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Aloe vera and ascorbic acid coatings maintain postharvest quality and reduce microbial load of strawberry fruit

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ABSTRACT

Rapid loss of quality and decay causes economic loss of strawberries after harvest. The effects of an edible coating based on natural *Aloe vera* (AV) gel in combination with ascorbic acid (AA; 0, 1, 3 and 5% (w/v)) on postharvest quality of strawberries was studied. After treatment, fruit weight loss, firmness, titratable acidity, soluble solids content (SSC), pH value, concentrations of ascorbic acid, anthocyanin and total phenolics, total antioxidant activity, and microbial activity were evaluated at 0, 3, 6, 9, 12, 15 and 18 days of storage (1 °C, 95% relative humidity). Compared with untreated fruit, AV + AA treatments delayed weight loss, had higher SSC, vitamin C concentrations and titratable acidity. The coatings reduced total aerobic mesophilic, yeasts and molds populations. AV + 5% AA was the most effective in delaying changes in the ripening and reducing microbial populations among the treatments. These results demonstrate that AV and AA coatings have potential to maintain postharvest fruit quality of strawberry fruit.

1. Introduction

Strawberries (*Fragaria X ananassa* Duch.), one of the most popular summer fruit worldwide, are characterized by unique and highly desirable taste and flavor, and are rich in polyphenols and anthocyanin, vitamins and amino acids (Campaniello et al., 2008). However, the fruit are highly perishable resulting in a short postharvest life due to mechanical injury, physiological deterioration, water loss, fungal decay and high respiration rate (Perkin-Veazie, 1995; Vargas et al., 2006). Cold temperatures and modified atmospheres increase the storage life of fruit (Martinez-Romero et al., 2003), but additional methods of maintaining quality are still under investigation.

Recently, applications of edible coatings have been shown to be promising as a tool to improve the quality and extend storage and shelf life of various fruit such as papaya (Tapia et al., 2008) and strawberries (Vargas et al., 2006). Coatings can act as moisture and gas semi-permeable barriers, resulting in control of microbial growth, preservation of color and texture (Bourtoom, 2008). One such product is *Aloe vera* (AV), a novel edible coating for fruit storage (Serrano et al., 2006; Valverde et al., 2005). AV has antifungal activity against several pathogenic fungi including *Botrytis cinerea* (De Rodrıguez et al., 2005). AV coatings modify the internal gas atmosphere, reduce moisture loss, softening, respiration rates, delay oxidative browning and reduce microorganism proliferation in fruit such as sweet cherries, table grapes, nectarines and papaya (Ahmed et al., 2009; Marpudi et al., 2011; Martínez-Romero et al., 2006; Valverde et al., 2005). AV coating alone or in combination with shellac, preserves physicochemical parameters such as color and firmness in apple slices (Chauhan et al., 2011).

Ascorbic acid (AA) and its derivatives have been used in numerous studies in fruit in concentrations ranging from 0.5 to 4% (w/v). Anti-browning effects of AA have been demonstrated in several fruit fresh-cut products under a wide range of conditions (Gil et al., 1998; Tapia et al., 2008). In addition, AA as an antioxidant that reduces vitamin C lost can be added to the edible coating material. Some studies (Tajkarimi and Ibrahim, 2011) have suggested that AA in combination with lactic acid has antimicrobial effects against *Listeria monocytogenes* and on *Escherichia coli* O157:H7 in carrot juice. Antimicrobial effects of AA on fresh cut fruit such as jackfruit (Acedo et al., 2012), apple (Perez-Gago et al., 2006; Qi et al., 2011) and papaya (Tapia et al., 2008) have been reported.

The objective of this study was to evaluate the use of AV as an edible coating for strawberries in combination with AA on quality

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and microbial characteristic of fresh strawberry fruit during storage.

2. Materials and methods

2.1. Plant material

Strawberry (*Fragaria X anannasa* Duch.), cv. 'Parous', was harvested from commercial farm located near Kurdistan University, Sanandaj, Iran. The maturity stage of the fruit was 80% red color on the fruit surface. Fruit were selected for uniformity in size, shape and color without signs of mechanical damage, blemishes and disease, and divided randomly into 93 replicates of 10 fruit. Three replicates were sampled immediately to assess fruit characteristics at harvest (day 0). The replicates were then divided into 5 treatment groups of 18 (3 replicates each at each of 6 storage periods).

2.2. A. vera *(AV) gel preparation*

Mature leaves of *A. vera* plants were obtained from a commercial greenhouse and washed with a mild chlorine solution of 0.03% (v/v). The AV matrix was then separated from the outer cortex of leave and the colorless hydroparenchyma was uniformly mixed in a blender. The resulting mixture was filtered to remove the fibers, and constituted fresh AV.

2.3. Coating and storage conditions

Fruit was dipped at 20 °C for 5 min in AV diluted 1:3 with distilled water (Hassanpour, 2015; Shahkoomahally and Rameza-nian, 2014) in combination with 0, 1, 3 or 5% AA, or distilled water as untreated (control). Following all fruit were air-dried at room temperature for 1 h, then placed in polystyrene box (each a 10 fruit replicate) and stored at 1 °C with 95% relative humidity. Fruit were sampled at 3, 6, 9, 12, 15 and 18 days of storage.

2.4. Weight loss (WL)

The fruit weight of each replicate was recorded on the day of treatment and at each sampling time. Cumulative weight loss was expressed as percentage loss of the original fresh weight.

2.5. Firmness

Firmness was evaluated using a texture analyzer (Santam, STM-1), fitted with an 8 mm probe with constant speed of 20 mm min^{-1}. Two different measurements were carried out on two opposite side of central zone of berries in each replicate. Values were expressed as newton (N).

2.6. Titratable acidity (TA), soluble solid concentration (SSC) and pH

A bulked sample of all fruit with 1/8th of each fruit per replicate juiced together and used for vitamin C, TA, SSC and pH measurements. For TA, aliquots of 10 mL were titrated to pH 8.1 with 0.1 N NaOH and expressed as % citric acid. The juice was also used to measure SSC using an Atago Digital Refractometer (Brix 0–32%, Atago, Japan). The pH of fruit juice was measured using a pH meter (Metrohm, 827).

2.7. Vitamin C assay

Vitamin C content was determined by titration with 2,6-dichlorophenolindophenol (DCPIP) (AOAC, 2000), using different AA concentrations for the standard curve, and expressed as mg kg^{-1} of vitamin by fresh weight.

2.8. Total anthocyanin and total phenolic (TP) concentrations

After firmness evaluation, a bulked sample of all fruit with 1/8th of each fruit per replicate were removed, immediately frozen in liquid nitrogen, and stored at −80 °C until used for extraction and analysis of the total anthocyanin, TP concentration and antioxidant activity.

Total anthocyanin concentrations (TAC) were determined using the pH differential method of Cheng and Breen (1991). Absorbance was measured with spectrophotometer (UV-2100, New Jersey) at 520 nm and 700 nm in buffers at pH 1.0 and 4.5. Results were expressed as mg kg^{-1} of pelargonidin-3-glucoside on a fresh weight basis. The absorbance difference between the buffer systems was calculated according to the Eq. (1):

$$A = (A520 - A700\text{nm})\text{pH } 1.0 - (A520 - A700\text{ nm})\text{pH } 4.5 \quad (1)$$

Then, the concentration of total anthocyanin was calculated according to the Eq. (2):

$$\text{TAC}\left(\text{mg L}^{-1}\right) = \frac{A \times MW \times DF \times 1000}{\varepsilon} \quad (2)$$

MW: molecular weight of the pelargonidin 3-glucoside = 433.39 g mol^{-1}.

DF: dilution factor = 10.

ε: coefficient of molar absorptivity = 15,600.

TP concentrations were measured by homogenizing 1 g of frozen tissue from each replicate with 3 mL ice cold 1% HCl–methanol solution and then centrifuged at 4 °C for 15 min at 12,000 × *g*. The supernatant was collected and used for phenol determination. TP concentration in the extracts were determined according to the Folin–Ciocalteu procedure (Orthofer and Lamuela-Raventos, 1999), using gallic acid for the standard curve. Results were expressed as mg kg^{-1} of gallic acid on a fresh weight basis.

2.9. Total antioxidant activity (TAA)

Antioxidant activity was determined by the 2,2-diphenyl-1-picryl-hidrazil (DPPH) radical-scavenging method according to Sanchez-Moreno et al. (1999). The absorbance was measured at 517 nm, using a spectrophotometer (UV-2100). Total antioxidant activity was expressed as the percentage inhibition of the DPPH radical and was determined using the following equation:

$$\text{TAA}(\%) = \frac{\text{Abs}_{\text{sample}} - \text{Abs}_{\text{control}}}{\text{Abs}_{\text{sample}}} \times 100$$

2.10. Microbiological evaluations

Fruit (1/8th of each fruit) per replicate were homogenized and diluted with sterile peptone water to obtain the microbial count. Serial dilutions were performed in triplicate. Total aerobic mesophilic bacteria counts were enumerated using the pour plate method on the plate count agar (PCA, Scharlau Chemie, S.A., Barcelona, Spain) after incubation at 30 °C for 2 days. Total yeasts and molds were enumerated using the surface plate method on potato dextrose agar (PDA, Scharlau Chemie, SA., Barcelona, Spain). Incubation for total yeast and mold counts was performed at 25 °C for 2 days. Each test was performed in duplicate and results were expressed as colony-forming units (CFU) per mL (Emamifar et al., 2010).