

Effect of edible coating on postharvest quality of bell pepper at ambient storage

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Abstract

Red colour bell pepper (*Capsicum annuum* L.) was coated either with chitosan (1.5% and 2% solution) or Aloe vera (AV) gel and the coated surface was air dried by using high speed fan. Coated peppers were kept into paper cartoon and stored in ambient condition (25±2°C and 55±5% RH). The success of coating in retaining postharvest quality of bell pepper was evaluated by determining respiration rate, ethylene production, firmness, weight loss, external colour change, β-carotene content, ascorbic acid content, TSS, pH, fungal decay and sensory quality. The incidence of rot started on 6 days after in uncoated bell pepper. Fruits coated with 1.5% chitosan affected by fungal decay on 9 days after storage. On the other hand, rot incidence was initiated in 2% chitosan and AV gel coated bell peppers on 12 days after storage. AV gel or chitosan coating reduced respiration rate, weight loss, decay and preserved colours, firmness, ascorbic acid content and other quality parameters. Therefore, delaying the progress of bell pepper decay due to senescence or microbial attack was observed.

Keywords: Aloe vera; chitosan, edible coating, respiration, rot incidence

Introduction

Bell pepper (*Capsicum annuum* L.) is one of the most important commercial vegetables that is valued for colour, flavor and different phytochemicals including vitamins A and C, phenolic compounds, flavonoids and carotenoids (Chuah *et al.*, 2008). Nevertheless, it is a very perishable vegetable with a short shelf life and high susceptibility to fungal diseases (Hardenburg *et al.*, 1990). The green bell peppers are in general less expensive than ripe peppers (red, yellow, purple) because of colored peppers leads to greater losses owing to decay and also leads to various other types of damage on the plant ripening. In addition, green bell peppers can better withstand in transport and have a longer postharvest life than ripe-colored fruits but colored bell peppers are high in demand, nutrition and cost. The storage life of pepper is limited by pathological deterioration, rapid water loss, flaccidity, shrivelling and susceptibility to chilling injury (Fallik *et al.*, 2009).

However, many areas in the world are without stable power and would benefit from postharvest techniques that increase shelf life without refrigeration (World Bank, 2014). Green bell peppers individually wrapped in plastic film showed reduction of water loss and softening, which extended shelf life.

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However, plastic film has its limitations for commercial use due to proliferation of aerobic microorganisms as a result of water condensation caused by temperature fluctuation (Brackett, 1990). Moreover, disposal of plastic films generates solid waste problems.

Primarily, post-harvest diseases of fresh produce are controlled by the application of chemical fungicides. However, it is encouraging research on novel, natural and renewable products that can be applied as edible coatings, since consumer concern over pesticide residues on foods, along with pathogen resistance to many currently used pesticides, (Tripathi and Dubey, 2004). Aloe vera (AV) gel is natural, tasteless, colorless and odorless and can be produced from matured leaves of AV plants. This has been identified as a novel coating agent due to its ability to control loss of moisture and firmness, delay oxidative browning and reduce respiration and microorganism proliferation through its various antibacterial and antifungal compounds in sweet cherry, table grapes and nectarines (Ahmed *et al.*, 2009). On the other hand, chitosan which is a modified natural biopolymer has broad anti-microbial activity and film forming property (Devlieghere *et al.*, 2004). Chitosan coatings have been reported to limit fungal decay and delay the ripening of several commodities, including strawberry (Ribeiro *et al.*, 2007). Hence, the aim of the present work is to study the effect of AV gel and chitosan coatings on bell pepper quality during ambient storage. Assessment of the treatments was based on their effects on microbiological, physical, chemical, and sensory quality attributes of bell peppers stored for 12 days at ambient condition ($25\pm 2^{\circ}\text{C}$ and $55\pm 5\%$ RH).

Materials and Methods

Material: Bell pepper, (*Capsicum annuum* L. variety. BARI Misti Morich-1), was collected from Vegetable Research Farm of Horticulture Research Centre (HRC) in Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh. Bell pepper was selected based on uniformity of size, absence of physical damage, fungal infection and >50% of the surface showing red colour. Chitosan-652 (high molecular weight) was purchased from Mahtani Chitosan Pvt. Ltd, India. AV leaf was collected from Flower Research Farm of HRC, BARI, Gazipur. Other chemicals used in this study were chemical grade.

Edible coating formulations: To prepare 100 mL of 1.5 or 2% chitosan solution, 1.5 or 2 g of chitosan, respectively, was dissolved in 75 mL of distilled water dissolved with 1 mL of glacial acetic acid. The mixture was heated with continuous stirring at 55°C for 500 rpm for proper dissolution of chitosan. The final pH of the solution was adjusted to 5.6 with 2N NaOH and volume was made up to 100 mL with distilled water.

Matured leaves of AV plants were washed with a mild 25% chlorine solution. AV matrix was then separated from the outer cortex of leaves and this colorless hydro parenchyma was ground using blender and filtered to remove the fibers. The gel was pasteurized at 70°C for 45 minutes and allowed to cool immediately to an ambient temperature. Ascorbic acid (2.0g/l) and citric acid (4.5g/l) were then added to maintain its pH around 4.0. To improve the viscosity and coating efficiency of AV gel, 1% carboxyl methyl cellulose (gelling agent) was added and then stored in amber bottle to prevent oxidation (Nasrin *et al.*, 2017)

Coating application: Sorted bell peppers were randomly divided into four groups (75 fruits per group and 3 replications/ treatment). Each group was treated with any one of the following treatment. The treatments consisted in immersing fruits for 1 min in: (a) normal tap water (uncoated/control); (b) 1.5% chitosan solution; (c) 2% chitosan solution; and (d) 100% AV gel. Surfaces coating was allowed to air dried using high speed fan, kept into paper cartoon and stored at ambient condition ($25\pm 2^{\circ}\text{C}$ and $55\pm 5\%$ RH). Measurements on various physico-chemical attributes were done at the day of experiment setting and on 3, 6, 9, and 12 days after storage. From each replication, 10 fruits were kept separately for weight loss and colour change measurement throughout the storage period.

Ethylene production and respiration rate measurement: The effect of coating on the ethylene production and respiration rate of bell pepper at ambient condition was determined of each replication during storage. Two fruits per replication were kept into 1000 ml sealed containers containing septa up for 2 h (incubation time) at ambient condition ($25\pm 2^{\circ}\text{C}$). Then one ml gas was taken from the container using syringe and examined by gas analyzer (CO_2/O_2 gas analyzer, Quantek Instrument, Model No. 902D, USA). Syringe of gas analyzer (Ethylene Spy, Model No. ES100) was pushed to the head space of the container through septa and amount of C_2H_4 gas was measured in ppm. Finally, respiration and ethylene production rate was determined by fruit volume, weight and gas volume in the container and incubation time.

Measurement of whole fruit firmness: Firmness was analyzed by Fruit Texture Analyzer (GUSS, Model Number: GS-25, SA). An 8 mm diameter of flat end probe was pushed to a depth of 3 mm into bell pepper (same position of each sample) at 5 mm per sec speed. The utmost penetration force was used as firmness value of bell pepper in Newton. Two bell peppers (6 opposite locations) from each replication were analyzed and the mean value was used.

Measurements of surface colour: External colour of bell pepper was evaluated with a Chroma Meter (Model CR-400, Minolta Corp., Japan) based on CIE ($L^*a^*b^*$). L^* is lightness whereas a^* and b^* values were transformed to chroma (c) and hue angle (h°) automatically in this Chroma meter. Before measurement, calibration was done using supplied white plate. Ten bell peppers from each replication were analyzed and the mean value was used.

Weight loss measurement: Initial weight of 10 fruits from each replication was taken immediately after treatment conducted surface coating with air drying and then it was 3 days interval throughout storage time. It was calculated by the weight difference between initial and specific time interval divided by initial weight and finally denoted (%).

Ascorbic acid, pH, total sugar, β -carotene and total soluble solids (TSS) determination: The ascorbic acid content, total sugar, β -carotene and TSS of bell pepper were analyzed according to the method of AOAC (1994). pH of blended sample was assessed by pH meter (HANNA Instrument Inc, pH-211; Microprocessor, pH Meter, Italy).

Decay incidence: All fruits in each treatment were examined for microbial decay in naked eye by 5 investigators with one pathologist during the storage. Bell pepper showing any symptoms of microbial incidence was marked as decayed. Decay incidence was calculated as the number of decayed bell peppers divided by total number of fruits. Causal pathogens of infected samples were also examined.

Sensory quality: Sensory quality of bell pepper was evaluated at 9 days after storage. The sensorial attributes of the bell pepper (appearance, flavor, texture and overall acceptability) were evaluated by a

panel of judges consisting of 15 scientific personnel and consumers including both sexual members. Bell peppers were presented in a completely randomized order, in a monadic form using white saucers. A 9-point unstructured scale ranging from 1 (dislike extremely) to 9 (like extremely) was used to evaluate these sensory parameters (Nasrin and Anal, 2015). An average score of 4.5 was considered the limit for acceptability.

Statistical analysis: A completely randomized design (CRD) was done with three replications for each experiment and mean \pm standard deviation was shown. Analysis of variance (ANOVA) was done according to the procedures of MSTAT-C software. Comparison among data was performed using Duncan's Multiple Range Test (DMRT) ($p < 0.05$).

Results and Discussion

Respiration rate

Fig. 1 illustrates the effect of skin coatings based on the CO_2 production of bell pepper stored at ambient condition ($25 \pm 2^\circ\text{C}$ and $55 \pm 5\%$ RH) for 12 days. Initial respiration rate of bell pepper was 40.68 mg/kg.h and it was reduced to around half when it was coated with AV gel or 2% chitosan at 3 days after storage.

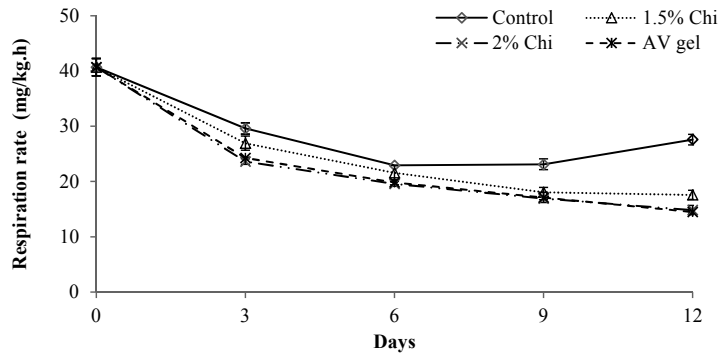


Fig. 1. Respiration rate of uncoated and edible coated bell peppers throughout the storage period ($25 \pm 2^\circ\text{C}$ and $55 \pm 5\%$ RH). Control = uncoated, 1.5% Chi = 1.5% chitosan coated, 2% Chi = 2% chitosan coated, AV gel = 100% Aloe vera gel coated. Vertical bars indicate standard deviation.

The control samples presented higher respiration rate during storage time compared with coated bell pepper. It was also observed that the respiration rate of bell peppers decreased as the concentration of chitosan on the coating increased. The lowest respiration rate was observed in AV gel coated bell peppers throughout the storage period that was more or less similar with the bell pepper coated with 2% chitosan. The explanation for the observed results is the existence of gas barrier between the bell pepper surface and the environment, promoted by edible coatings, that modifies the atmosphere around the fruit and so reduces its respiration rate. The intensity of change in the respiration rate of fruits and vegetables depends on the coating formulation and also on the storage conditions of the products. Similar respiration rate behavior observed in the present work was reported by El Ghaouth, *et al* (1991) who observed a reduction of respiration rate in bell pepper because of the use of chitosan edible coatings. Saltveit (1997)

observed that the respiration rate of bell pepper stored at 20°C was shown 32 to 36 mg/kg.h.

Ethylene production

Ethylene production patterns of coated and uncoated bell peppers stored at ambient condition ($25\pm 2^\circ\text{C}$ and $55\pm 5\%$ RH) are represented in Fig. 2. Initial ethylene production rate of bell pepper was $1.11 \mu\text{l/kg.h}$ and it was reduced gradually and reached to around $0.13 \mu\text{l/kg.h}$ in case of coated fruits. On the other hand, ethylene production rate of uncoated fruits was decreased up to 6 days after storage and was $0.67 \mu\text{l/kg.h}$ at 12 days after storage. Because of, incidence of rotting in control fruits was started at 6 days after storage which increased the ethylene production rate. Rough handling causes wounding, rotting and severe shrivelling of citrus fruits stimulate respiration and ethylene production (Ladaniya, 2010). Lim et al. (2007) also reported that initial ethylene production of bell pepper (breaker and red ripe stage) was around $1.2 \mu\text{l/kg.h}$ and it was reduced gradually during 28 days of storage at 10°C and finally achieved $0.5 \mu\text{l/kg.h}$.

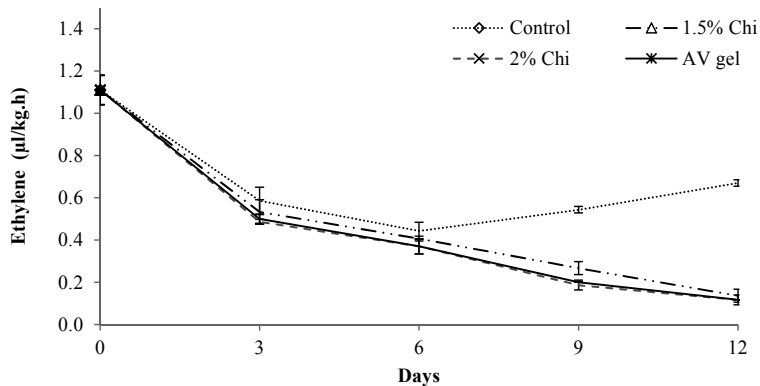


Fig. 2. Ethylene production of uncoated and edible coated bell peppers throughout the storage period ($25\pm 2^\circ\text{C}$ and $55\pm 5\%$ RH). Control=uncoated, 1.5% Chi=1.5% chitosan coated, 2% Chi=2% chitosan coated, AV gel= 100% Aloe vera gel coated. Vertical bars indicate standard deviation.

Firmness

Firmness or texture is a critical quality attribute in the consumer acceptability of fresh fruit and vegetables. Bell pepper suffers a rapid loss of firmness during ambient storage which contributes greatly to its short postharvest life and susceptibility to fungal contamination. Fruit texture properties are affected by cell turgidity and the structure and composition of the cell wall polysaccharides. Bell pepper softening has been associated with the degradation of the middle lamella of cortical parenchyma cells, resulting in a dramatic increase in pectin solubilisation, having slight changes in pectin molecular weight and showing small decreases in the content of hemicelluloses (Koh and Melton, 2002).

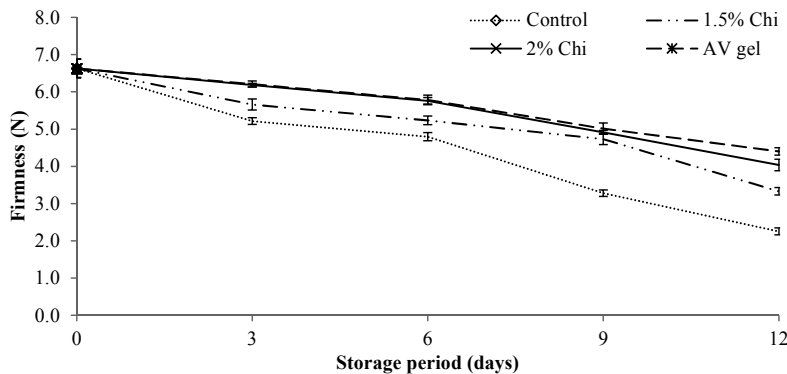


Fig. 3. Firmness of uncoated and edible coated bell peppers throughout the storage period ($25\pm 2^{\circ}\text{C}$ and $55\pm 5\%$ RH). Control=uncoated, 1.5% Chi=1.5% chitosan coated, 2% Chi=2% chitosan coated, AV gel= 100% Aloe vera gel coated. Vertical bars indicate standard deviation.

Fig. 3 represents the changes in flesh firmness of control and coated bell peppers during the storage period at ambient condition ($25\pm 2^{\circ}\text{C}$ and $50 \pm 5\%$ RH). Initially, the firmness value of bell pepper was 6.63 N and it was decreased gradually with time but the rate was different for different treatments. Among the treatment, AV gel coated bell pepper was firmest during the storage period and it lost only 33.63% firmness, whereas uncoated bell pepper had lost almost 66.03% firmness at 12 days after storage period. Chitosan coatings also exerted a beneficial effect on fruit firmness throughout the storage period, especially 2% chitosan coated bell pepper showed more firmness compared to the 1.5% chitosan coated. The beneficial effect of the elevated chitosan concentration on firmness has also been reported for peach, Japanese pear, kiwifruit and strawberry (Hernandez-Munoz *et al.*, 2008).

Weight loss

Fruit weight loss is mainly associated with respiration and moisture evaporation through the skin. The rate of water loss depends on the water pressure gradient among the fruit tissue, the surrounding atmosphere, and the storage temperature. Edible coatings act as barriers, thereby restricting water transfer and protecting fruit skin from mechanical injuries, as well as sealing small wounds and thus delaying dehydration.

Fig. 4 shows the weight loss during storage at $25\pm 2^{\circ}\text{C}$ and $55 \pm 5\%$ RH of uncoated bell peppers compared to fruits coated with chitosan and Aloe vera gel. All samples demonstrated a gradual loss of weight during storage. Throughout storage, the weight loss of uncoated fruit was significantly greater than that of coated fruit. At 12 days after storage, uncoated bell peppers showed 10.61% weight loss, whereas the losses of samples coated with 2% chitosan and Aloe vera gel were 5.85% and 5.89%, respectively. The greater viscosity of chitosan solution results in a coating of greater thickness, further reducing moisture loss. Mohebbi *et al.* (2012) found that at 30 days after storage, Aloe vera and gum tragacanth coated green bell peppers showed 15.44 and 16.15% weight loss at 4°C , respectively, as compared with 26.80 % weight loss in control fruit. Besides, chitosan coatings have been effective in controlling water loss from cucumber and bell pepper (El Ghaouth *et al.*, 1991).

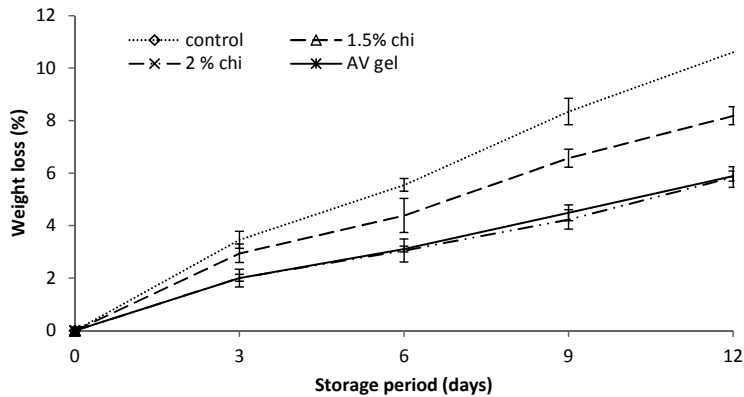


Fig. 4. Weight loss of uncoated and edible coated bell peppers throughout the storage period ($25\pm 2^{\circ}\text{C}$ and $55\pm 5\%$ RH). Control=uncoated, 1.5% Chi=1.5% chitosan coated, 2% Chi=2% chitosan coated, AV gel= 100% Aloe vera gel coated. Vertical bars indicate standard deviation.

External fruit colour

Colour is an important factor in the perception of bell pepper fruit quality. Fig. 5 illustrates the changes in surface colour of bell peppers stored at ambient condition for 12 days, as given by lightness (L^*), hue angle (h) and chroma (c). All the samples showed increasing lightness values with storage time. Initially, harvested bell peppers (<50% red colour) have a turning colour from green to red that is dark to final red colour of bell peppers. So the lightness values were increasing with storage time. The rate of its change was more in control than coated fruits and after 9 days it was decreased little bit and finally reached to 34.53 at 12 days. On the other hand, this value was 35.53 and 35.87 for 2% chitosan and AV gel coated fruits at 12 days after storage (Fig. 5a).

Changes in the chroma value of the bell pepper surface during storage are presented in Fig. 5b. Chroma values increased during storage in all treatments without significant difference as it turns from dull (greenish red) colour to shiny red colour. Initially, chroma value was 15.19 and it was 32.96 and 31.20 in case of AV gel coated and control fruits respectively, at 12 days after storage.

Changes in hue angle of the bell pepper surface during storage are presented in Fig. 5c. The hue angle decrease with storage time as the bell peppers turns from greenish red colour to dark red colour. Initial value of hue angle was 65.24 and at 12 days after storage it was around 30 in all treatments even in control fruits. Hochmuth *et al.* (2004) reported that the range of color values of red bell peppers were lightness (34-37), hue angle ($29-31^{\circ}$) and chroma (37-42). Lim *et al.* (2007) also found the initial value of lightness was 34.4, hue angle was red (28.3°) and chroma (31.7) of red ripe bell pepper. Moreover, 28 days after storage at 10°C temperature, it was changed to lightness was (33.7), hue angle was red (27.8°) and chroma was fairly intense (31.9), respectively.

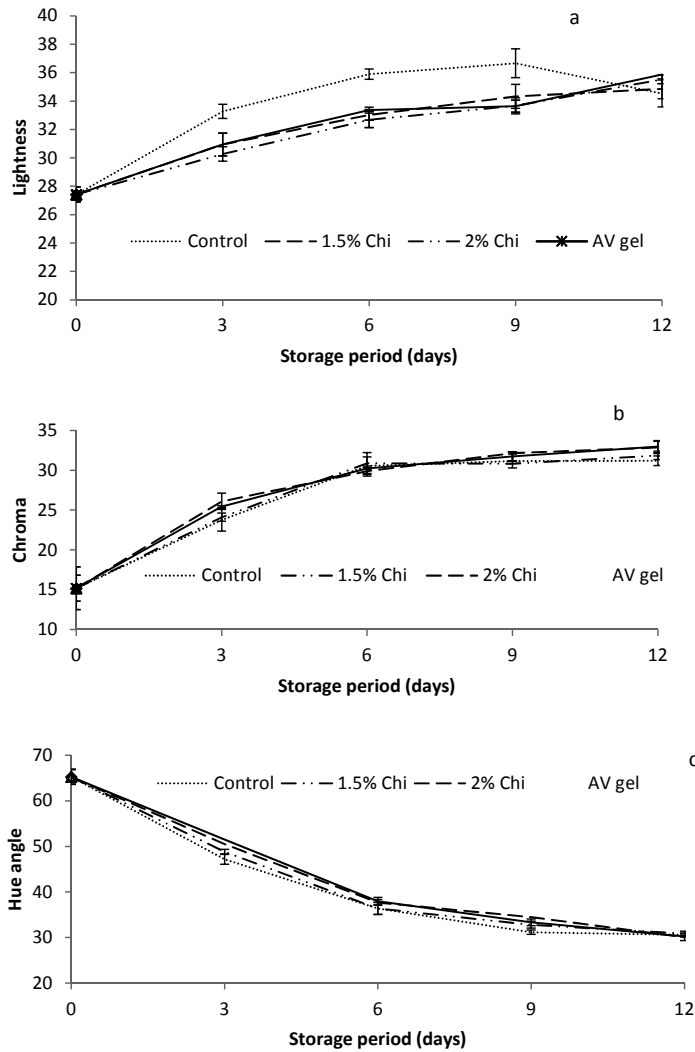


Fig. 5. External colour evolution (a) lightness, (b) chroma and (c) hue angle of uncoated and edible coated bell peppers throughout the storage period ($25\pm 2^\circ\text{C}$ and $55\pm 5\%$ RH). Control=uncoated, 1.5% Chi=1.5% chitosan coated, 2% Chi=2% chitosan coated, AV gel= 100% Aloe vera gel coated. Vertical bars indicate standard deviation.

Microbial incidence

The diseases that appeared on bell pepper were *Botrytis* or grey mold decay, *Alternaria* rot and Bacterial soft rot during storage at ambient condition. The incidence of microbial decay started on 6 days after storage in uncoated/ control fruits (Fig. 6). Fruits coated with 1.5% chitosan affected by microbes at 9 days after storage period. On the other hand, rot incidence was initiated in 2% chitosan and AV gel coated bell peppers at 12 days after storage period.

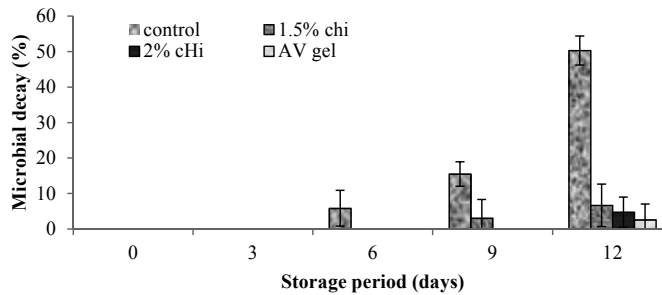


Fig. 6. Microbial decay of uncoated and edible coated bell peppers throughout the storage period ($25\pm 2^{\circ}\text{C}$ and $55\pm 5\%$ RH). Control=uncoated, 1.5% Chi=1.5% chitosan coated, 2% Chi=2% chitosan coated, AV gel= 100% Aloe vera gel coated. Vertical bars indicate standard deviation.

Ascorbic acid, total sugar, TSS, β -Carotene, and pH

Initial ascorbic acid in red ripe bell pepper was 131.17 mg/100g. The coated fruits preserved more ascorbic acid than uncoated one. At 9 days after storage, ascorbic acid content reduced significantly to 113.3 mg/100g in uncoated fruits, while 121 mg/100g in the bell pepper coated with 2% chitosan that is statistically similar with AV gel coated fruits contained 120.33 mg/100g.

Table 1. Effect of edible coating on some chemical parameters of bell peppers throughout the storage period ($25\pm 2^{\circ}\text{C}$ and $55\pm 5\%$ RH)

| Treatment | Ascorbic acid (mg/100g) | | Total sugar (%) | | TSS (%) | | β -Carotene (mg/kg) | | pH | |
|-----------|-------------------------|---------------------|-----------------|------------------|---------|------------------|---------------------------|--------------------|-------|-------------------|
| | 0 day | 9 day | 0 day | 9 day | 0 day | 9 day | 0 day | 9 day | 0 day | 9 day |
| Control | 131.17 | 113.30 ^a | 5.2 | 5.8 ^a | 7.1 | 7.8 ^a | 17.4 | 23.32 ^a | 4.78 | 4.34 ^a |
| 1.5% Chi | 131.17 | 117.24 ^b | 5.2 | 5.5 ^a | 7.1 | 7.5 ^a | 17.4 | 24.87 ^a | 4.78 | 4.52 ^a |
| 2% Chi | 131.17 | 121.67 ^c | 5.2 | 5.5 ^a | 7.1 | 7.6 ^a | 17.4 | 23.78 ^a | 4.78 | 4.4 ^a |
| AV gel | 131.17 | 120.33 ^c | 5.2 | 5.7 ^a | 7.1 | 7.5 ^a | 17.4 | 23.83 ^a | 4.78 | 4.40 ^a |

For each sample, means with different letters within each column are significantly different ($p < 0.05$). Control = uncoated, 1.5% Chi = 1.5% chitosan coated, 2% Chi = 2% chitosan coated, AV gel = 100% Aloe vera gel coated.

Shaha *et al.* (2013) reported that vitamin c content of 3 different variety of red bell pepper was 120.25 to 135.45 mg/100g. Just after harvest, total sugar content in red bell pepper was 5.2% and after ambient storage, it was increased and peaked to 5.8% in control fruits. Jamiołkowska *et al.* (2016) reported that total sugar content of 6 different variety of red bell pepper was ranged from 5.67 to 6.32 g/100g. β -Carotene content in fresh bell pepper was 17.4 mg/kg. At 9 days after storage, β -Carotene content in all treatments was increased significantly. The highest amount of β -Carotene (24.87 mg/kg) was found in 1.5% chitosan coated fruits at 9 days that was statistically similar with that of other treatments. Initial pH and TSS content is 4.78 and 7.1 % respectively. At 9 days of storage, pH decreased slightly and TSS increased. Maximum TSS was found in control fruits as maximum water loss was occurred here. Fox *et al.* (2005) found that variety 'Robusta' showed 29.5 mg/kg β -Carotene, TSS 7.9% and pH 5.0 in red ripe capsicums.

Sensory quality

Sensory data of coated and uncoated bell peppers was taken at 9 days after storage in case of appearance, flavor, texture and overall acceptability. Throughout the storage time, all the fruit showed a loss of sensory quality.

Table 2. Sensory quality of bell pepper at 9 days after storage (25±2°C and 55±5% RH)

| Sensory attributes | samples | 9 days |
|-----------------------|---------------|--------|
| Appearance | control | 4.14c |
| | 1.5% chitosan | 6.09b |
| | 2% chitosan | 7.86a |
| | Aloe Vera gel | 7.77a |
| flavour | control | 4.43c |
| | 1.5% chitosan | 5.91b |
| | 2% chitosan | 7.69a |
| | Aloe Vera gel | 7.58a |
| Texture | control | 4.86c |
| | 1.5% chitosan | 6.86b |
| | 2% chitosan | 8.17a |
| | Aloe Vera gel | 8.29a |
| Overall Acceptability | control | 4.26c |
| | 1.5% chitosan | 6.14b |
| | 2% chitosan | 8.17a |
| | Aloe Vera gel | 8.20a |

For each sample, means with different letters within each column are significantly different ($p < 0.05$). Control = uncoated, 1.5% Chi = 1.5% chitosan coated, 2% Chi = 2% chitosan coated, AV gel = 100% Aloe vera gel coated.

In all sensory attributes, uncoated fruits obtained lowest value but 2% chitosan and AV gel coated fruits obtained the highest score. In case of overall acceptability, control/uncoated bell pepper secured 4.26 (dislike moderately to dislike slightly) scores, while the highest 8.20 (like very much to like extremely) score were obtained by the bell pepper coated with AV gel that was statistically similar with the value of 2% chitosan coated ones.

Conclusion

Edible coated bell peppers had respiration and ethylene production rate and preserved their moisture, firmness, fresh like appearance and overall acceptability for more days than uncoated. Fungal decay was initiated at 6 days after storage in uncoated or control fruits whereas, it was shown in AV gel or 2% chitosan coated bell peppers at 12 days in ambient storage.

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