

Food-grade coatings can improve fresh fruit postharvest preservation by creating a customized atmosphere in the fruit region, lowering the rates of oxidative reactions and respiration, retaining fruit quality (Shami et al., 2019). Chitosan's ability to induce enzyme synthesis for fruit defense and reduce fruit rotting is another intriguing biopolymer action (Gutierre-Martine et al., 2018). Many researchers (Sogvar et al., 2016; Ali et al., 2019; Sayed et al., 2021) are interested in *Aloe vera* since it is an eco-friendly postharvest remedy. According to Hamman (2008), it is mostly composed of polysaccharides and contains phenolic compounds, antioxidants, vitamins (B_1, B_2, B_6, C, β-carotene, choline, folic acid, and α-tocopherol), minerals (calcium, iron, magnesium, phosphorus, potassium, sodium, zinc, copper, and manganese). As a moisture and oxygen barrier, *Aloe vera* reduces gaseous exchange through the coating of the lenticel, resulting in delayed respiration and good fruit preservation (Maan et al., 2018). By decreasing water loss, firmness, respiration, microbial deterioration, and other features, *Aloe vera* with extracts improves fruit postharvest quality (Nourozi & Sayyari 2020). *Aloe vera* gel coatings may reduce

fruit-firmness, loss of weight and browning (Hosseinifarahi et al., 2020).

A natural substance, Chitosan is with exceptional layer-forming properties that is non-hazardous, recyclable, and non-poisonous (Kumar et al., 2021). It may also treat mango fruit postharvest diseases with antibacterial properties (Shah et al., 2020). Chitosan, either alone or in combination with other substances, decreases respiration, tissue softening, weight loss, disease incidence, or so on (Zahedi et al., 2019). Bisen et al. (2012) found that the outer layer of coconut oil bound stomata and lenticels, which reduced bacterial activity, transpiration, respiration, and ethylene generation. This study suggests that *Aloe vera* with chitosan may improve postharvest nutritional quality at ambient storage of mishribhog mango.

MATERIALS AND METHODS

Mature mangoes were harvested from an orchard near Hajee Mohammad Danesh Science and Technology University, Dinajpur-5200, Bangladesh (25° 38' 11.6664" N latitude and 88° 38' 10.9592" E longitude). When a mango's peel turned yellow from the bottom up while staying green, it was chosen (Goutam et al., 2010). Mechanical damage-free fruits were identical in size, color, and ripeness. Fruits arrived in two hours at the lab. Before use, mangoes were washed with 1% sodium hypochlorite and dried at room temperature. Each lot of fruits was randomly assigned to one of six treatments: control (distilled water), *Aloe vera* gel (AV; 1:1 v/v), 1.5% chitosan solution (CH; w/v), coconut oil (CoO; 1:1 v/v), AV+CH, and AV+CoO. Fruits are coated for five minutes and then allowed to dry for two hours at room temperature, then stored at ambient conditions (25±2°C, 80–85% RH). Sample was examined every four days for 16 days.

Preparation of *Aloe vera* gel (AV), chitosan (CH), *Aloe vera*-chitosan (AV+CH) and *Aloe vera* coconut oil (AV+CoO)

Fresh *Aloe vera* leaves were collected, parenchyma layers separated, and then homogenized into a mucilaginous jelly and filtered to eliminate fibrous elements. 1 mL of glycerin and 100 mL of 1% aqueous lactic acid (v/v) are used to dissolve (1.5 g) of chitosan powder. The solution was harmonized for 4 hours at 25°C using a magnetic stirrer. Four layers of muslin were used to filter this mixture. For 4 hours at room temperature, chitosan (1:1 v/v) and *Aloe vera* solution were magnetically swirled. In a beaker set in a hot water bath, *Aloe vera* gel and coconut oil (1:1) were melted to create an apparent liquid.

Measurement of color parameters

A chroma meter from CR-2000 Japan was functional to determine the color of the mango skin at two points on the opposite sides of the fruit. The results were displayed as L* (positive value: lightness, negative value: darkness), a* (negative: green, positive: red), and b* (negative: blue, positive: yellow) points.

Physico-chemical parameters

Weight loss (%), fruit firmness ($kgcm^{-2}$), decay (%), total soluble solids (°Brix), acidity (%), pH, ascorbic acid ($mg100\ g^{-1}$), total phenol (mg GAE/100 g FW), DPPH scavenging activity (µmol/g), enzyme activity (POD, CAT and PPO) as described by Begum et al. (2023a). Respiration rate ($mlCO_2Kg^{-1}h^{-1}$) and ethylene production ($\mu lC_2H_4Kg^{-1}h^{-1}$) were followed by Begum et al. (2023b).

Statistical analysis

Data was evaluated using a completely randomized design with three replications and two factorial designs. STAR (version 2.0.1; IRRI, Laguna, Philippines) and R (version 3.4.2; R Core Team, 2017) with one-way ANOVA were used to analyze the data. LSD measures statistical differences between mean values ($Pd \leq 0.05$).

RESULTS AND DISCUSSION

Control fruits lost more weight than others (Fig. 1a). Fruit weight loss was lowest (8.60%) in AV+CH and highest (14.55%) in the control treatment after storage. CH, AV, CoO, and AV+CoO reduced weight 13.80%, 13.28%, 12.05%, and 10.34%, respectively. Each coated treatment compacts weight loss better than controls. Fruit weight loss is caused by respiration and transpiration-induced water evaporation. Sayed et al. (2021) discovered that AV+CH significantly prevented weight loss during storage.

Regardless of treatment, mango firmness decreased during storage (Fig. 1b). AV+CH, the mango's initial firmness value of 7.25 kg/cm^2 was intensely modified, with control, CH, AV, CoO, AV+CH, and AV+CoO fruits lowering to 3.75, 3.79, 4.00, 3.88, 5.19, and 5.17 kg/cm^2, respectively, on the 16th day of storage.

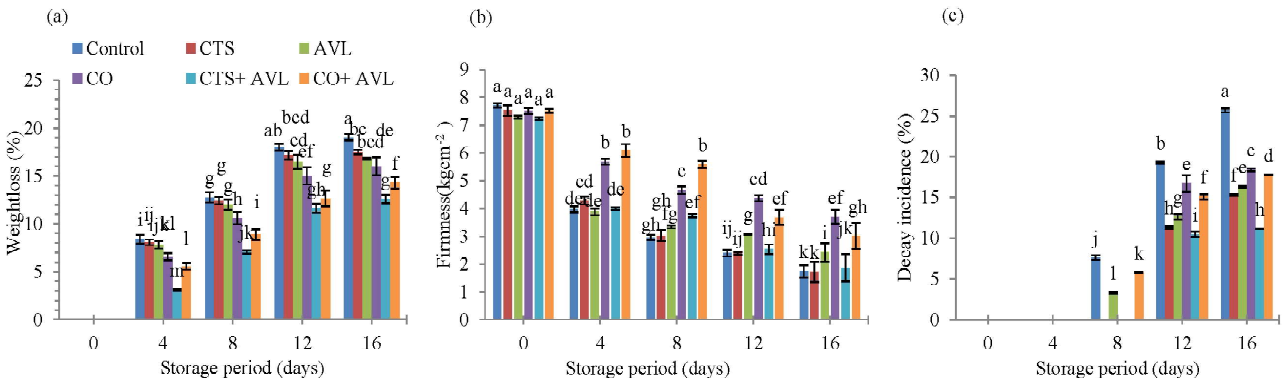

Fig. 1 : Interaction between storage periods and different coatings on weight loss (a), firmness (b) and decay incidence (c) of mango fruit during 16 days' storage at 25±2°C and 80-85% relative humidity. The vertical bar indicates the standard error of the means (n=3). Distinct letters at the various storage intervals showed significant variations among treatments as per the LSD test ($p<0.05$). Control: distilled water, CH: 1.5% chitosan solution, AV: *Aloe vera* gel, CoO: coconut oil, CH+AV: 1.5% chitosan solution + *A. vera* gel, CoO + AV: coconut oil + *A. vera* gel

Avoiding fruit softening, AV+CH made fruits 5.19 kg/cm^2 firmer than controls. Pectin solubility rises as fruit ripens owing to cell wall weakness.

Fruit firmness may be maintained by reducing cell wall activity and breaking down enzymes such as polygalacturonase (PG), pectin methylesterase (PME), and galactosidase. Mango fruit firmness can be delayed by chitosan coating alone or in combination with *Aloe vera*, according to Rastegar & Atrash (2021).

Fruit decayed faster during storage (Fig. 1c). In storage, four days deteriorated and peaked at 16. At the end of storage, the control, AV, and AV+CoO - coated mangoes had decomposed at 25.64%, 16.31%, and 17.74%, respectively. AV+CH-coated mangoes deteriorated 11.14% less than control fruits after 16 days. Chitosan coating helped mango fruit retain quality and avoid disease degeneration (Hasan et al., 2020). (a)

The TSS concentration in mango fruits considerably increased (Fig. 2a). Control had highest (21.73%) and AV+CH lowest (11.17%). Additionally, treatment-storage period interactions were significant. TSS may rise gradually during postharvest storage of fruit due to hydrolyzing cell wall polysaccharides, starch break down into simple sugars, or water loss (Sayed et al. 2021). However, by controlling the respiration and metabolic rate in the coated fruits, edible coatings can stop sharp rises in TSS (Dong & Wang 2018). This was consistent with the present findings (Yu et al., 2021).

Mango acidity was significantly impacted by coating and storage (Fig. 2b). CoO had a lower mean acidity (0.11%) after storage. In comparison to AV+CoO and AV+CH coated fruits, the control exhibited a considerably greater mean acidity (0.16%). Acidity plummeted after organic acid oxidation. Due to reduced gas exchange and respiration, coated fruits may have a higher acidity value because organic acid oxidation is prevented. Due to organic acid oxidation, control group fruits were less acidic. Mango studies showed AV+CH had the greatest acidity (Sayed et al., 2021).

Mango fruit pH was considerably impacted by coatings and storage (Fig. 2c). The mean pH of CoO-treated fruits was 3.34, lower than the control fruits. Control treatment had the highest mean pH (4.59) at storage end. As fruits age, organic acid concentration decreases, raising pH. Increased pH reduced fruit titratable acidity. Control samples had a greater pH rise than coated samples (Sogvar et al., 2016).

Coating and storage significantly impacted mango ascorbic acid (Fig. 3a). All treatments intensely lowered mango ascorbic acid from 27.41 mg/100 g. AV+CH-coated mangoes preserved the highest ascorbic acid (16.53 mg/100 g) on the penultimate day of storage, while, control mangoes lost 9.85 mg/ 100 g. Edible coverings reduce oxygen permeability, enzyme activity, and ascorbic acid oxidation, preserving fruits. Similarly, Khalil et al. (2022) discovered that chitosan increased mango vitamin C content higher than other treatments.

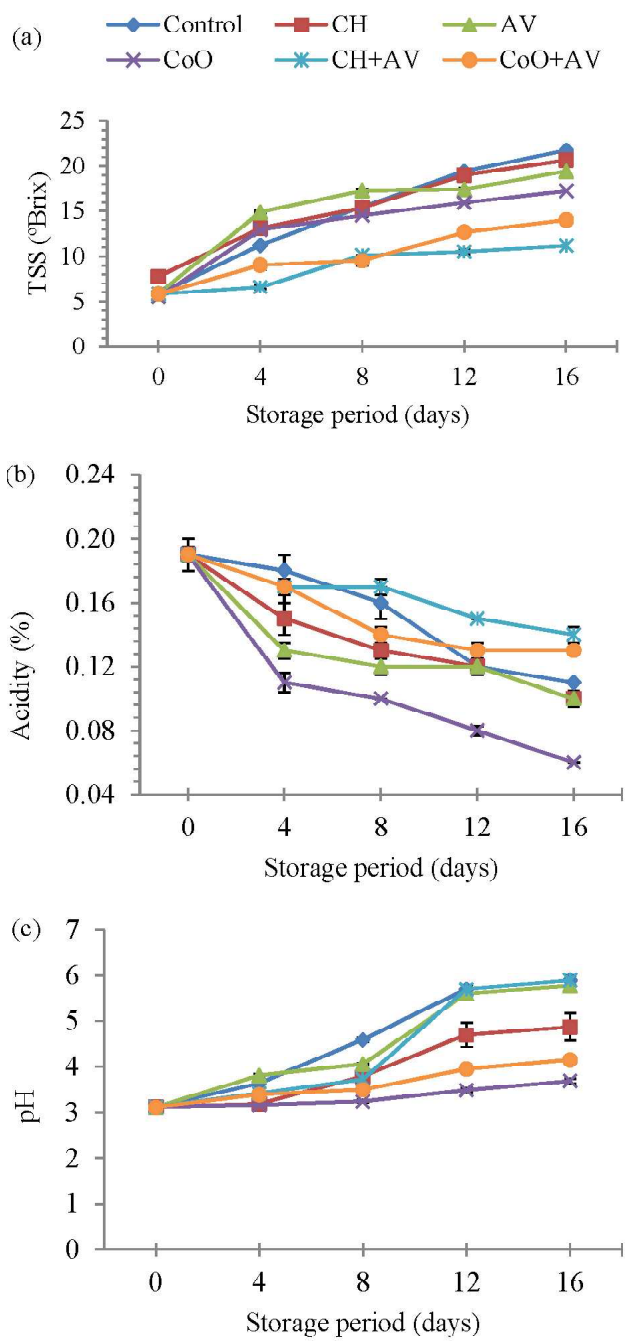

Fig. 2 : Interaction between storage periods and different coatings on TSS (a), acidity (b) and pH (c) of mango fruit during 16 days' storage at 25±2°C and 80-85% relative humidity

The storage and coatings significantly affected the mean total phenol content of mango fruit. All treatments significantly reduced storage phenol loss (Fig. 3b). The fruit coated with AV+CH contained greater phenol (97.99 mg GAE/100 g) at the end of storage than the control (65.02 mg GAE/100 g). Phenolics, which are lost during ripening, are needed

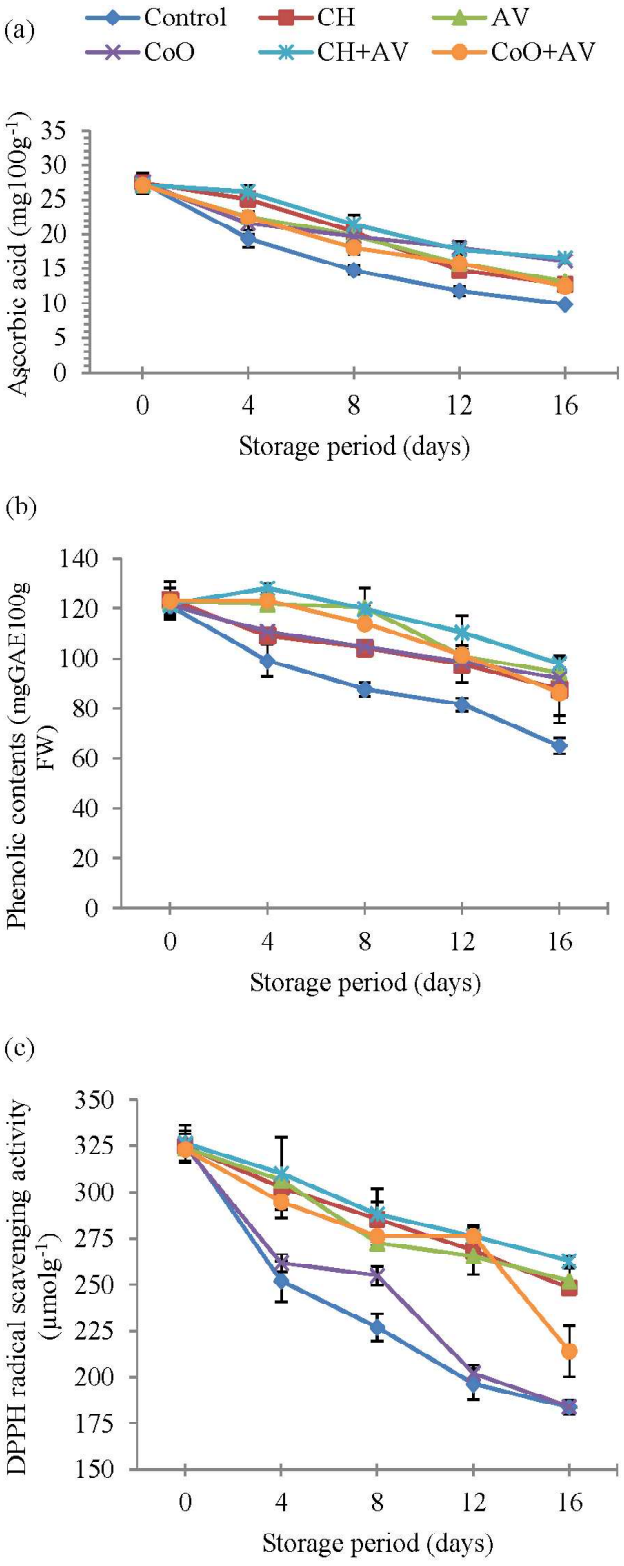

Fig. 3 : Interaction between storage periods and different coatings on ascorbic acid (a), phenolic contents (b) and DPPH (c) content of mango fruit during 16 days' storage at 25±2°C and 80-85% relative humidity

Table 1 : Effect storage period and fruit coating treatments on peel color parameters L*, a* and b* of mango fruit peel (cv. Mishribhog) during storage at 25±2°C temperature and 80-85% relative humidity for 16 days

Treatment	Storage Periods (days)					Mean (Treatment)
	0	4	8	12	16	
L*						
Control	52.54±0.46^{a}	49.35±0.28^{b}	43.35±2.09^{defg}	38.53±1.02^{klm}	36.86±0.39^{mno}	44.12A
CH	45.71±0.36^{cd}	42.26±0.13^{efgh}	40.48±0.34^{hijk}	37.76±1.54^{lmn}	35.43±0.35^{nop}	40.33B
AV	47.93±3.38^{bc}	41.56±0.44^{ghij}	40.36±0.13 ^{hijk}	33.71±1.44^{p}	31.05±0.70^{qr}	38.92C
CoO	42.35±0.31 ^{efgh}	39.44±1.05 ^{jkl}	37.60±0.36 ^{lmno}	29.76±1.73 ^{r}	29.76±1.73 ^{r}	35.78D
CH+AV	52.09±1.70^{a}	48.43±1.13^{b}	44.19±1.01^{def}	40.24±0.86^{hijk}	38.57±0.83^{klm}	44.70A
CoO+AV	44.66±1.50 ^{de}	42.03±0.01 ^{fghi}	39.80±0.87 ^{ijkl}	35.26±1.84 ^{op}	33.26±0.31 ^{pq}	39.00C
Mean (Storage)	47.55A	43.84B	40.96C	35.87D	34.16E	
a*						
Control	-8.12±0.84^{a}	-7.12±0.07 ^{a}	-4.86±0.19 ^{a}	-0.50±1.06^{a}	-0.36±0.69^{a}	- 4.19A
CH	-8.47±0.09 ^{a}	-7.49±0.18 ^{a}	-6.53±0.22 ^{a}	-5.33±0.36 ^{a}	-3.66±0.17 ^{a}	- 6.30 AB
AV	-6.99±0.08 ^{a}	-5.45±0.17 ^{a}	-4.31±0.23 ^{a}	-1.22±2.39 ^{a}	-0.88±1.72 ^{a}	- 3.77A
CoO	-6.28±0.22 ^{a}	-5.75±0.02 ^{a}	-4.45±0.34 ^{a}	-2.60±0.45 ^{a}	-1.27±0.12 ^{a}	- 4.07A
CH+AV	-6.09±0.12 ^{a}	-5.40±0.16 ^{a}	-3.13±0.74 ^{a}	-2.33±0.33 ^{a}	-1.70±0.26 ^{a}	- 3.73A
CoO+AV	-6.94±0.44 ^{a}	-25.28±18.86^{b}	-5.85±0.26 ^{a}	-4.07±1.15 ^{a}	-2.07±0.16 ^{a}	- 8.84B
Mean (Storage)	- 7.15BC	- 9.42C	- 4.85AB	- 2.67A	- 1.66A	
b*						
Control	23.90±0.56^{klmn}	27.59±0.57^{ghij}	40.20±1.46^{b}	34.53±0.47^{c}	31.86±0.97^{d}	31.62A
CH	14.90±0.78^{q}	21.51±0.26^{no}	27.34±1.00^{hij}	22.94±1.50^{lmno}	21.30±0.30^{o}	21.60E
AV	22.97±0.21^{lmno}	28.01±0.27^{fghi}	36.04±0.37^{c}	31.64±1.44^{d}	30.31±0.16^{def}	29.80B
CoO	18.76±1.71 ^{p}	23.99±0.16 ^{klm}	30.04±0.04 ^{defg}	25.70±1.52 ^{ijk}	22.70±0.97 ^{mno}	24.24D
CH+AV	22.05±1.40^{mno}	26.18±0.07^{hijk}	44.25±0.33^{a}	28.50±0.46^{efgh}	26.84±0.59^{hij}	29.57B
CoO+AV	21.42±1.65 ^{o}	27.01±0.11^{hij}	30.51±0.26 ^{de}	27.01±0.56 ^{hij}	25.34±0.59 ^{jkl}	26.26B
Mean (Storage)	20.67D	25.72C	34.73A	28.39B	26.39C	

Mean followed by the same letter(s) is not significantly different within the columns or rows according to an LSD test ($P < 0.05$); n = 3 replicates, ± SE, control: distilled water, CH: 1.5% chitosan solution, AV: *Aloe vera* gel, CoO: coconut oil, CH+AV: 1.5% chitosan solution + *A. vera* gel, CoO + AV: coconut oil + *A. vera* gel

to preserve fruit's color, bitterness, astringency, acidity, and taste. Phenolic substances, ROS-scavenging secondary plant metabolites, boost fruit antioxidant activity (Swallah et al., 2020). Edible coverings inhibit respiration and oxidation, helping phenolic component metabolism (Hassan et al., 2018). The current investigation confirmed Sayed et al. (2021) that AV+CH coatings retained mango phenolic throughout storage.

DPPH scavenging activity reduced in all treated and control fruits following storage. However, control fruits shriveled faster. AV+CH-treated fruits had increased DPPH scavenging activity (262.86 µmol/g) after storage, while, control fruits had reduced activity (183.65 µmol/g) (Fig. 3c). Ripening and storing fruit increases ROS production, producing oxidative stress and fruit deterioration. Fruits include SOD, CAT, APX, phenolics, ascorbic acid, and glutathione, which degrade ROS.

Regardless of treatment, the L* value decreased with increasing storage time. The control fruits showed considerably lower L* values after storage than the

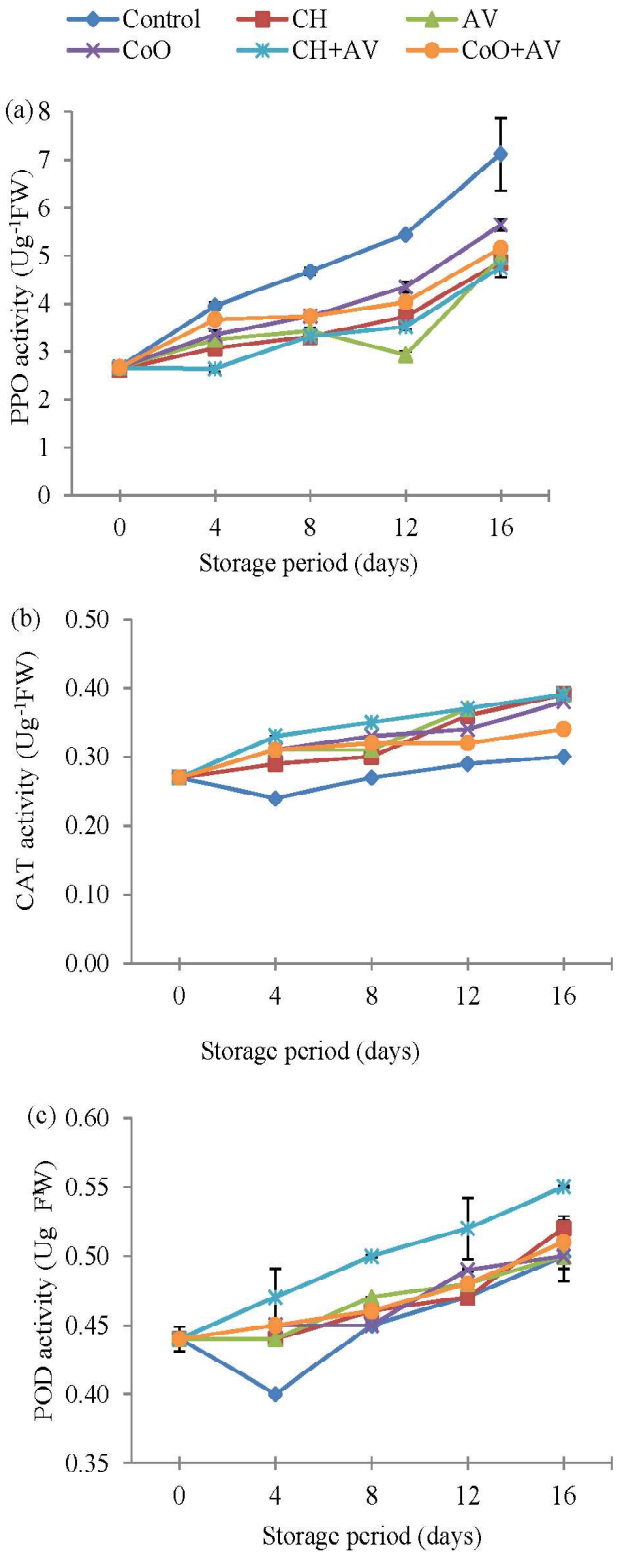

Fig. 4 : Interaction between storage periods and different coatings on polyphenol oxidase (PPO) (a), catalase (CAT) (b) and peroxidase (POD) (c) activity of mango fruit during 16 days' storage at 25±2°C and 80-85% relative humidity

AV+CH-treated fruits. Fruits coated with AV+CH showed higher L* values (38.57) after storage than controls (36.86) and other treatments. All treatments had significantly higher a* values during storage. The fruits with CH coatings had the lowest a* value after 16 days of storage (-3.66) and control fruits the highest (-0.36). Control and treated mangoes had higher b*. When stored for 16 days, CH and AV+CH fruits showed higher b* values (Table 1). The fruits are brilliant green when harvested, then chlorophyll breaks down into carotenoids, anthocyanins, and xanthophyll, turning them yellow or red. According to this study, the L* value dropped with all treatments, with treated fruits having lower L* value than controls. All covered fruits in this trial kept greenness (a*) throughout storage, unlike the control. Fruits coated with peel greenness prevent chlorophyll breakdown, restrict gaseous exchange, and inhibit respiration, extending shelf life (Loay & Taher, 2018). The control lost more chlorophyll than *A. vera* gel-covered guava fruits after storage (Rehman et al., 2020). Sayed et al. (2021) found that *A. vera* gel and chitosan inhibit mango fruit color change during storage.

Storage and coatings drastically reduced antioxidant capacity. PPO activity was greater in other treated fruits than AV+CH during storage. All treated fruits had lower PPO activity after storage than controls (Fig. 4a). After storage, all coated fruits and the control displayed equal CAT activity (Fig. 4b). It boosted catalase activity till storage terminated. CAT activity was considerably higher in treated fruits. The control fruits' peroxidase (POD) enzyme levels dropped for 8 days before rising following storage. POD activity changes after fruit treatment. POD was higher in treated fruits (Fig. 4c). Coatings lowered PPO activity, which may have triggered defense enzymes and protected fruit. Like Molamohammadi et al. (2020), chitosan-salicylic acid-coated pistachio fruit inhibited PPO. Increased CAT activity removes O_2 and H_2O_2. Mango chitosan increases CAT activity (Shah & Hashmi 2020). Fruits' POD enzyme may reduce oxidative damage (Xing et al., 2020).

Fig. 5a shows mangoes' initial respiration rate of 8.89 $mgkg^{-1}h^{-1}$. All treatments boosted it considerably until the 12th day of storage, and then steadily reduced. CH-coated fruits' respiration rate peaked at 21.64 $mgkg^{-1}h^{-1}$ on day 12 and the control plants at 27.64 $mgkg^{-1}h^{-1}$ on day 8. Each coated fruit took longer to reach maximal respiratory value than the control

group. Because mangoes respire and mature quickly, they have a limited shelf life at room temperature (Sousa et al., 2021). This limits their sale in distant places. Fruit respiration slows and shelf life is extended by edible covering. A thin chitosan coating on fruit negatively affected gas and environment exchange, maturation, and respiration (Ali et al., 2019).

During storage, control mango produced more ethylene than coated mango. The coated treatments likely inhibited ethylene production, reducing fruit ripening independent of storage (Fig. 5b). During 16 days of storage, mango fruit coated with CH+AV produced less endogenous ethylene (0.30 µl $C_2H_4kg^{-1}h^{-1}$) than other coated fruits or the control. Fruits emit more ethylene, the major ripening hormone. Dautt-Castro et al. (2019) observed that ethylene production during climacteric ripening increases signal transmission and gene expression for color, taste, texture, and fragrance enzymes. Since CH+AV lowered fruit respiration, fruits with coatings might have lower ethylene levels (Shah & Hashmi, 2020). Pea starch and guar gum prevented orange fruit ethylene (Saberi et al., 2018).

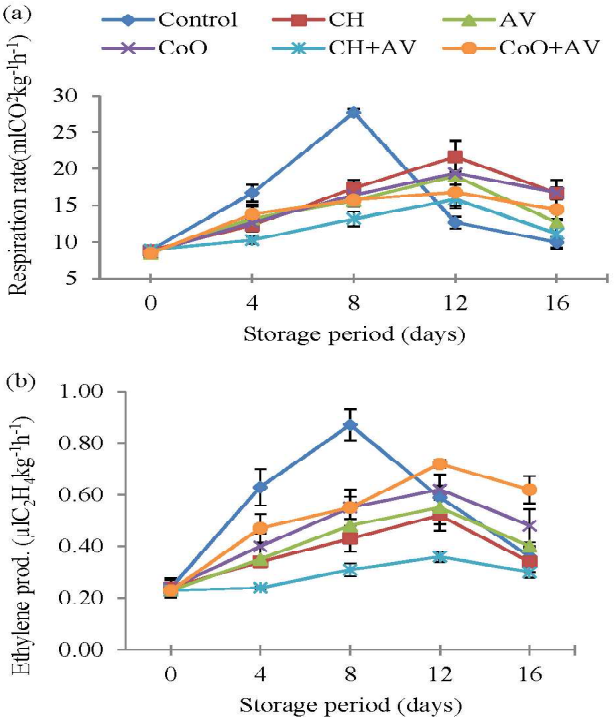

Fig. 5 : Interaction between storage periods and different coatings on respiration rate (a) and ethylene production (b) of mango fruit during 16 days' storage at 25±2°C and 80-85% relative humidity

The study found that *Aloe vera* and chitosan lower mango ethylene.

CONCLUSION

Aloe vera gel with chitosan might improve mango shelf life by minimizing weight loss and TSS changes. *A. vera* gel and chitosan retained ascorbic acid, titratable acidity, firmness, and peel color after harvest. These coatings may increase CAT and POD antioxidant enzymes and decrease PPO during storage. This combination increased mango fruit bioactives such total phenol and antioxidant (DPPH) in contrast to the control. Fruit ripening is also delayed by *A. vera* gel and chitosan coatings, which lower respiration rate and ethylene generation. *A. vera* gel and chitosan may preserve mango fruit quality with reducing postharvest decay.

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