PAPER

EFFECT OF GELATIN-BASED EDIBLE COATINGS INCORPORATED WITH *ALOE VERA* AND GREEN TEA EXTRACTS ON THE SHELF-LIFE OF FRESH-CUT APPLE

S. AMIRI[1,2], H.R. AKHAVAN[3,4], N. ZARE[2] and M. RADI*[1,2]

[1]Young Researchers and Elite Club, Yasooj Branch, Islamic Azad University, Yasooj, Iran

[2]Department of Food Science and Technology, Yasooj Branch, Islamic Azad University, Yasooj, Iran

[3]Department of Food Science and Technology, Faculty of Agriculture, Shahid Bahonar University of Kerman, Kerman, Iran

[4]Research and Technology Institute of Plant Production (RTIPP), Shahid Bahonar University of Kerman, Kerman, Iran

*Corresponding author. Tel.: + 98 9177007984

E-mail address: s.amiri@iauyasooj.ac.ir

ABSTRACT

The objective of the present study was to evaluate the combined effect of edible coatings (gelatin, citric acid, ascorbic acid, and calcium chloride) incorporated with *Aloe vera* (50, 100, and 150%) and green tea (5, 10, and 15%) extracts on physicochemical, microbial, and sensorial properties of fresh-cut apples at 4ºC for 16 days. Significant differences in terms of quality parameters were observed between the control and coated apple slices. The highest variation in quality parameters was observed in the control, while the least variations were observed in coated slices with 150% *Aloe vera*. Also, the softening trend was slowed down by edible coatings. Furthermore, in basic coatings, the microbial growth inhibition was a function of the *Aloe vera* and green tea extract concentrations. Generally, the higher concentrations of *Aloe vera* and green tea extracts were found to maintain the quality parameters of apple slices for a longer time during the storage period.

Keywords: apple slice, edible coating, *Aloe vera*, green tea extract

1. INTRODUCTION

In order to preserve freshness and to control spoilage and pathogenic bacteria growth, it is recommended to use edible coatings on fresh-cut fruit to extend their shelf life. For this purpose, natural polysaccharides, proteins, and antioxidants are used as raw materials for edible coatings and films (DHALL, 2013). Edible coatings can also be used as carriers of antimicrobials, antioxidants, anti-browning, flavouring, and colouring agents that improve the nutritional, sensorial, and microbiological properties of fresh-cut fruit (OMS-OLIU *et al*., 2010; VALENCIA-CHAMORRO *et al*., 2011). A dip treatment of fresh-cut fruit in organic acids (such as citric acid and ascorbic acids) and calcium salts as an alternative to sulphites were used to prevent enzymatic browning after fruits peeling and/or cutting (OMS-OLIU *et al*., 2010). Also, calcium treatments can maintain or improve the tissue firmness and crispness (OMS-OLIU *et al*., 2010). In this regards, edible coatings containing *Aloe vera* and green tea extracts are well documented in the literature. *Aloe vera* gel and gelatin have been used as edible coatings in fruit storage technology (ANDRADE *et al*., 2014; DANG *et al*., 2008). The barrier properties of Aloe gel coatings towards respiratory gases (CHAUHAN *et al*., 2011), as well as its antimicrobial functions (MARTÍNEZ-ROMERO *et al*., 2006) in coated fruit and fresh-cut fruit are reported. Besides, gelatin coatings show good barrier characteristics against oxygen and aroma transfers at low and intermediate relative humidity. However, gelatin has poor barrier properties against water vapour transfer due to its hydrophilic nature (ANDRADE *et al*., 2014). In recent years, the *Aloe vera* gel has been used as an edible coating for sweet cherries (MARTÍNEZ-ROMERO *et al*., 2006), mangoes (DANG *et al*., 2008), apples (CHAUHAN *et al*., 2011; SONG *et al*., 2013), papayas (MARPUDI *et al*., 2011), fresh-cut kiwifruit (BENÍTEZ *et al*., 2015; BENÍTEZ *et al*., 2013), and fresh-cut orange (RADI *et al*., 2017). Besides, the effect of *Aloe vera* coating, containing anti-browning solution, on apples slices (SONG *et al*., 2013) has been published in literature.

Furthermore, tea (*Camellia sinensis*), is a good source of polyphenolic compounds, which have strong antioxidant properties. The high antioxidant capacity and overall antimicrobial activity of green tea have been attributed to catechins and their oxidized condensation products (MARTÍN-DIANA *et al*., 2008; MATAN *et al*., 2015). Coating with gelatin incorporated with green tea extract successfully retarded the microbial growth and therefore extended the shelf life of fresh-cut orange during cold storage (RADI et al., 2017). Such properties made us use green tea as our coating alternative.

The aim of the present study was to investigate the combined effects of edible coatings containing gelatin, calcium chloride, ascorbic acid, and citric acid as well as various concentrations of *Aloe vera* and green tea extracts on physicochemical and microbial characteristics of fresh-cut apples during storage.

2. MATERIALS AND METHODS

2.1. Materials

Gelatin, sodium hydroxide, calcium chloride, citric acid, ascorbic acid, and plate count agars (PCA) were purchased from Merck (Darmstadt, Germany). *Aloe vera* leaves and green tea were purchased from a local wholesale market (Yasooj, Iran). Red apples (*Red Delicious*) grown at Semirom Orchard (Isfahan, Iran) were freshly harvested at a commercially mature stage, sorted to eliminate the damaged ones, and selected for uniform size and colour.

2.2. Preparation of the film-forming solutions for coating the apple slices

Aloe vera extract was obtained from fresh *Aloe vera* leaves according to the method described by NAVARRO *et al*. (2011). The extract was used intact (for *Aloe vera* 100% treatment) or was diluted 50:50 with distilled water (for *Aloe vera* 50% treatment). Moreover, the *Aloe vera* gel was concentrated to 150% using a rotary evaporator (Heidolph, Germany) at 45°C. Moreover, green tea extract was prepared, based on the SIRIPATRAWAN and HARTE (2010) method. The total solid content (TSC) of tea extract was determined by the air oven method at 105°C. According to the TSC of tea, the final concentration of extracts was adjusted at 5, 10, and 15% TSC using a Rotary evaporator (Heidolph, Germany) at 45°C. Gelatin powder was dissolved in distilled water or concentrated-adjusted *Aloe vera* and tea extracts by stirring and heating to 50°C under nitrogen gas atmosphere to form 1% gelatin solution.
The following coating solutions were assigned: (A) basic formula 1 (BF1): gelatin (1%), citric acid (0.1%), and calcium chloride (0.5%); (B) basic formula 2 (BF2): gelatin (1.0%), citric acid (0.1%), calcium chloride (0.5%), and ascorbic acid (0.5%); (C) the basic formula 1 and 2 with *Aloe vera* extract at three levels (50, 100, and 150%) that was abbreviated as BF1 or BF2+50, 100, and 150% Aloe; (D) the basic formula 1 and 2 with green tea extract at three levels (5, 10, and 15%) that was abbreviated as BF1 or BF2+5, 10, and 15% GT; and (E) coated with water which served as control.

2.3. Coating the apple slices

Apples of uniform size and shape, and without any signs of mechanical damage, were selected, washed with chlorinated water (50 mg Cl_2/kg H_2O) and manually sliced in chilled water (5–6°C). Apple slices were dipped in the above-mentioned coating solutions for 1 min. and then drained for 30 min. The prepared apple slices were placed in polyethylene terephthalate (PET) clamshells (140 × 128 × 30 mm^3) (Pars Plastic Khuzestan, Ahwaz, Iran), and stored at 4°C for 16 days.

2.4. Measurement of titratable acidity (TA) and total soluble solids (TSS)

The apple slices were homogenized in a blender (Moulinex, Barcelona, Spain) and centrifuged at 2000 rpm for 1 min. to obtain a clear juice. The titratable acidity and total soluble solid of clear juice were measured (RADI *et al*., 2010).

2.5. Weight loss determination

The weight loss in the samples was calculated as loss in weight of the apple slices in each container during storage and the values were reported on a percentage basis (RADI *et al*., 2010).

2.6. Firmness measurement

The firmness of the apple slices was measured using a Texture Analyzer (CT3, Brookfield Engineering Laboratories, Stoughton, MA, USA) with a uniaxial penetration test. A stainless steel flat-end probe of 4 mm diameter was used to evaluate the firmness of the apple slices. The test conditions used for the measurement were pre-test speed 2mm/s; test speed 1 mm/s; post-test speed 10 mm/s; penetrating distance of 10 mm into the fruit, and a trigger force of 5 g (BENÍTEZ *et al*., 2013).

2.7. Measurement of colour

The surface colour of the samples was measured using a Hunter colorimeter (Colorflex, Virginia, USA). Hunter CIE L* for lightness, a* for redness, and b* for yellowness were determined (RADI *et al*., 2017).

2.7. Microbiological evaluation

The microbiological analysis of the apple slices was carried out for standard plate counts in accordance with CHAUHAN *et al*. (2011) procedures. The results were expressed as log CFU/g of sample.

2.8. Sensory analysis

Sensory evaluation was performed immediately after the apple slices were prepared at storage times of 0, 8, and 16 days. Twelve panellists were asked about the different quality attributes (colour, aroma and flavour, texture or firmness, and overall acceptance) of the apple slices using a scale with anchors at 0 and 5 as follows: colour, ranging from dark (0) to colour normal (5); aroma and flavour of apple, from weak (0) to strong (5), texture from soft (0) to hard (5). A final, overall preference test was also performed with a hedonic scale from dislike extremely (0) to like extremely (5). Scores from 2.5 to 5 were considered acceptable.

2.9. Statistical analysis

All the experiments were run in triplicate. Statistics on a completely randomized design were performed with the analysis of variance (ANOVA) procedure in SAS (Release 9.1, SAS Institute Inc., Cary, NC) software and mean comparisons were carried out by Duncan's multiple range test ($p<0.05$).

3. RESULTS AND DISCUSSIONS

3.1. Titratable acidity (TA) and total soluble solids (TSS)

The effects of coating treatments on the TA and TSS parameters during cold storage are shown in Tables 1 and 2. The TA levels in the control and coated samples gradually decreased during the storage period, and the difference was significant in the control sample only on day 16. But, the decreasing trends of TA in coated samples were not significant during the storage period (data not shown for apple slices coated with BF1 and BF2 containing *Aloe vera* and green tea extracts).
A further reduction of acidity in the control sample in comparison with trehalose/NaCl/sucrose-coated apple slices on the eighth day (ALBANESE *et al*., 2007) and gel-coated apple slices with cysteine, citric acid, ascorbic acid, and *Aloe vera* during the 16th day (SONG *et al*., 2013) were also reported. This phenomenon was linked to the malic acid decrease due to an increase in the respiration rate following peeling and cutting (ALBANESE *et al*., 2007). The higher acidity of coated apple slices could be attributed to the barrier properties of Aloe gel coatings towards respiratory gases (CHAUHAN *et al*., 2011; RADI *et al*., 2017). It seems that during storage, organic acids are used as substrates in respiration metabolism, thereby decreasing the TA and increasing the TSS (BENÍTEZ *et al*., 2013).

Table 1. Titratable acidity changes in the control and coated apple slices with basic formulas (BF1 and BF2) during the 16 days of storage at 4°C.

Treatment	Storage time (day)				
	0	4	8	12	16
Control	0.37±0.02Aa*	0.35±0.03Aa	0.34±0.03Aa	0.35±0.03Aa	0.27±0.02Bb
BF1	0.37±0.05Aa	0.36±0.02Aa	0.33±0.04Aa	0.31±0.01Aa	0.31±0.03Aa
BF2	0.34±0.04Aa	0.38±0.05Aa	0.35±0.03Aa	0.35±0.03Aa	0.32±0.02Aa

*Mean ± standard deviation (n = 3); Means followed by the different small letter within the same row or by the different capital letter within the same column are statistically different ($p<0.05$).

Table 2. TSS changes in the control and coated apple slices with basic formulas (BF1 and BF2) incorporated *Aloe vera* and green tea extracts during the 16 days of storage at 4°C.

Group	Treatment	Storage time (day)				
		0	4	8	12	16
1	Control	16.03±0.02Ae*	16.08±0.01Ad	16.18±0.02Ac	16.31±0.02Ab	16.36±0.02Aa
	BF1	16.01±0.02Ad	16.03±0.01Bd	16.08±0.02Bc	16.17±0.02Bb	16.22±0.02Ba
	BF2	16.02±0.01Ad	16.02±0.02Bd	16.08±0.01Bc	16.15±0.02Bb	16.23±0.02Ba
2	BF1	16.01±0.02Ad	16.03±0.01Ad	16.08±0.02Ac	16.17±0.02Ab	16.22±0.02Aa
	BF1+50% Aloe	16.01±0.01Ae	16.04±0.01Ad	16.07±0.02Ac	16.15±0.02Ab	16.23±0.02ABa
	BF1+100% Aloe	16.02±0.01Ad	16.04±0.01Ad	16.06±0.01Ac	16.13±0.01Bb	16.19±0.02BCa
	BF1+150% Aloe	16.02±0.02Ad	16.03±0.02Ad	16.05±0.01Ac	16.11±0.01Cb	16.17±0.02Ca
3	BF2	16.02±0.01Ad	16.02±0.02Ad	16.08±0.01ABc	16.15±0.02ABb	16.23±0.02Aa
	BF2+50% Aloe	16.02±0.01Ad	16.03±0.02Ad	16.09±0.02Ac	16.16±0.02Ab	16.20±0.01Aa
	BF2+100% Aloe	16.01±0.01Ad	16.03±0.01Ad	16.06±0.02Bc	16.13±0.01BCb	16.18±0.02Ba
	BF2+150% Aloe	16.01±0.01Ae	16.04±0.01Ad	16.05±0.01Bc	16.11±0.02Cb	16.15±0.01Ca
4	BF1	16.01±0.02Ad	16.03±0.01Ad	16.08±0.02Ac	16.17±0.02Ab	16.22±0.02Aa
	BF1+5% GT	15.99±0.02Ae	16.03±0.02Ad	16.08±0.02Ac	16.18±0.01Ab	16.21±0.01ABa
	BF1+10% GT	16.02±0.01Ad	16.04±0.01Ad	16.07±0.02ABc	16.16±0.02ABb	16.20±0.02ABa
	BF1+15% GT	16.00±0.05Ad	16.02±0.01Adc	16.05±0.01Bc	16.14±0.02Bb	16.19±0.01Aa
5	BF2	16.02±0.01Ad	16.02±0.02Ad	16.08±0.01ABc	16.15±0.02ABb	16.23±0.02Aa
	BF2+5% GT	15.99±0.02Ae	16.03±0.01Ad	16.08±0.01Ac	16.15±0.02Ab	16.20±0.01Ba
	BF2+10% GT	15.98±0.03Ad	16.03±0.02Ac	16.06±0.01Bc	16.13±0.02Ab	16.18±0.01Ca
	BF2+15% GT	15.99±0.03Ad	16.01±0.01Ad	16.05±0.02Bc	16.12±0.02Ab	16.18±0.01Ca

*Mean ± standard deviation (n = 3); Means followed by the different small letter within the same row or by the different capital letter within the same column of each group are statistically different ($p<0.05$).

The TSS of the control and coated samples significantly increased with storage time, while the coated samples showed a slight increase compared to the control sample (Table 2). In this regard, there was a significant difference between the control and the coated samples with the basic formulas (BF1 and BF2 without *Aloe vera* and green tea extracts) only after four days of storage. But, no difference was observed between the BF1 and BF2, which indicated the same effect of BF1 and BF2 treatments on apple slices during storage time.
Increasing the concentration of *Aloe vera* and green tea extracts in the basic formulas (BF1 and BF2) increased the TSS significantly only after eight days of storage, and especially at

the end of the storage period. Furthermore, no significant differences were found between BF1+Aloe and BF2+Aloe treatments in similar concentrations of the *Aloe vera* extract (50, 100, and 150%). Without considering the BF1 and BF2 coatings, samples coated with higher concentrations of *Aloe vera* and green tea extracts showed a lower increase in TSS at the end of the storage periods. The highest increase of TSS was observed in the control (~ 2.5%, TSS increased from 16.0 to 16.4 after 16 days of storage at 4°C), while the lowest increase was observed in samples coated with BF2+150% Aloe (~ 1.3%, TSS increased from 16.0 to 16.2).

The findings of this study were similar to the results of AHMED *et al*. (2009), MARPUDI *et al*. (2011), and RADI *et al*. (2017), who reported that TA decreased and TSS increased with increasing storage time in nectarines, papaya and fresh-cut orange, respectively. During ripening, organic acids are used as substrates in respiration metabolism, thereby resulting in an increase in TA and decrease in TSS. In general, it seems that the total soluble solid content tends to increase over the storage period as a consequence of the ripening process (BENÍTEZ *et al*., 2013). A reduction in the respiration rate has been observed in sweet cherries (MARTÍNEZ-ROMERO *et al*., 2006) and kiwifruits (BENÍTEZ *et al*., 2013) coated with *Aloe vera* gel.

Furthermore, softening occurs primarily because of an enzymatic degradation (pectin methylesterase and polygalacturonase) of the cell wall, which is mainly composed of cellulose, hemicelluloses, and pectins (OMS-OLIU *et al*., 2010). This may affect some physicochemical characteristics such as pH, TA, TSS, etc., of fresh-cut fruit. In this regard, the increasing trend of TSS in apple slices can be attributed to the softening and may, therefore, be associated with ripening (BENÍTEZ *et al*., 2013).

3.2. Weight loss

The weight loss is mainly associated with moisture evaporation through the surface of fruit slices (OLIVAS *et al*., 2007). All samples demonstrated a gradual weight loss during storage (Table 3). The weight loss of uncoated fruit (25.10 %) was significantly greater than those of coated fruits during storage time. The weight loss of apple slices coated with BF1 and BF2 treatments was significantly lower than the control ($p<0.05$). In this regard, no significant difference was observed between BF1 and BF2 treatments until the eighth day, but the difference was significant on the 12th and the 16th days, and also the weight loss of BF1was significantly lower than BF2 at the end of the storage time.

The least rate of weight loss (11.18 % and 11.52 %) was observed, respectively, in the samples coated with BF1+150% Aloe and BF2+150% Aloe treatments. Consequently, the weight loss of apple slices coated with BF+Aloe was significantly lower than other samples ($p<0.05$). Accordingly, the BF+Aloe coating was more effective than the BF+Green tea coatings. In the case of BF+15% GT weight loss was ~18.5%. Furthermore, weight loss of samples coated with both basic coatings (BF1 and BF2) containing 150% Aloe and 15% GT was significantly lower than of those coated with a lower level of extracts at the end of the storage periods.

Similar results were obtained by SONG *et al*. (2013) and RDAI *et al*. (2017). These authors reported that the weight loss increased during storage, but the weight loss of the *Aloe vera* gel-coated apple slices was significantly ($p<0.05$) reduced compared to the control during storage. The binding of *Aloe vera* gel molecules to the surface of apple slices may have reduced the porosity of apple slices, resulting in lower water loss (SONG *et al*., 2013). It is reported that *Aloe vera* gel reduces the respiration rate, ethylene production, weight loss and, therefore, the softening of fresh-cut fruit textures (BENÍTEZ *et al*., 2013).

Table 3. Weight loss changes in the control and coated apple slices with basic formulas (BF1 and BF2) incorporated *Aloe vera* and green tea extracts during the 16 days of storage at 4°C.

Group	Treatment	Storage time (day)				
		0	4	8	12	16
1	Control	0.5±0.2Ae*	12.13±0.26Ad	19.68±0.14Ac	23.32±0.26Ab	25.10±0.37Aa
	BF1	0.3±0.1Ae	8.34±0.36Bd	12.19±0.29Bc	16.5±0.7Bb	18.41±0.19Ba
	BF2	0.3±0.2Ae	7.7±0.43 Bd	12.63±0.23Bc	15.59±0.26Cb	19.55±0.3Ca
2	BF1	0.3±0.1Ae	8.34±0.36Ad	12.19±0.29Ac	16.5±0.7Ab	18.41±0.19Aa
	BF1+50% Aloe	0.43±0.15Ae	7.9±0.58ABd	11.69±0.17Ac	14.90±0.28Bb	17.20±0.2Ba
	BF1+100% Aloe	0.23±0.15Ae	7.23±0.32Bd	10.3±0.35Bc	13.09±0.24Cb	15.41±0.2Ca
	BF1+150% Aloe	0.2±0.10Ae	6.2±0.2Cd	8.15±0.39Cc	9.50±0.22Db	11.18±0.19Da
3	BF2	0.3±0.2Ae	7.7±0.43Ad	12.63±0.23Ac	15.59±0.26Ab	19.55±0.3Aa
	BF2+50% Aloe	0.27±0.15Ae	7.78±0.14Ad	12.40±0.25Ac	14.59±0.27Bb	17.51±0.29Ba
	BF2+100% Aloe	0.23±0.15Ae	7.24±0.39Ad	10.69±0.17Bc	12.50±0.17Cb	15.51±0.34Ca
	BF2+150% Aloe	0.37±0.21Ae	5.99±0.32Bd	8.72±0.21Cc	10.20±0.17Db	11.52±0.23Da
4	BF1	0.3±0.1Ae	8.34±0.36BCd	12.19±29Bc	16.5±0.7Ab	18.41±0.19Aa
	BF1+5% GT	0.27±0.15Ae	8.10±0.14Cd	11.72±0.20Cc	14.87±0.21Bb	17.23±0.25Ba
	BF1+10% GT	0.37±0.15Ae	8.84±0.33ABd	11.81±0.25BCc	13.27±0.36Cb	17.50±0.32Ba
	BF1+15% GT	0.17±0.12Ae	9.2±0.36Ad	12.68±0.18Ac	14.70±0.23Bb	18.4±0.22Aa
5	BF2	0.3±0.2Ae	7.7±0.43Bd	12.63±0.23Bc	15.59±0.26Bb	19.55±0.3Aa
	BF2+5% GT	0.23±0.15Ae	10.09±0.29Ad	12.19±0.4Bc	14.56±0.21Cb	17.51±0.40Ca
	BF2+10% GT	0.17±0.12Ae	9.65±0.34Ad	12.69±0.18Bc	15.84±0.24ABb	18.11±0.21Ba
	BF2+15% GT	0.27±0.15Ae	9.81±0.28Ad	13.31±0.28Ac	16.09±0.24Ab	18.50±0.20Ba

*Mean ± standard deviation (n = 3); Means followed by the different small letter within the same row or by the different capital letter within the same column of each group are statistically different ($p<0.05$).

3.3. Texture evaluation

The texture degradation and softening trend continued through the storage time, but its rate was slowed down by the BF1 and BF2 coating compared to the control sample (Table 4).

The maximum firmness was observed in BF1+150% Aloe (firmness decreased from 10.51 to 9.82 N after 16 days of storage at 4°C), while the least firmness was observed in control (firmness decreased from 10.44 to 5.62 N after 16 days of storage at 4°C). In addition, similar concentrations of *Aloe vera* (50, 100, and 150%) and green tea (5, 10, and 15%) extracts used in the BF1 and BF2 coatings had no significant effect on firmness, which indicated the same effects of BF coatings on apple slices during storage. Regardless of the BF1 and BF2 coatings, samples coated with the higher concentration of *Aloe vera* and green tea extracts had higher firmness. There was also no significant difference between coated samples with green tea and *Aloe vera* extracts.

The lower firmness of the control sample than the coated samples was probably due to the growth of spoilage microorganisms in the sliced apple, but which was limited in coated samples due to the antimicrobial properties of *Aloe vera* and green tea extracts (BENÍTEZ *et al*., 2013; MATAN *et al*., 2015). Softening occurred primarily due to the enzymatic degradation (pectin methylesterase and polygalacturonase) of the cell wall. Calcium is reported to maintain firmness by cross-linking with pectins to form insoluble calcium pectates, which strengthen the structure of the cell wall (OMS-OLIU *et al*., 2010). In this

regard, the fresh-cut apples, treated with calcium, showed no significant differences throughout the three weeks of storage (ALANDES *et al*., 2006).

Table 4. Apple slices firmness changes (N) in the control and coated apple slices with basic formulas (BF1 and BF2) incorporated *Aloe vera* and green tea extracts during the 16 days of storage at 4°C.

Group	Treatment	Storage time (day)				
		0	4	8	12	16
1	Control	10.44±0.25Aa*	8.70±0.13Cb	6.34±0.18Cc	6.02±0.08Bd	5.62±0.11Be
	BF1	10.48±0.24Ab	10.88±0.09Aa	9.68±0.20Ac	9.13±0.08Ad	8.87±0.06Ad
	BF2	10.24±0.08Aa	10.23±0.06Ba	9.33±0.11Bb	9.10±0.07Ac	8.86±0.11Ad
2	BF1	10.48±0.24Ab	10.88±0.09Aa	9.68±0.20Bc	9.13±0.08Cd	8.87±0.06Cd
	BF1+50% Aloe	10.43±0.09Aa	10.50±0.12Ba	9.91±0.08ABb	9.52±0.11Bc	8.98±0.08Cd
	BF1+100% Aloe	10.34±0.11Aa	10.26±0.06Ca	9.96±0.06Ab	9.73±0.09Ac	9.25±0.11Bd
	BF1+150% Aloe	10.51±0.13Aa	10.41±0.08BCa	10.05±0.10Ab	9.86±0.06Ac	9.82±0.10Ac
3	BF2	10.24±0.08Ca	10.23±0.06Ba	9.33±0.11Cb	9.10±0.07Cc	8.86±0.11Cd
	BF2+50% Aloe	10.35±0.13BCa	10.16±0.05Bb	9.87±0.08Bc	9.45±0.10Bd	9.09±0.14BCe
	BF2+100% Aloe	10.52±0.09ABa	10.27±0.09ABb	10.06±0.09Ab	9.71±0.17Ac	9.32±0.12ABd
	BF2+150% Aloe	10.55±0.08Aa	10.43±0.12Aa	10.04±0.07Ab	9.87±0.06Ab	9.47±0.14Ac
4	BF1	10.48±0.24Ab	10.88±0.09Aa	9.68±0.20Bc	9.13±0.08Cd	8.87±0.06Dd
	BF1+5% GT	10.27±0.08Aa	10.21±0.02Ba	9.99±0.04Ab	9.46±0.12Bc	9.05±0.10Cd
	BF1+10% GT	10.34±0.14Aa	10.22±0.04Bab	10.03±0.15Ab	9.63±0.12Bc	9.23±0.08Bd
	BF1+15% GT	10.47±0.03Aa	10.34±0.03Ba	10.13±0.06Ab	9.83±0.07Ac	9.50±0.07Ad
5	BF2	10.24±0.08Ba	10.23±0.06Aa	9.33±0.11Bb	9.10±0.07Cc	8.86±0.11Cd
	BF2+5% GT	10.33±0.09ABa	10.27±0.05Aa	9.93±0.07Ab	9.64±0.12Bc	9.34±0.07Bd
	BF2+10% GT	10.34±0.08ABa	10.23±0.08Aa	9.96±0.09Ab	9.85±0.10Ab	9.46±0.11ABc
	BF2+15% GT	10.44±0.06Aa	10.24±0.14Aab	10.08±0.14Ab	9.86±0.12Ac	9.53±0.10Ad

*Mean ± standard deviation (n = 3); Means followed by the different small letter within the same row or by the different capital letter within the same column of each group are statistically different ($p<0.05$).

The results of studies have indicated that *Aloe vera* reduces the respiration rate and ethylene production, weight loss, and softening (BENÍTEZ *et al*., 2013). In this regard, CHAUHAN *et al*. (2011) showed that Aloe gel coating alone or in combination with shellac, preserves the firmness in apple slices. Further, the *Aloe vera* edible coating application generally resulted in harder kiwifruit slices (BENÍTEZ *et al*., 2013).
In addition to the antimicrobial effects, the improvement in mechanical properties of the films incorporating green tea extracts may be responsible for the interaction between polymeric matrix and polyphenolic compounds from green tea extracts (SIRIPATRAWAN and HARTE, 2010).

3.4. Colour change

Colour is an important factor in the perception of the quality of fresh-cut fruit during their shelf-life. The colour indices (L^*, a^*, and b^*) of apple slices stored at 4°C for 16 days were measured and only L^* is reported in Table 5. Statistical analysis showed that the L^*, a^*, and

*b** colour indices significantly changed during storage. A significant increase in colorimetric *a** and *b** values, and a significant decrease in the *L** value were observed in apple slices during storage time. The colour indices of apple slices showed a significant difference ($p<0.05$) between the uncoated and coated samples.

Table 5. *L** changes in the control and coated apple slices with basic formulas (BF1 and BF2) incorporated *Aloe vera* and green tea extracts during the 16 days of storage at 4°C.

Group	Treatment	Storage time (day)				
		0	4	8	12	16
1	Control	76.00±2.00Aa*	72.33±0.58Ab	69.00±1.00Ac	66.33±1.53Cd	64.67±1.53Bd
	BF1	74.00±1.00Aa	71.66±0.58Ab	70.00±1.00Ac	68.66±0.58Bcd	68.00±1.00Ad
	BF2	75.66±1.15Aa	73.00±1.00Ab	71.00±1.00Abc	71.33±1.14Abc	70.00±1.00Ac
2	BF1	74.00±1.00Aa	71.66±0.58Ab	70.00±1.00Bc	68.66±0.58Acd	68.00±1.00Cd
	BF1+50% Aloe	74.33±1.53Aa	71.66±0.58Ab	70.33±0.56ABbc	68.66±0.55Acd	68.00±1.00Cd
	BF1+100% Aloe	74.66±1.53Aa	72.33±1.50Aab	71.33±0.57ABcb	70.33±1.00Aa	70.33±0.58Ba
	BF1+150% Aloe	74.67±0.56Aa	72.67±1.53Aab	72.00±1.00Acb	70.33±1.53Ac	70.67±0.55Ac
3	BF2	75.66±1.15Aa	73.00±1.00Ab	71.00±1.00Abc	71.33±1.14Abc	70.00±1.00Ac
	BF2+50% Aloe	75.33±1.50Aa	73.00±2.00Aab	70.67±1.15Acb	69.66±1.12Ac	69.00±1.00ABc
	BF2+100% Aloe	75.34±1.14Aa	73.33±1.50Ab	72.33±0.54Ab	70.33±0.59Ac	70.00±1.00ABc
	BF2+150%Aloe	76.67±1.55Aa	74.66±1.12Aa	72.00±1.00Ab	71.67.00±1.50Ab	71.33±1.10Bb
4	BF1	74.00±1.00Aa	71.66±0.58Bb	70.00±1.00Bc	68.66±0.58Ccd	68.00±1.00Bd
	BF1+5% GT	75.00±0.95Aa	72.00±1.00Bb	71.00±1.00ABb	69.00±1.00BCc	68.66±1.12ABc
	BF1+10% GT	75.33±1.49Aa	74.33±1.50Aa	71.67±1.45ABb	70.66±0.52ABb	69.33±1.50ABb
	BF1+15% GT	76.33±1.44Aa	74.67±1.10Aab	73.00±1.00Abc	71.66±1.50Acd	70.66±0.51Ad
5	BF2	75.66±1.15Ba	73.00±1.00Bb	71.00±1.00Abc	71.33±1.14ABbc	70.00±1.00Ac
	BF2+5% GT	75.00±1.00ABa	72.67±1.60Bb	71.00±1.05Acb	69.66±0.62Bc	69.33±0.60Ac
	BF2+10% GT	76.33±1.61ABa	75.33±1.55Aa	72.66±1.49Ab	71.00±1.00ABb	70.66±1.09Ab
	BF2+15% GT	77.66±1.55Aa	76.33±0.63Aa	73.34±1.60Ab	72.33±1.17Abc	71.00±1.00Ac

*Mean ± standard deviation (n = 3); Means followed by the different small letter within the same row or by the different capital letter within the same column of each group are statistically different ($p<0.05$).

The reduction trend of *L** values in coated and uncoated samples occurred at different rates during the storage ($p<0.05$), showing a darkening tendency in the surface colour of the apple slices. The least reduction trend for *L** was observed in the coated samples with both basic coatings (BF1 and BF2) containing 150% Aloe and 15% GT (~ 7.0%), in contrast to the control, which had the highest *L** reduction (14.9%). The *L** reduction during storage may be related to the occurrence of browning (MARTÍN-DIANA *et al*., 2008).

The least increasing trend for *a** and *b** was observed in the coated samples with both basic coatings (BF1 and BF2) containing 150% Aloe and 15% GT in contrast to control, which had the highest *a** and *b** increasing (*a** and *b** respectively increased from -5.33 and 22.0 to 4.33 and 33.67 after 16 days of storage at 4°C).

The variations of *L**, *a**, and *b** in the coated samples were significantly low at the highest concentrations of *Aloe vera* and green tea extracts at the end of the storage periods, confirming the effect of these coatings in preventing the darkening and browning of apple slices. But at the same concentrations (50, 100, and 150%) of *Aloe vera* and green tea (5, 10,

and 15%) extracts, there was no significant difference between BF1 and BF2 treatments in any of the measured colour parameters.
Colour is a critical quality property of fresh-cut fruit, since the slicing of fruit may often lead to enzymatic browning by polyphenol oxidases and peroxidases, which react with phenolic compounds and cause surface browning (ALBANESE *et al*., 2007; OMS-OLIU *et al*., 2010). Furthermore, the oxidative degradation of ascorbic acid and non-enzymatic browning are reported to be a major deteriorative reactions occurring during storage (WIBOWO *et al*., 2015). Thus, anti-browning agents such as ascorbic acid, thiol-containing substances, carboxylic acids, and certain phenolic acids have been studied (OMS-OLIU *et al*., 2010). In this study, citric and ascorbic acids were used as anti-browning agents to inhibit enzymatic browning. Cut-surface colour of apple slices that had been treated with ascorbic acid (in BF2) was well maintained than BF1-coated samples, but this effect was not significant.
An increase in the browning reactions in fresh-cut apples during storage was observed after increases in Hunter a^* and b^* values and a decrease in L^* (PEREZ-GAGO *et al*., 2006; SONG *et al*., 2013). The findings of this study indicated that the variations of colour in Aloe-treated apple slices, especially at higher concentration (150%), were significantly lower than BF1- and BF2-coated apple slices. Similarly, CHAUHAN *et al*. (2011) reported that the L^*, a^*, and b^* values of the *Aloe vera* gel-coated apple slices showed fewer changes compared to the control during storage for 30 days at 6°C, suggesting the anti-browning functionality of the *Aloe vera* coating.
It is reported that the application of *Aloe vera* gel coating is an effective method for maintaining the colour of fresh-cut apple slices, as the *Aloe vera* gel coating can act as an oxygen barrier film, thus reducing enzymatic browning. However, the coating does not completely prevent oxidative browning (SONG *et al*., 2013). Therefore, to inhibit enzymatic browning, anti-browning agents were added to the *Aloe vera* gel coating solution (SONG *et al*., 2013). In this regard, SONG *et al*. (2013) reported that *Aloe vera* gel, containing 0.5% cysteine, was most effective in delaying the browning of apple slices during storage.
The L^* levels of coated apple slices increased with green tea extract concentrations. But the increase was not significant, indicating the anti-browning effects of green tea extract. Conversely, MARTÍN-DIANA *et al*. (2008) reported that an increase in green tea concentrations decreased the L^* values of coated lettuce.

3.5. Microbial analysis

Fresh-cut fruit is highly susceptible to pathogenic and spoilage microorganisms during the preparatory steps as a consequence of cross-contamination, the presence of a large area of cut surfaces, and juice and sugar leakage from damaged tissues (OMS-OLIU *et al*., 2010). The microbial growth on the surface of coated apple slices showed significant differences between the coated and uncoated samples (Table 6).
A significant difference was found between the BF1- and BF2-coated samples after 12 days of storage. The total viable counts gradually and significantly increased with storage time in all treatments (Table 6). The microbial population of the control sample was higher than in the other treatments (2.63 and 6.78 log CFU/g at 0 and 16 days of storage, respectively), while samples coated with BF1+15% GT had the lowest microbial count compared to other treatments (2.42 and 3.17 log CFU/g at day 0 and 16 of storage period, respectively). The microbial counts in the *Aloe vera*- and green tea-coated samples did not exceeded 4.0 log CFU/g during storage time and were significantly lower than the coated samples with BF1 and BF2 ($p<0.05$). Therefore, the addition of *Aloe vera* and green tea extracts in BF1 and BF2 coatings reduced the microbial population significantly, and this effect was

enhanced at higher concentrations of these extracts. In both the BF1 and BF2 coatings, the inhibition of microbial growth was a function of the *Aloe vera* and green tea extracts. Significant differences were also found between BF1 and BF2 treatments in similar concentrations of *Aloe vera* (100 and 150%) and also green tea extract (10% and 15%). The results showed that the antimicrobial effect of green tea was more than that of *Aloe vera*, especially in the higher concentrations of these extracts.

Table 6. Microbial growth (log CFU/g) in the control and coated apple slices with basic formulas (BF1 and BF2) incorporated *Aloe vera* and green tea extracts during the 16 days of storage at 4ºC.

Group	Treatment	Storage time (day)				
		0	4	8	12	16
1	Control	2.48±0.06Ae*	3.16±0.07Ad	5.25±0.13Ac	6.10±0.04Ab	6.78±0.04Aa
	BF1	2.63±0.09Ad	2.73±0.09Cd	3.22±0.05Bc	4.02±0.04Bb	4.94±0.07Ba
	BF2	2.52±0.11Ae	2.92±0.05Bd	3.17±0.06Bc	3.73±0.08Cb	4.65±0.11Ca
2	BF1	2.63±0.09Ad	2.73±0.09Ad	3.22±0.05Ac	4.02±0.04Ab	4.94±0.07Aa
	BF1+50% Aloe	2.47±0.06Bd	2.56±0.05Bd	3.03±0.08Bc	3.32±0.07Bb	3.91±0.09Aa
	BF1+100% Aloe	2.45±0.09Bd	2.56±0.07Bd	2.96±0.07Bc	3.22±0.01BCb	3.92±0.05Aa
	BF1+150% Aloe	2.43±0.05Be	2.56±0.08Bd	2.92±0.06Bc	3.17±0.08Cb	3.95±0.07Aa
3	BF2	2.52±0.11Ae	2.92±0.05Ad	3.17±0.06Ac	3.73±0.08Ab	4.65±0.11Aa
	BF2+50% Aloe	2.47±0.06Ae	2.62±0.06Bd	2.95±0.09Bc	3.51±0.09Bb	3.99±0.06Ba
	BF2+100% Aloe	2.49±0.06Ad	2.59±0.02Bd	2.86±0.11Bc	3.19±0.07Cb	3.65±0.10Ca
	BF2+150% Aloe	2.43±0.05Ad	2.54±0.05Bd	2.80±0.12Bc	3.14±0.11Cb	3.56±0.08Ca
4	BF1	2.63±0.09Ad	2.73±0.09Ad	3.22±0.05Ac	4.02±0.04Ab	4.94±0.07Aa
	BF1+5% GT	2.47±0.04ABd	2.57±0.04Bd	2.96±0.06Bc	3.29±0.09Bb	4.14±0.10Ba
	BF1+10% GT	2.43±0.09Bd	2.49±0.02BCcd	2.62±0.04Cc	3.08±0.13Cb	3.64±0.09Ca
	BF1+15% GT	2.42±0.12ABc	2.47±0.03Cc	2.55±0.06Cc	2.85±0.06Db	3.17±0.06Da
5	BF2	2.52±0.11Ae	2.92±0.05Ad	3.17±0.06Ac	3.73±0.08Ab	4.65±0.11Aa
	BF2+5% GT	2.51±0.05Ad	2.59±0.05Bd	2.89±0.08Bc	3.26±0.10Bb	4.10±0.08Ba
	BF2+10% GT	2.42±0.03Ad	2.46±0.06Cd	2.58±0.02Cc	3.11±0.09Bb	3.85±0.10Ca
	BF2+15% GT	2.48±0.03Ac	2.44±0.03Cc	2.52±0.03Cc	2.86±0.09Cb	3.30±0.07Da

*Mean ± standard deviation (n = 3); Means followed by the different small letter within the same row or by the different capital letter within the same column of each group are statistically different ($p<0.05$).

According to Table 6, lower microbial populations in samples coated with *Aloe vera* and green tea extracts can be attributed to antimicrobial properties of the coated compounds (BENÍTEZ *et al*., 2013; MATAN *et al*., 2015; RADI *et al*., 2017)). *Aloe vera* extract was reported to have antimicrobial functions, significantly reducing mesophilic bacteria, and especially showing antifungal activity (MARTÍNEZ-ROMERO *et al*., 2006; VALVERDE *et al*., 2005). Some individual components found in *Aloe vera* gel, such as saponins, acemannan, and anthraquinone derivatives, are known to have antibiotic activity and could be responsible for its antibacterial activity (VALVERDE *et al*., 2005). Green tea, too, is a rich source of polyphenols (mainly catechins and catechin derivatives) and the antimicrobial activity of green tea has been attributed to these compounds (MARTÍN-DIANA *et al*., 2008; MATAN *et al*., 2015). MATAN *et al*. (2015) and RADI *et al*. (2017)

confirmed the antimicrobial activity in green tea extracts on fresh-cut dragon and fresh-cut orange, respectively.
The reduction of microbial populations presented in this study was in good agreement with the antimicrobial effects of *Aloe vera* coating on table grape ((VALVERDE *et al*., 2005), sweet cherry (MARTÍNEZ-ROMERO *et al*., 2006), apple slices (CHAUHAN *et al*., 2011; SONG *et al*., 2013), kiwifruit slices (BENÍTEZ *et al*., 2015), raspberry fruit (HASSANPOUR, 2015), and fresh-cut orange (RADI *et al*., 2017) which reduced the aerobic bacteria, as well as yeast and mould counts during storage.

3.6. Sensory analysis

The quality attribute scores (colour, aroma and flavour, texture or firmness, and overall acceptance) for the control and coated samples were studied on days 0, 8, and 16 (Fig. 1).

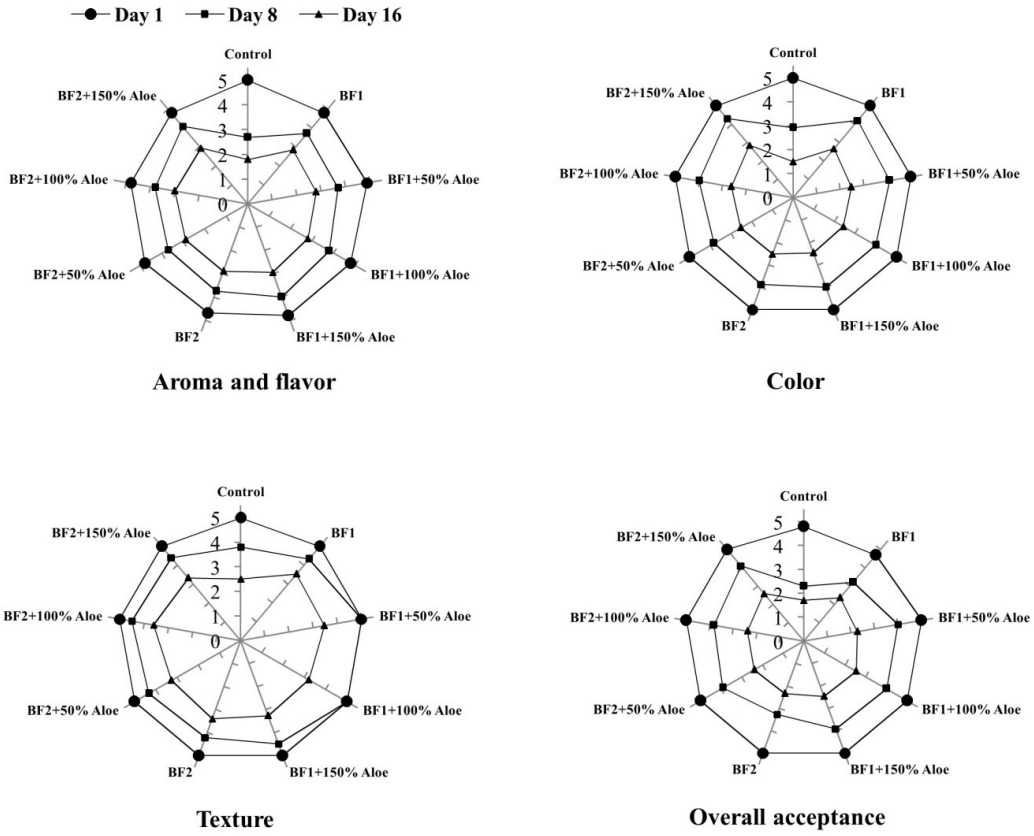

Figure 1: Sensory attributes of apple slices coated with basic formulas (BF1 and BF2) incorporated with *Aloe vera* extracts during the 16 days of storage at 4ºC.

The panellists gave greater sensory scores to coated slices than uncoated slices at the three stages of the experiment (Days 0, 8, and 16). Thus, the sensory analyses revealed the beneficial effects of coating in terms of delaying browning and maintaining the sensory quality of the apple slices. All edible coating treatments resulted in higher sensory scores than uncoated apple slices for all quality factors tested. But, except for colour, the other sensory characteristics were not significantly different in control and BF1 and BF2. In this

regard, the colour score of the BF1 was significantly higher than those of BF2 and control samples. Although increasing the concentration of *Aloe vera* and green tea extract in the basic formulas led to higher sensory scores, no significant difference was observed between the apple slices coated with different concentrations of *Aloe vera* and green tea extracts. But, at the end of the storage, the panellists gave greater sensory scores (colour and overall acceptance) to BF2+150% Aloe-coated slices than the other treatments. Unexpectedly, Aloe gel-coated samples showed the lowest firmness at the end of storage even at high concentrations. The higher scores of coated slices compared to the uncoated ones were reported in the *Aloe vera* gel-coated apple slices (CHAUHAN *et al*., 2011; SONG *et al*., 2013) and Aloe-coated orange slices (RADI *et al*., 2017).

4. CONCLUSIONS

In this study, an attempt was made to use *Aloe vera* and green tea extracts in gelatin-based coating to maintain the freshness of apple slices. Although gelatin-based coatings obtained higher quality attributes than those of control during storage time, the coatings did not completely prevent chemical and biochemical reactions. The addition of *Aloe vera* and green tea extracts in the gelatin-based coatings maintained the quality parameters of apple slices for a longer time during the storage period. In this regard, the least increasing trend for a^* and b^* was observed in samples coated with both gelatin-based coatings (BF1 and BF2) containing 150% *Aloe vera* and 15% green tea extracts. The samples coated with higher concentrations of *Aloe vera* and green tea extracts had lower increases in TSS at the end of storage periods. In terms of microbial count, the total count gradually and significantly increased with storage time in all treatments. The antimicrobial compounds *Aloe vera* and green tea extracts contributed to the lower microbial populations in samples coated with them. Slices coated with 150% *Aloe vera* and 15% green tea extracts obtained higher values for firmness. Moreover, the panellists gave greater sensory scores to coated apple slices than uncoated samples during the storage period. In this regard, the BF2+150% *Aloe vera* sample achieved higher sensory attributes than those of other treatments at the end of storage time.

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