Hindawi
Journal of Food Quality
Volume 2017, Article ID 2142409, 11 pages
https://doi.org/10.1155/2017/2142409

Research Article

Influence of Edible Coatings on Biochemical Fruit Quality and Storage Life of Bell Pepper cv. "Yolo Wonder"

Abad Ullah, N. A. Abbasi, M. Shafique, and A. A. Qureshi

Department of Horticulture, Faculty of Food and Crop Sciences, Pir Mehr Ali Shah Arid Agriculture University, Rawalpindi, Murree Road, Shamsabad, Rawalpindi 46000, Pakistan

Correspondence should be addressed to N. A. Abbasi; nadeemabbasi65@yahoo.com

Received 10 June 2017; Revised 28 August 2017; Accepted 7 September 2017; Published 31 October 2017

Academic Editor: Marta M. Sanz

The present study was carried out to investigate the influence of food grade coatings on fruit quality and storage life of bell pepper cv. "Yolo Wonder" at 8 ± 1°C with 90–95% RH for 24 days. Coating treatments were given to bell pepper fruits by dipping in aqueous solutions of gum arabic (6, 9, and 12%), *Aloe vera* gel (4, 5, and 6%), and cinnamon oil (0.5, 0.75, and 1%). Physicochemical characteristics as well as quality of bell pepper fruits improved in all coating treatments. Results revealed that 12% gum arabic coating exhibited significantly reduced weight loss, membrane leakage, chilling injury, and decay incidence with less increase in pH, total soluble solids, and sugar percentage, whereas appealing fruit color (L^*, a^*, and b^*) along with higher values of ascorbic acid (1.84 mg/100 g), titratable acidity (0.19%), and firmness (4 N) was observed in cold storage environment. Our results clearly suggested that coating of bell pepper fruits with 12% gum arabic can maintain postharvest storage quality of bell pepper fruits.

1. Introduction

Bell pepper is the most commonly used fruit of the solanaceous family with excellent nutritive value and a high content of ascorbic acid and vitamins such as vitamins A and E and whole range of vitamin B complex. Its consumption and demand have increased due to the rapid increase of population in current years pertaining to its use in ready-to-eat meals [1]. Bell pepper fruit, due to its short shelf life, is susceptible to flaccidity, wilting, shriveling, fungal diseases, and decay. These problems reduce premium price in market and consumer acceptance after harvest [2]. Postharvest quality of bell pepper is influenced by various factors like moisture loss and chilling injury (CI) that deteriorate the quality of bell pepper fruit during postharvest operations [3].

Fruits are usually stored at low temperature to delay quality deterioration; however, this technique has not proven enough to maintain fruit quality. Therefore, food grade edible coatings combined with certain oils are considered beneficial in improving shelf life to facilitate food consumption [4]. Application of chitosan as an edible coating improved the physical appearance of papaya by creating a barrier against respiration and moisture loss [5]. These coatings develop a modified atmosphere which can induce diverse alterations in fresh and minimally processed foodstuff in some areas such as antioxidant properties, microbial growth inhibition, color, sensory quality, firmness, ethylene production, and volatile compounds as a consequence of anaerobic processes [6].

Previously, the role of different edible coatings has been investigated on many fruit crops. *Aloe vera*, being a plant of tropics, is known for its medicinal value [7] and its main liquid components are clear gel and yellow latex [8]. *Aloe vera* gel has been used in a number of horticultural crops like plum [9], sweet cherries [10], mangoes [11], nectarines [8], and apples [12]. Moreover, *Aloe vera* gel coating application preserves fruit quality by reducing fungal decay in table grapes [7] and sweet cherries under cold storage condition [13]. Raspberry fruits coated with *Aloe vera* gel have an antioxidant capacity with a lower decay incidence [14]. Meanwhile, gum arabic, as a naturally occurring polysaccharide exuded from the stems or branches of the *Acacia* tree, has been widely used in food, textile, and pharmaceutical industry [15]. It is a composite blend of polysaccharides, arabinogalactan oligosaccharides, and glycoproteins [16] and has emulsifying properties [17]. Dipping of an apple fruit in gum arabic substantially delayed ripening in cold storage [18]. Earlier, tomatoes coated with gum arabic and kept at 20°C up to 20 days showed improved quality without production of any spoilage or off-flavors [19]; meanwhile, gum arabic coating in sweet cherries delayed the ripening process and off-flavor development [20]. In another study, gum arabic coating reduced textural damage and decay of green bell pepper [21], whereas gum arabic in combination with silver nanoparticles inhibited microbial growth and increased shelf life of green bell peppers [22]. A recent report showed that gum arabic along with calcium chloride enhanced low temperature tolerance in mango by improving the antioxidant defense system and reducing oxidative damage of mango fruit [23]. On the other hand, cinnamon, being a natural antimicrobial essential oil, is also known for its antimicrobial properties and reduces decay in fruits [24–26]. It contains antioxidative properties which are mostly derived from phenolic contents [27]. Previously, cinnamon oil in combination with chitosan reduced decay percentage in sweet peppers [28], whereas combined application of cinnamon oil with gum arabic on papaya and banana fruit showed promising control of diseases like anthracnose [29]. Cinnamon oil incorporated with carnauba wax effectively controlled postharvest green and blue mold in citrus fruit [30], whereas cinnamon oil combined with chitosan coating preserved jujube fruit quality under low temperature storage [31].

It appears from the literature that postharvest application of edible coatings like *Aloe vera* gel, gum arabic, and cinnamon oil is useful in maintaining fruit quality under cold storage. However, the comparative role of these edible coatings on fruit quality, chilling injury, and decay of bell pepper cv. "Yolo Wonder" at a low temperature is yet to be explored. Therefore, current research was planned to further probe the ability of *Aloe vera* gel, cinnamon oil, and gum arabic to improve the postharvest quality as well as visual appearance of bell pepper fruit under prolonged cold storage conditions.

2. Materials and Methods

2.1. Plant Material. Bell pepper cv. "Yolo Wonder" was harvested at commercial maturity stage (TSS = 5.66, $L = 39.23$, $a = -18.10$, $b = 26.51$) from a local farm located at Chakwal (32.93°N, 72.86°E), Punjab, Pakistan. Gum arabic in solid form was ground before making further concentrations, whereas *Aloe vera* gel and cinnamon oil were in liquid form. After grinding, 100 g of gum arabic powder was dissolved in 100 ml of water on a heating plate and was further diluted to make 6, 9, and 12% gum arabic concentration. For *Aloe vera* gel, 4, 5, and 6 ml of *Aloe vera gel* were dissolved in 100 ml of distilled water to obtain concentrations of 4, 5, and 6% *Aloe vera* gel. Similarly, 0.5, 0.75, and 1 ml of cinnamon oil were dissolved in 100 ml of distilled water to obtain 0.5, 0.75, and 1% concentrations of cinnamon oil. The harvested fruits were immediately transported to the Postharvest Laboratory of the Department of Horticulture, Pir Mehr Ali Shah Arid Agriculture University, Rawalpindi. Pest, disease, and blemish free uniform sized mature fruit were washed with 0.05% solution of sodium hypochlorite (NaClO) for 3 min followed by drying at room temperature. *Aloe vera* gel, cinnamon oil, and gum arabic powder of 100% purity were obtained from a local supplier. Fruits were dipped in different concentrations of *Aloe vera* gel (4, 5, and 6%), gum arabic (6, 9, and 12%), and cinnamon oil (0.5, 0.75, and 1%) for 5 min. The coated fruits were dried, packed in soft board cartons, and stored for 24 days at 8 ± 1°C with 90–95% RH. Fruits were removed from cold storage at a four-day interval to determine weight loss, fruit color, juice, pH, TSS, TA, ascorbic acid, decay incidence, fruit firmness, membrane leakage, and chilling injury (CI).

2.2. Weight Loss. Bell pepper fruits were weighed initially before shifting to a cold storage container, and the amount of weight loss that took place during cold storage was determined using the following formula and expressed as percentage:

$$\text{Weight loss (\%)} = \frac{(W1 - W2)}{W1} \times 100, \quad (1)$$

where

W_1 is the initial weight (g);

W_2 is the weight loss under cold storage (g).

2.3. Fruit Firmness. Fruit firmness was measured using a hedonic scale ranging from 1 to 9, extremely soft and extremely hard, respectively [32].

2.4. Total Soluble Solids (TSS). TSS of the bell pepper was determined by the method described by Dong et al. [33] in °Brix by placing a juice drop on the lens of a handheld refractometer.

2.5. pH. pH from bell pepper fruit juice was expressed by using a digital pH meter (model: Knick 646) [34].

2.6. Titratable Acidity (TA). TA of the bell pepper juice was determined by the method given by AOAC [34] and calculated as a percentage.

2.7. Ascorbic Acid Content. Ascorbic acid contents from extracted juice of bell pepper were recorded according to the procedure described by Hans [35] and measured as mg/100 g of the edible portion.

2.8. Membrane Leakage. Membrane leakage from bell pepper was measured by using a method described by Wang et al. [36] and expressed as a percentage: % membrane leakage = (1 − leakage after 60 min of incubation/total leakage) × 100.

2.9. Decay Incidence. The degree of decay incidence was evaluated as described by Zheng and Zhang [37]. Fruit surface was observed visually by using a scale ranging from 0 to 5, where 0 means no signs and 5 indicates >50% decay. Decay incidence was calculated using the following formula:

$$\text{Decay (\%)} = \frac{(\text{Number of fruits decayed})}{\text{Total number of fruits}} \times 100. \quad (2)$$

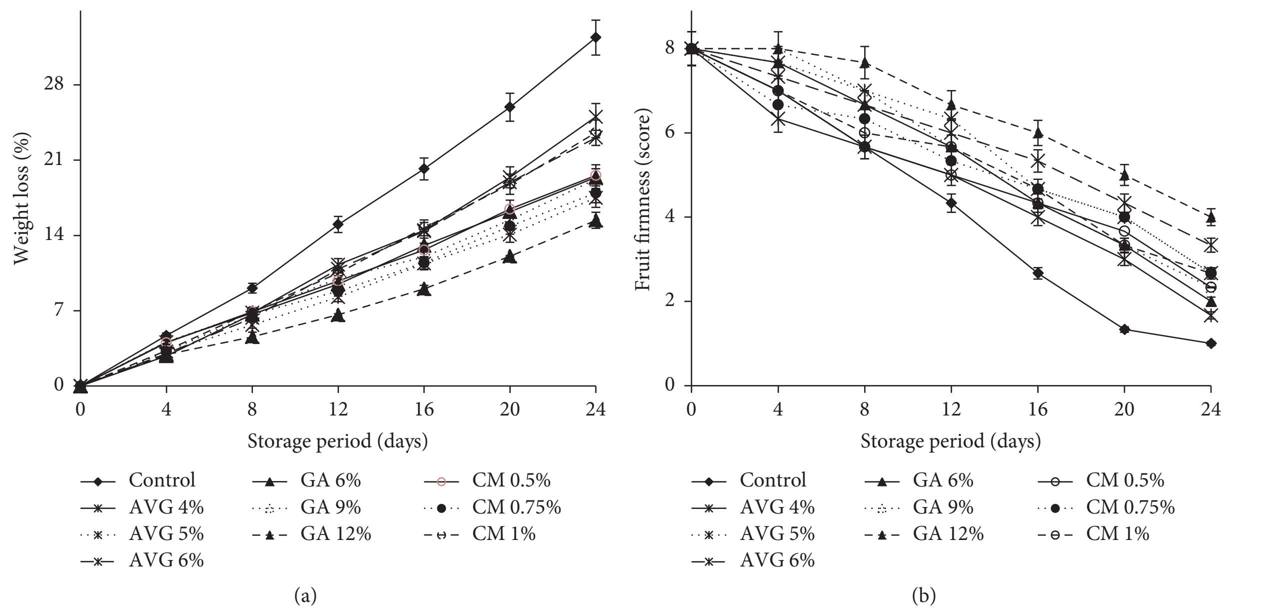

Figure 1: Effect of different coating treatments on the weight loss and fruit firmness of bell pepper during cold storage at 8 ± 1°C for 24 days.

2.10. Chilling Injury (CI). Incidence of CI was calculated based on the method described by Lim et al. [38]. CI symptoms were assessed visually by evaluating marks of pitting on the surface of bell pepper fruits. The following scale was used for CI determination and measured in percentage, that is, 0 = 0%, 1 = 5%, 2 = 6–10%, 3 = 11–15%, 4 = 16–20%, and 5 = more than 21%.

2.11. Fruit Color. Color development of nine randomly selected fruits from each treatment was checked. Fruit color change coordinates including L^* (higher positive values indicate more lightness while negative readings indicate darkness), a^* (greenness is indicated by negative readings while redness is indicated by positive values), and b^* (negative readings are indicative of blueness and higher positive readings are indicative of yellowness) were measured at opposite sides of each fruit by using Chroma Meter CR-400 (Konica Minolta Sensing, Inc., Japan).

2.12. Sugars. Determination of reducing, nonreducing, and total sugars was done by the method reported by Hortwitz [39].

2.13. Statistical Analysis. Completely randomized design (CRD) was used in laying out the postharvest experiment and the data was subjected to analysis of variance (ANOVA) for further analysis, while the least significant difference test (LSD) was used to differentiate the means at 95% confidence level [40].

2.14. Results

2.14.1. Weight Loss and Fruit Firmness. Coating treatments and cold storage period significantly affected weight loss of bell pepper fruits. Weight loss increased with the progression of storage period and reached the maximum on the 24th day. All the coating treatments exhibited less fruit loss than control fruit and the lowest weight loss was observed in 12% gum arabic coated bell pepper fruit. Coating bell pepper with 12% gum arabic exhibited about 2.1-fold less fruit weight loss compared to control (Figure 1(a)). A gradual increase in fruit weight loss decreased fruit firmness throughout the cold storage period. Fruit firmness did not show any significant decrease up to 8 days of storage, but it decreased substantially as storage time increased and was the lowest on the 24th day, irrespective of coating treatments. Coating bell pepper fruit with *Aloe vera* gel, gum arabic, and cinnamon oil significantly delayed loss of firmness. Maximum loss of firmness was observed in control treatment and minimum loss of firmness was observed in 12% gum arabic coated fruit. Bell pepper coated with 12% gum arabic exhibited about 1.5-fold higher firmness after 24 days of cold storage, as compared to the control (Figure 1(b)).

2.14.2. TSS and TA. TSS of bell pepper fruit was significantly affected by coating treatments, storage period, and their interactions. Both edible coated and control fruits showed increased TSS; however, coating treatments significantly delayed increment in TSS of bell pepper fruit during cold storage period. After 24 days of storage, a very little increase in TSS was observed in fruits coated with 12% gum arabic, which was 1.3 times less than the control treatment (Figure 2(a)). Similarly, TA of bell pepper fruit was significantly affected by coating treatments and storage interval. Results showed that TA decreased with increased storage period in both coated and uncoated fruit. However, all coating treatments resulted in higher TA compared to uncoated fruit. Among all coating treatments, 12% gum arabic coated fruit exhibited a lower decrease in TA, while uncoated fruit showed a higher decrease in TA during cold storage (Figure 2(b)). TSS

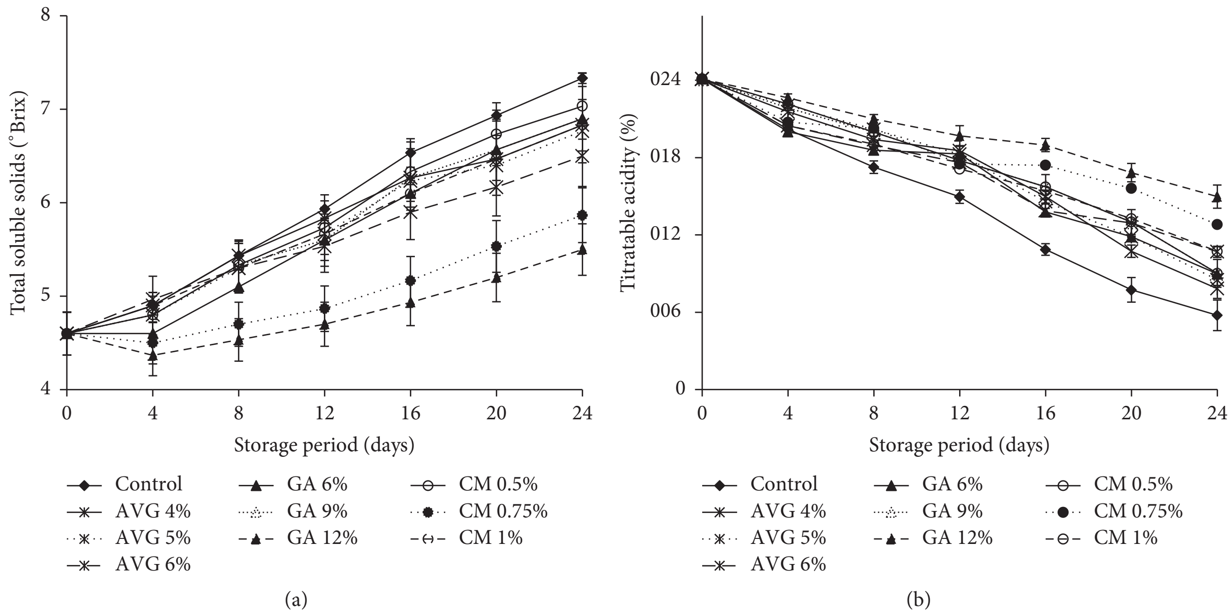

Figure 2: Effect of different coating treatments on the TSS and TA of bell pepper during cold storage at 8 ± 1°C for 24 days.

increased and slower TA reductions indicated the slower ripening process that occurred with 12% gum arabic treatment.

2.14.3. Ascorbic Acid Content, pH, and Membrane Leakage. Coating treatments, storage period, and treatments interactions significantly affected ascorbic acid content of bell pepper fruit. Results revealed that ascorbic acid declined slowly in both coated and uncoated bell pepper fruit with the increase in the storage period. Nevertheless, coating treatments significantly retained higher ascorbic acid contents. After 24 days of cold storage, minimum loss in ascorbic acid contents was recorded in fruits coated with 12% gum arabic which was about 3.2-fold lower as compared to control (Figure 3(a)). Coating treatments and storage period significantly influenced the pH of bell pepper fruit as well. Results revealed that pH increased gradually with the progression in storage. After 24 days of storage, fruit coated with 12% gum arabic showed a smaller increase in pH which was 1.1-fold more in comparison with control fruit (Figure 3(b)). Coating treatments, storage period, and their interaction significantly affected the membrane leakage of bell pepper fruit. However, coating bell pepper fruit with *Aloe vera* gel, gum arabic, and cinnamon oil maintained reduced leakage rate compared with the control; however, membrane leakage was consistent throughout the storage period. After 24 days of storage, fruit coated with 12% gum arabic showed reduced membrane leakage that was about 1.2-fold less as compared to control fruit (Figure 3(c)).

2.14.4. Decay Incidence. Incidence of decay on bell pepper fruit was significantly affected by coating treatments and storage period. Edible coatings significantly controlled decay and symptoms of decay were significantly less in all coated bell pepper fruits. The lowest symptoms of decay were observed in gum arabic coated bell pepper fruit compared with cinnamon oil and *Aloe vera* gel coatings. Fruit coated with 12% gum arabic exhibited the lowest decay incidence which was about 3-fold less as compared to control fruit after 24 days of storage (Figure 4).

2.14.5. Chilling Injury (CI). Fruit coated with different edible coatings exhibited significantly less CI symptoms than control treatment. Gum arabic coated fruit maintained the lowest CI symptoms, whereas maximum symptoms of CI were observed in control fruit. Coating of bell pepper fruit with 12% gum arabic maintained the lowest CI symptoms which were about 5.4-fold less as compared with uncoated fruits (Figure 5)

2.14.6. Color. Coating treatments, cold storage, and interaction of treatments significantly affected the fruit color of bell pepper fruit. Lightness (L^*) of bell pepper was decreased with the advancement in storage duration, irrespective of coating treatments. Bell pepper fruit coated with 12% gum arabic exhibited 1.26-fold higher L^* value than control fruit. Similarly, skin blush value (a^*) increased with the storage period and reached the maximum on the 24th day of cold storage. The lowest value of a^* was noted in fruit coated with 12% gum arabic that was about 1.6-fold less in comparison with control. On the other hand, b^* color value declined in all the treatments with the progression of cold storage period. However, all coating treatments significantly retained higher b^* color value. Uncoated fruit exhibited maximum b^* color value; whereas the lowest value of b^* was observed in 12% gum arabic coated bell pepper fruit. Coating of bell pepper fruit with 12% gum arabic showed 1.1-fold lower b^* *value*, as compared to uncoated fruit (Table 1).

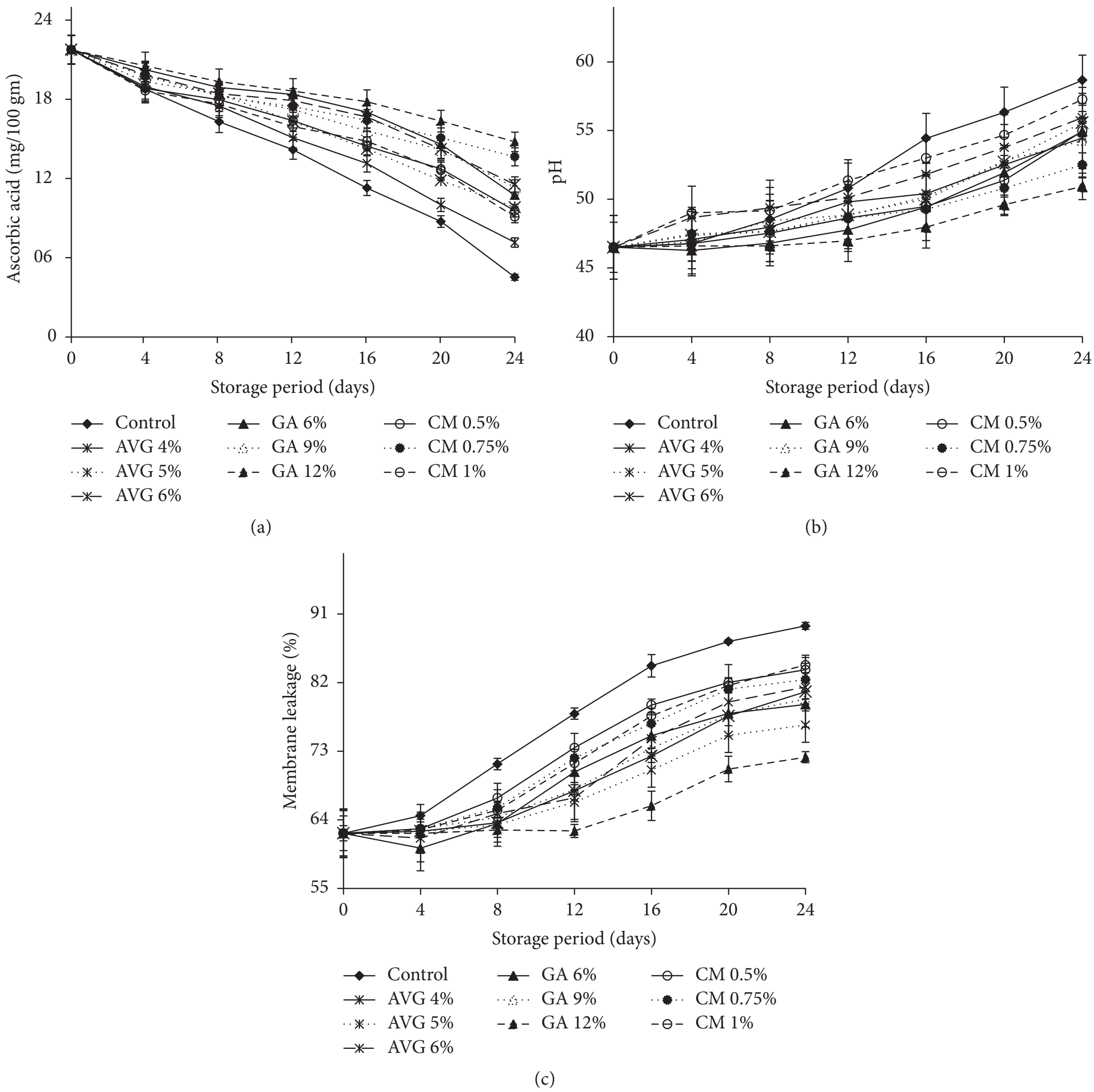

Figure 3: Effect of different coating treatments on the ascorbic acid, pH, and membrane leakage of bell pepper during cold storage at 8 ± 1°C for 24 days.

2.14.7. Reducing, Nonreducing, and Total Sugars. Coating treatments significantly affected sugar content of bell pepper fruit. Irrespective of coating treatments, an increase in reducing sugars was observed with the progression of cold storage. However, fruit coated with 12% gum arabic exhibited 3.1-fold lower increase, as compared to control. On the other hand, nonreducing sugars increased during storage period in both coated and uncoated fruit. However, after 24 days of storage, fruit treated with 4% *Aloe vera* gel coating exhibited 1.8-fold lower increase, as compared to uncoated fruit. Moreover, total sugars showed increasing trends with the advancement of cold storage period. Fruit coated with 12% gum arabic exhibited 1.4-fold lower increment in total sugars than uncoated fruit after 24 days of cold storage (Table 2).

3. Discussion

Weight loss increased gradually throughout the cold storage period irrespective of treatments, which could be due to water loss driven by active metabolic processes, such as transpiration and respiration in the fruit [41]. However, gum arabic coated fruit maintained higher weight throughout the storage period as compared to uncoated fruit. Reduced weight loss in gum arabic coated fruit could be due to the blockage of stomata and guard cells that ultimately slowed down the active metabolic processes and respiration. Moreover, reduced weight loss in gum arabic treated fruit could be attributed to the semipermeable effect of coatings during moisture loss, respiration, and movements of solutes across the membrane. Similar reduction in fruit weight loss has been

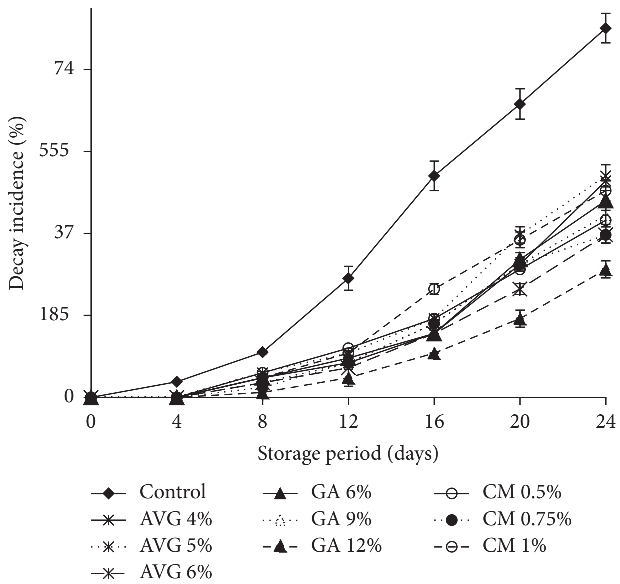

Figure 4: Effect of *Aloe vera* gel, gum arabic, and cinnamon oil coatings on the decay incidence in bell pepper during cold storage. AVG: *Aloe vera* gel; GA: gum arabic; CM: cinnamon oil.

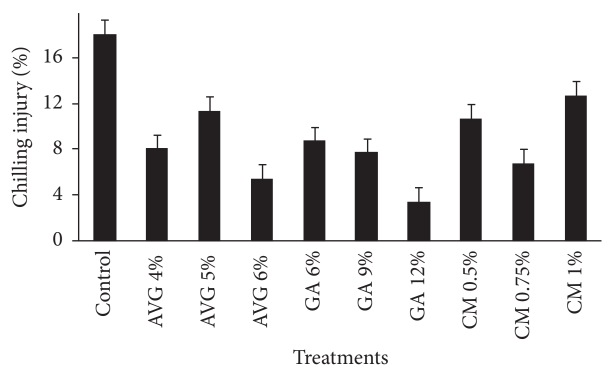

Figure 5: Effect of *Aloe vera* gel, gum arabic, and cinnamon oil coatings on chilling injury percentage of bell pepper during cold storage. AVG: *Aloe vera* gel; GA: gum arabic; CM: cinnamon oil.

reported in banana [25] and apple [18] when coated with different concentrations of gum arabic.

Similarly, bell pepper fruit dipped in edible coatings (*Aloe vera* gel, gum arabic, and cinnamon oil) also exhibited more firmness, as compared to control throughout the cold storage period. Generally, softening of the fruit increases with the progression in ripening due to the depolymerization of pectin substances [42]. Previously, softening enzymes including polygalacturonase and pectin esterase altered the cell wall and caused softening in nectarines [43]. Edible coatings might have inhibited pectin enzyme by slowing down the metabolic processes and kept bell pepper fruit firmer as reported by Mohebbi et al. [44]. Furthermore, coated bell pepper fruits might have developed resistance against compositional changes in cell wall and moisture loss, thereby resulting in reduced softening or more firmness. Our findings are in accordance with Al-Juhaimi et al. [45] who reported that cucumber fruit coated with 20% gum arabic solution notably maintained firmness by acting as a barrier against nutrients and water loss. In another study, Maqbool et al. [29] reported that banana fruit coated with gum arabic combined with chitosan efficiently maintained higher firmness during cold storage.

TSS and TA determine the flavor and nutritional status of fruit. In the current study, TSS showed an increasing trend with the progression of the cold storage period. However, fruit treated with edible coatings showed a lower increase in TSS, as compared to control. Increased TSS in untreated bell pepper fruits could be due to volatility of soluble compounds and water at a faster rate due to lack of protecting barriers [21]. A lower increase in TSS of coated bell pepper fruit might be due to delayed ripening. Our results were in agreement with the findings of Ali et al. [19] who reported that 10% gum arabic coating delayed changes in soluble solids of tomato. On the other hand, postharvest application of edible coatings retained higher TA, as compared to control. Rapid decrease in TA in uncoated fruit could be due to the increased respiration and oxidation of organic acids, whereas higher TA in coated fruit could be the result of less respiration ultimately preventing organic acids from oxidation. Previous findings showed that gum arabic coating resulted in higher TA in tomatoes [46]. Our results are in confirmation with the findings of Khaliq et al. [47] where 10% gum arabic alone or in combination with 3% calcium exhibited higher TA by preventing degradation of organic acids in mango fruit during cold storage.

Ascorbic acid content showed a gradual decline, while pH was increased with the increase in ripening during cold storage. The decrease in ascorbic acid could be attributed to the increased respiration and oxidation of acids into sugars [48]. Coated gum arabic application might have reduced oxidation of acids, thus resulting in higher values of ascorbic acid content [49]. Previously, gum arabic application maintained higher ascorbic acid content in tomato slices [50]. Our results are also in agreement with the findings of Hedayati and Niakousari [22] who reported that gum arabic significantly reduced loss in ascorbic acid contents in green bell pepper. Moreover, the linear increase in pH might be ascribed to biochemical, structural, and physiological alterations taking place during respiration. The increase in pH could be attributed to the accumulation of dry matter content and depolymerization of pepper polysaccharides under cold storage [51]. Meanwhile, membrane leakage was increased with the progression of cold storage period; however, coated bell pepper fruit exhibited reduced membrane leakage compared to the uncoated fruit. Coating treatments might have developed a protective layer around cellular membranes, thus resulting in reduced membrane leakage. Recently, gum arabic coated mango fruits maintained reduced leakage under cold storage conditions [23], whereas our results are also in agreement with the findings of Xing et al. [28] who reported reduced membrane leakage in chitosan coated sweet pepper fruit. Our results are further endorsed. Meanwhile, increased membrane leakage under low temperature storage might be due to changed composition of fatty acids that prompted membrane leakage [52].

Table 1: Effect of *Aloe vera* gel, gum arabic, and cinnamon oil on color L^*, color a^*, and color b^* of bell pepper during cold storage.

Treatments (T)	Storage period (days)							Means*
	0	4	8	12	16	20	24	
				Color L^*				
Control	39.23 a–i	37.56 h–o	34.93 s–y	34.07 w–a	32.87 z–d	31.80 c–e	30.41 e	*34.41 E*
Aloe vera gel 4%	38.83 d–j	38.88 c–j	38.93 b–j	37.31 j–p	36.42 l–t	35.74 o–w	34.92 s–y	*37.29 C*
Aloe vera gel 5%	40.77 ab	40.23 a–e	39.77 a–f	38.93 b–j	37.81 g–m	37.64 g–n	36.08 m–v	*38.75 B*
Aloe vera gel 6%	40.80 a	39.22 a–i	35.79 n–w	35.07 r–y	34.62 t–z	33.96 w–a	33.60 x–z	*36.14 D*
Gum arabic 6%	39.70 a–f	39.31 a–h	36.25 m–u	34.79 s–y	34.36 v–z	33.17 y–d	31.93 b–e	*35.65 D*
Gum arabic 9%	38.89 c–j	38.70 d–k	36.64 l–s	35.10 q–x	34.42 u–z	33.825 x–z	33.21 y–z	*35.83 D*
Gum arabic 12%	40.72 a–c	40.83 a	40.93 a	40.26 a–e	39.71 a–f	39.18 a–i	38.55 e–k	*40.03 A*
Cinnamon oil 0.5%	40.87 a	39.93 a–f	37.39 i–o	36.90 k–q	36.18 m–v	35.31 q–x	34.08 w–a	*37.24 C*
Cinnamon oil 0.75%	41.0 a	40.48 a–d	38.14 f–l	37.64 g–n	36.84 k–r	35.99 m–v	35.34 q–x	*37.92 C*
Cinnamon oil 1%	39.71 a–f	39.50 a–g	36.58 l–s	35.45 p–x	34.32 v–z	32.60 a–d	31.39 d–e	*35.65 D*
Means (T)	*40.05 A*	*39.46 A*	*37.54 B*	*36.54 C*	*35.76 D*	*34.92 E*	*33.95 F*	
				Color a^*				
Control	−18.10 z	−16.59 o	−14.48 f–j	−13.39 c–f	−12.60 b–d	−11.11 ab	−9.74 a	*−13.71 A*
Aloe vera gel 4%	−17.46 u	−16.17 k	−15.50 h–q	−14.27 e–i	−13.67 c–g	−12.70 b–e	−11.72 b	*−14.50 B*
Aloe vera gel 5%	−17.93 x	−17.32 t	−16.91 q–z	−16.28 l–v	−16.31 l–v	−15.76 i–s	−14.79 f–l	*−16.47 E*
Aloe vera gel 6%	−18.39 ab	−17.06 q	−16.29 l–w	−14.84 f–m	−14.59 f–k	−13.52 c–f	−12.45 b–d	*−15.30 C*
Gum arabic 6%	−17.27 t	−16.44 n	−15.62 i–r	−14.29 e–i	−13.53 c–g	−12.61 b–d	−11.70 b	*−14.49 B*
Gum arabic 9%	−18.05 y	−16.98 q	−16.49 n–y	−16.02 j–u	−15.31 h–p	−14.62 f–k	−13.96 d–h	*−15.92 DE*
Gum arabic 12%	−18.12 z	−17.88 w	−17.65 v–z	−17.11 r–z	−16.67 o–y	−16.30 l–u	−16.01 j–s	*−17.11 F*
Cinnamon oil 0.5%	−17.63 v	−17.23 s	−16.42 m–x	−14.94 f–n	−14.30 e–i	−13.48 c–f	−12.1 bc	*−15.17 C*
Cinnamon oil 0.75%	−18.52 b	−16.45 n	−15.98 j–u	−15.64 i–s	−14.73 f–l	−14.48 f–j	−13.51 c–f	*−15.62 CD*
Cinnamon oil 1%	−17.43 u	−16.78 p	−16.15 k–v	−15.64 i–s	−15.12 g–o	−14.26 e–i	−13.40 c–f	*−16.47 DE*
Means (T)	*−17.89 G*	*−16.89 F*	*−16.15 E*	*−15.24 D*	*−14.68 C*	*−13.88 B*	*−12.95 A*	
				Color b^*				
Control	26.51 a	23.33 f	22.98 g	21.75 j	21.43 j	19.62 t–v	19.51 u–w	*22.16 A*
Aloe vera gel 4%	25.69 b	22.61 h	22.08 i	19.93 q–t	19.81 s–u	19.40 v–y	18.44 d–g	*21.14 B*
Aloe vera gel 5%	24.65 c	22.26 i	21.08 k	20.32 n–p	19.49 u–x	19.54 uv	18.70 b–d	*20.86 C*
Aloe vera gel 6%	23.48 ef	20.65 m	19.49 u–x	19.17 x–z	18.46 c–f	17.78 jk	17.06 l	*19.44 H*
Gum arabic 6%	22.93 g	21.05 kl	19.91 r–t	19.22 w–z	19.22 w–z	18.29 f–i	17.64 k	*19.75 G*
Gum arabic 9%	23.73 de	21.61 j	20.64 m-n	20.25 o–q	20.14 p–r	18.93 z–b	18.37 e–i	*20.53 D*
Gum arabic 12%	23.00 g	20.74 lm	20.51 m–o	18.77 a–c	18.13 g–i	17.17 l	16.63 m	*19.28 I*
Cinnamon oil 0.5%	24.60 c	22.58 h	20.51 m–o	19.73 tu	19.09 y–a	18.41 d–h	18.08 ij	*20.43 D*
Cinnamon oil 0.75%	23.41 ef	20.81 k–m	20.13 r–s	19.76 tu	19.20 w–z	18.69 b–e	18.06 ij	*20.01 F*
Cinnamon oil 1%	23.92 d	21.66 j	21.43 j	19.69 t–v	19.05 za	18.09 h–j	17.55 k	*20.20 E*
Means (T)	*24.19 A*	*21.73 B*	*20.88 C*	*19.86 D*	*19.40 E*	*18.59 F*	*18.01 G*	

LSD ($P \leq 0.05$). For color L^*: T = 0.357*, SP = 0.299*, T × SP = 0.945; for color b^*: T = 0.644*, SP = 0.538*, T × SP = 1.704; for color a^*: T = 0.305*, SP = 0.255*, T × SP = 0.808. *Means not sharing the same letter are significantly different at $P \leq 0.05$.

Application of edible coatings significantly reduced decay incidence during cold storage, as compared to uncoated bell pepper fruit. Gum arabic, due to its certain film forming and antimicrobial characteristics, might have prevented pathogen attack, thereby reducing decay incidence. Our results are in line with the findings of Khaliq et al. [47] who had reported a reduced decay incident in gum arabic coated mango fruit. On the other hand, coated fruit exhibited significantly lower CI than untreated (uncoated) bell pepper fruit. Low CI symptoms in coated bell pepper fruit describe the ability of edible coatings to act as a semipermeable barrier, thereby providing extra protection to fruit against low temperature injury. De Reuck et al. [53] successfully alleviated CI in litchi fruit by using chitosan based coatings.

All coating treatments significantly retained the fruit color as compared to uncoated bell pepper fruit. Lower values of a^* and b^* with higher L^* in bell pepper could refer to the changes in epicuticular wax as a result of different coating treatments. Higher L^* value in coated bell pepper fruit describes the ability of edible coatings to delay the breakdown of chlorophyll and synthesis of carotenoids. Green color change in pepper could be due to the conversion

Table 2: Effect of *Aloe vera* gel, gum arabic, and cinnamon oil on reducing sugars (%), nonreducing sugars (%), and total sugars (%) of bell pepper during cold storage.

Treatments (T)	Storage period (days)							Means
	0	4	8	12	16	20	24	
				Reducing sugars (%)				
Control	1.64 c	2.20 y–c	3.92 r–v	6.68 m–o	8.77 h–j	10.98 c–e	13.36 a	*6.79 A*
Aloe vera gel 4%	1.64 c	2.09 z–c	3.56 t–w	4.92 qr	6.34 n–p	8.87 h–j	11.93 bc	*5.62 C*
Aloe vera gel 5%	1.64 c	2.25 x–c	3.85 s–v	5.43 pq	8.01 j–l	10.12 e–g	12.04 b	*6.19 B*
Aloe vera gel 6%	1.64 c	1.98 a–c	2.93 v–a	3.97 r–u	6.20 n–p	8.11 j–l	10.55 d–f	*5.05 D*
Gum arabic 6%	1.64 c	1.90 bc	3.24 t–x	6.06 op	7.70 kl	10.06 e–g	11.50 b–d	*6.01 B*
Gum arabic 9%	1.64 c	2.16 z–c	3.36 t–w	5.55 pq	8.18 i–k	9.90 fg	11.96 bc	*6.11 B*
Gum arabic 12%	1.64 c	1.80 bc	2.32 x–c	3.65 t–w	5.34 pq	7.11 l–n	9.13 g–i	*4.43 E*
Cinnamon oil 0.5%	1.64 c	2.02 z–c	2.75 w–b	3.94 r–u	7.14 l–n	9.37 gh	11.51 b–d	*5.48 C*
Cinnamon oil 0.75%	1.64 c	1.65 c	3.19 t–y	4.14 r–t	5.64 pq	7.68 k–m	9.54 gh	*4.78 DE*
Cinnamon oil 1%	1.64 c	1.86 bc	2.99 u–z	4.66 q–s	7.11 l–n	9.26 gh	11.41 b–d	*5.56 C*
Means (T)	*1.64 G*	*1.99 F*	*3.21 E*	*4.90 D*	*7.04 C*	*9.15 B*	*11.29 A*	
				Nonreducing sugars (%)				
Control	1.30 p–t	1.53 m–t	1.55 l–t	2.06 h–r	3.36 a–d	3.67 a	3.64 a	*2.44 AB*
Aloe vera gel 4%	1.30 p–t	1.45 m–t	0.88 t	2.11 g–r	2.42 d–m	1.71 k–t	1.94 i–s	*1.69 D*
Aloe vera gel 5%	1.30 p–t	1.01 st	0.99 st	2.09 g–r	2.05 h–r	3.03 a–h	2.15 f–p	*1.82 D*
Aloe vera gel 6%	1.30 p–t	1.22 r–t	1.44 m–t	2.28 e–p	2.40 d–m	3.07 a–g	2.08 g–q	*1.97 CD*
Gum arabic 6%	1.30 p–t	1.21 r–t	2.37 d–n	2.60 b–k	3.33 a–d	2.32 e–o	2.43 d–m	*2.22 BC*
Gum arabic 9%	1.30 p–t	1.26 q–t	2.12 f–r	2.54 c–l	3.34 a–d	3.27 a–e	2.89 a–i	*2.39 AB*
Gum arabic 12%	1.30 p–t	1.39 n–t	1.59 l–t	1.72 k–t	2.13 f–p	2.25 f–q	2.29 e–o	*1.81 D*
Cinnamon oil 0.5%	1.30 p–t	0.86 t	1.30 p–t	3.51 a–c	3.55 ab	3.11 a–f	2.81 a–j	*2.35 AB*
Cinnamon oil 0.75%	1.30 p–t	1.35 o–t	1.27 q–t	1.83 j–t	2.70 a–k	2.69 a–k	2.40 d–m	*1.93 CD*
Cinnamon oil 1%	1.30 p–t	1.24 r–t	1.38 n–t	3.08 a	3.41 a	3.47 ab	3.61 a–c	*2.31 A*
Means (T)	*1.30 C*	*1.25 C*	*1.49 C*	*2.44 B*	*2.89 A*	*2.87 A*	*2.61 AB*	
				Total sugars (%)				
Control	3.01 de	3.81 a–e	5.55 v–x	8.86 qr	12.31 h–k	14.85 b–d	17.19 a	*9.37 A*
Aloe vera gel 4%	3.01 de	3.61 a–e	4.49 yz	7.15 tu	8.89 qr	10.68 m–o	13.98 d–f	*7.40 E*
Aloe vera gel 5%	3.01 de	3.32 c–e	4.90 w–z	7.64 st	10.18 op	13.31 e–h	14.30 b–e	*8.09 CD*
Aloe vera gel 6%	3.01 de	3.27 c–e	4.45 y–b	6.38 uv	8.73 qr	11.34 k–n	12.74 g–i	*7.13 E*
Gum arabic 6%	3.01 de	3.18 c–e	5.75 vw	8.80 qr	11.22 l–n	12.51 g–j	14.06 c–e	*8.36 BC*
Gum arabic 9%	3.01 de	3.50 b–e	5.60 w	8.23 rs	11.7 j–m	13.34 e–g	15.01 bc	*8.63 B*
Gum arabic 12%	3.01 de	3.27 c–e	4.01 z–d	5.46 v–y	7.59 st	9.49 pq	11.72 i–l	*6.36 F*
Cinnamon oil 0.5%	3.01 de	2.93 e	4.12 z–c	7.64 st	10.88 l–o	12.65 g–j	14.4 b–d	*7.96 D*
Cinnamon oil 0.75%	3.01 de	3.08 de	4.53 x–z	6.06 v	8.49 q–s	10.52 n–p	13.91 d–f	*7.09 E*
Cinnamon oil 1%	3.01 de	3.17 c–e	4.45 yz	8.55 q–s	10.91 l–o	13.03 f–h	15.10 b	*8.32 B–D*
Means (T)	*3.01 F*	*3.31 F*	*4.78 E*	*7.48 D*	*10.09 C*	*12.17 B*	*14.25 A*	

LSD ($P \leq 0.05$). For reducing sugar: T = 0.192*, SP = 0.160*, T × PS = 0.508; for nonreducing sugar: T = 0.191*, SP = 159*, T × PS = 0.505; for total sugar: T = 0.196*, SP = 0.164*, T × PS = 0.520. Means not sharing the same letter are significantly different at $P \leq 0.05$.

of chloroplasts to chromoplasts pertaining to changes in pigment content of pepper fruit as ripening progresses [54], whereas the increasing trend in a^* value describes the loss of red color and formation of lycopene and β-carotene due to advancement of ripening [55]. These results clearly describe the effectiveness of edible coatings in improving the cosmetic look of bell pepper fruit by maintaining lower values of a^* and b^* with higher L^* values. Our results confirm the findings of Ali et al. [19] who reported that tomatoes coated with gum arabic delayed color change due to reduced respiration. Similarly, Ali et al. [56] illustrated that bell pepper coated with a combination of chitosan and essential oil slowed down the change in color. Furthermore, Al-Juhaimi et al. [45] reported that cucumber coated with 5–20% gum arabic retained a bright green color for 12 days under cold storage conditions.

Sugar content of bell pepper was increased throughout the cold storage period, irrespective of treatments. Higher sugar contents in uncoated bell pepper fruit may be attributed to increased metabolic activities due to which starch was converted to sugars [57]. However, bell pepper coated with

12% gum arabic exhibited a lower increase in sugar content, which may be described due to its ability to slow down the conversion of starch into sugars. Similar observations were also reported by Khan et al. [58] where putrescine treatment delayed the ripening process and maintained lower sugar levels in peach fruit.

4. Conclusions

Coating with gum arabic, *Aloe vera* gel, and cinnamon oil maintained quality and storage life of bell pepper fruit longer than control. Bell pepper coated with 12% gum arabic significantly reduced weight loss; maintained fruit firmness, ascorbic acid content, and TA; retained increment in color, CI, total soluble solids, sugars, membrane leakage, and pH; and delayed decay development. Results suggested that 12% gum arabic could be a promising treatment for extending storage life and maintaining postharvest quality of bell pepper fruit.

Additional Points

Practical Application. Bell pepper is one of the most widely used culinary purpose horticultural crops. It brings about excellent taste and flavor in a variety of foods along with excellent nutritional value. However, bell pepper is highly perishable and loses its freshness and flaccidity soon after harvest, reducing not only the visual appeal of the bell pepper fruit but also the quality. *Aloe vera* gel, cinnamon oil, and gum arabic are naturally occurring food grade edible coatings that not only preserve fruit quality but also play a protective role during cold storage. Hence, the results of this study could be used in bell pepper industry to delay the loss in freshness and improve the storage life of bell pepper fruits during cold storage.

Conflicts of Interest

The authors declare no conflicts of interest regarding the submission of this manuscript.

Acknowledgments

Abad Ullah highly acknowledges "Pakistan Science Foundation (PSF)" for funding Project no. PSF/NSLP/P-UAAR (264) titled "Improving Yield, Quality and Storage Life of Bell Pepper by Use of Food Grade Chemicals." The author further acknowledges the Department of Horticulture, PMAS-AAUR, for providing laboratory facilities and also time-to-time guidance that helped in successful completion of the project.

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