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Effect of edible coating containing *Aloe vera* extracts on the oxidative stability and quality parameters of cooked ground chicken meat

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SUMMARY: This study investigated the impact of incorporating *Aloe vera* gel (AVG) and *Aloe vera* leaf skin (AVLS) extracts into edible coating (EC) on retarding lipid oxidation and enhancing the quality characteristics of cooked ground chicken meat during 14 days of storage at 4 °C. The results indicated that both AVG and AVLS extracts had a similar amount of total phenolic contents. EC application resulted in a decrease in pH values, and an increase in aw values. The addition of 2% AVG or AVLS extracts into EC formulation also decreased TBARS and ORP values. Although textural properties were not affected by EC application containing AVG or AVLS extracts, this application retarded L^*, a^*, and b^* color values. The results indicated that *Aloe vera* extracts may be incorporated into EC by processors to improve lipid oxidation inhibition and maintain the quality characteristics of poultry meat products during refrigerated storage.

KEYWORDS: *Aloe vera gel; Aloe vera leaf skin; Edible coating; Poultry meat*

RESUMEN: ***Efecto de un recubrimiento comestible que contiene extractos de* Aloe vera *sobre la estabilidad oxidativa y los parámetros de calidad de la carne de pollo molida cocida.*** Este estudio investigó el impacto de la incorporación de extractos de gel de *Aloe vera* (AVG) y piel de hoja de aloe vera (AVLS) en un recubrimiento comestible (EC) para retardar la oxidación de lípidos y mejorar las características de calidad de la carne de pollo molida cocida durante 14 días de almacenamiento a 4°C. Los resultados indicaron que tanto los extractos AVG como AVLS tenían una cantidad similar de contenidos fenólicos totales. La aplicación de EC resultó en una disminución en los valores de pH, mientras que la misma aplicación provocó un aumento en los valores de aw. La adición de extractos de AVG o AVLS al 2 % en la formulación de EC también disminuyó los valores de TBARS y ORP. Aunque las propiedades texturales no se vieron afectadas por la aplicación de EC que contenía extractos AVG o AVLS, esta aplicación retrasó los valores de color L*, a* y b*. Los resultados indicaron que los procesadores pueden incorporar extractos de *Aloe vera* en la AE para mejorar la inhibición de la oxidación de lípidos y mantener las características de calidad de los productos cárnicos de aves durante el almacenamiento refrigerado**.**

PALABRAS CLAVE: *Carne de ave; Gel de aloe vera; Piel de hoja de aloe vera; Recubrimiento comestible*

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1. INTRODUCTION

Aloe vera (*Aloe barbadensis Miller*) is a tropical and subtropical succulent herb and is cultivated in many warm and dry regions of the world. The colorless mucilaginous *Aloe vera* gel that is isolated from *Aloe vera* leaves is extensively used in natural cosmetics and pharmaceutical industries. *Aloe vera* gel, which consists of 99.5 % water, has nutritional properties as it contains vitamins, minerals, amino acids and enzymes (Boudreau and Beland, 2006). Several authors have reported that *Aloe vera* extract has natural antioxidant, antimicrobial and antiviral effects (Rajkumar *et al.,* 2016). Recently, *Aloe vera* has been used as a functional ingredient by the food industry in drinks, beverages, ice cream and as an edible coating for fruits and vegetables to preserve their quality characteristics (Nicolau-Lapena *et al.,* 2021).

Over the years, the development and application of edible films and coatings have become an increasing trend in the food industry. Since edible films and coatings can be produced from a variety of sustainable and biodegradable materials, used as a carrier of various antioxidant and antimicrobial agents, and have a wide range of applications, edible films and coatings are promising alternatives to traditional packaging materials (Petkoska *et al.,* 2021). Edible films and coatings are thin layers made from polysaccharides, proteins and lipids. These materials act as a barrier to moisture and gases and reduce gas exchange, loss of water, flavors and aroma, and thereby improve the appearance, quality and shelf life of foods (Chauhan *et al.,* 2016).

The present study was undertaken to fill in missing information about the utilization of *Aloe vera* extracts in the area of the development of bioactive edible coating (EC). Therefore, the aim of this study was to evaluate the effects of whey protein isolate-based (WPI) EC with different concentrations of *Aloe vera* gel (AVG) or *Aloe vera* leaf skin (AVLS) extracts on the oxidative stability and quality features of cooked ground chicken meat under refrigerated storage.

2. MATERIALS AND METHODS

2.1. Materials

Whey protein isolate (BiPRO 100% WPI, Davisco Foods International Inc., USA) was provided by Hardline Nutrition (İstanbul, TR). Fresh *Aloe vera* was supplied by a commercial firm (Nisa Fidancılık, Yalova, Turkey).

2.2. Preparation of *Aloe vera* gel and leaf extracts

The extraction of *Aloe vera* was carried out according to the modified method of Lawrence *et al*. (2009). For the preparation of extracts, *Aloe vera* gel and *Aloe vera* leaf skin were dried in an oven at 40 °C for 72 h and then powdered. Ten grams of this powder were dissolved in 100 mL of ethanol for 72 h. The contents were filtered by filter paper (Whatman No. 1), and then the alcohol was evaporated by a rotary evaporator (Heidolph, Germany) at 40 °C. Extracts were stored at -80 °C, until analyses.

2.3. Preparation of WPI-based edible coating solution

The WPI-based EC solution was prepared according to the modified method of Akcan *et al.* (2017). The coating solution was produced by mixing 5% (w/v) WPI dissolved in distilled water with 5% (w/v) glycerol. The pH of the mixture was adjusted to 8.0 with 2 N NaOH. Then, the mixture was heated at 90 °C for about 30 min until obtaining a uniform solution which was then allowed to cool at room temperature. *Aloe vera* gel (AVG) and *Aloe vera* leaf skin (AVLS) extracts were added separately to the WPI-based EC solution at final concentrations of 0.1, 0.5 and 2% (v/v) (based on EC solution weight) and marked as AVG-0.1, AVG-0.5, AVG-2, AVLS-0.1, AVLS-0.5, and AVLS-2, respectively. In addition, two different groups were prepared as uncoated (UC) and coated with EC solution without extracts (C). After stirring the solution with a homogenizer (IKA T25, Germany) for about 1 min, it was filtered using a layer of cheesecloth.

2.4. Determination of total phenolic content

The total phenolic contents in *Aloe vera* gel (AVG) and *Aloe vera* leaf skin (AVLS) extracts were analyzed by the Folin-Ciocalteu method. Briefly, 200 µL Folin Ciocalteu reagent were added to 40 µL of extract dissolved in 2.4 mL of distilled water. After that, 600 µL a sodium carbonate solution were added to each tube. After vortexing, each tube was held for 2 h at room temperature in the dark. The mixture was then read at 765 nm against a blank. Total phenolic content was determined and represented

as gallic acid equivalent (GAE) in mg/g of extract using a standard curve established with various doses of gallic acid.

2.5. Preparation of ground chicken meat

Skinless and boneless fresh broiler breast meat (*Pectoralis major*) was obtained from a local abattoir (Isparta, Turkey). Chicken meat was minced in a mincer twice using 9.5-mm and 3.2-mm plates, respectively. 1% NaCl and 10% water were added to the ground chicken meat on weight basis. After that, the ground chicken meat was filled into centrifuge tubes (45 grams per tube) which were placed in a water bath at 60 °C. The water bath temperature was set to 85 °C, and the chicken meat was cooked. The internal temperature of the ground chicken meat was tracked with the thermocouple attached to the geometric center of the meat. The cooking process was stopped when the internal temperature of the samples reached 72 °C. Following cooking, the chicken meat was cooled at 25 °C for 20 min.

2.6. Coating of cooked ground chicken meat

Cooked ground chicken meat was divided into eight groups: uncoated (UC), coated with EC solution without extracts (C), and coated with EC solution containing different concentrations (0.1, 0.5 and 2% (v/v)) of AVG (AVG-0.1, AVG-0.5 and AVG-2) or AVLS (AVLS-0.1, AVLS-0.5, and AVLS-2) extracts. The coating process was done by immersing the cooked ground chicken meat into their respective coating solutions for 1 min, followed by drying for 30 s. This was done 3 times. The treated groups were dried at 30 °C for 1 h in an incubator (Ildam, ILD-EKH-55, Turkey), and stored for 14 days under refrigerated conditions (4 °C). Oxidation-reduction potential (ORP), pH, water activity (aw), color values, thiobarbituric acid reactive substances (TBARS), and texture profile analyses (TPA) were carried out at days 0, 1, 7, and 14.

2.7. pH, aw and ORP measurement

The pH value of the samples was determined with a pH meter (HI 9024, Hanna Instruments, Germany) equipped with a penetration spear electrode (FC 200, Hanna Instruments, Germany). The a_w value of the samples was determined using an aw device (Novasina LabTouch-aw) at 20 °C. Each chicken meat sample was cut into small pieces and placed in the sample cup. After the device reached stable humidity at 25 °C, the values on the screen were recorded. The ORP values for the samples were evaluated according to the procedure of Moiseev and Cornforth (1999). The pH meter (WTW pH 3110, Germany) with a redox electrode was set on the millivolt scale.

2.8. Color values

The color values for the chicken meat samples were evaluated by using a Minolta Colorimeter (CR-200, D65 Illuminant, Ramsey, USA). The instrument was set to measure CIE L^*, a^*, and b^* color scale using illuminant 65D and 10° standard observers with an opening size of 8.0 mm. It was calibrated using black and white calibration plates before starting the measurements.

2.9. TBARS

The TBARS values for the samples were evaluated as per the procedure of Kılıç *et al*. (2014). The TBARS values were calculated by a standard curve prepared with 1,1,3,3-tetraethoxypropane (TEP) and the results were expressed as μmol malondialdehyde (MDA)/ kg meat.

2.10. Texture profile analysis (TPA)

Textural parameters (hardness, resilience, adhesiveness, cohesiveness, gumminess, springiness, and chewiness) of the samples were measured using a TA.XT2 Texture Analyzer device (Stable Micro Systems, UK) with a rectangular aluminum probe (5 cm x 4 cm) for compression and a blade for cutting (50 kg load cell). The test speed, pre-test speed, post-test speed, and compression were 5 mm/s, 2 mm/s, 2 mm/s, and 70%, respectively.

2.11. Statistical analysis

The whole study was conducted in two replicates and each analysis was performed in duplicate for each replicate experiment performed. One-way analysis of variance using SPSS 25.0 software (SPSS Inc., USA) was used for statistical evaluation of the data. Statistical significance was identified using Tukey's multiple comparison test at the 95% confidence level ($P < 0.05$).

3. RESULTS AND DISCUSSION

3.1. Total phenolic content

The results of total phenolic content in AVG and AVLS extracts are shown in Table 1. The total phenolic contents in the AVG and AVLS extracts in this study were 8.93 mg GAE/g and 8.72 mg GAE/g of extract, respectively. These results demonstrated that the total phenolic contents in both AVG and AVLS extracts were similar. In previous studies it was reported that the total phenolic content in AVG extract was 19.56 mg GAE/g (Jairath *et al.,* 2016) and 17.84 mg GAE/g (Chauhan *et al.,* 2016). Kammoun *et al*. (2011) reported that the total phenolic content ranged from 2.07 mg GAE/g to 40.5 mg GAE/g in AVLS extracts. The reason for these differences in total phenolic contents among these extracts might be due to differences in extraction method, their contents in phenolic compounds, the phenolic acid equivalent, the environmental growing conditions, and the age of the plant (Kammoun *et al.,* 2011).

Table 1. Total phenolic content in *Aloe vera* gel (AVG) and *Aloe vera* leaf skin (AVLS) extracts

Extracts	Total phenolic content (mg GAE/g)
AVG	8.93
AVLS	8.72

3.2. pH, aw and ORP

The pH results of cooked ground chicken meat stored under refrigeration are shown in Table 2. It was observed that the edible coating application decreased the pH values. The group coated with the EC solution without extract had a lower pH value on manufacturing day than the uncoated group ($P < 0.05$). The mean pH values for all groups gradually increased throughout the storage period ($P < 0.05$). Chauhan *et al*. (2016) also reported that the use of *Aloe vera* gel-based edible coating including Moringa oleifera leaf extract on chicken bites increased pH values. The pH values for the uncoated group and the group coated with the EC solution without extract increased more at the end of the storage period compared to other groups ($P < 0.05$). Microbial and enzymatic activities may be responsible for this elevated pH in these groups. Besides texture degradation due to nitrogenous substances (ammonia, trimethylamine, histamine etc.) produced by the enzymatic activity of microorganisms during the storage period, the formation of these substances also results in increased pH in meat (Samani *et al.,* 2022). Some previous studies also reported elevated pH in chicken meat stored in aerobic conditions due to bacterial growth (Huang *et al.,* 2020). At the end of the storage period, the highest pH values were obtained for the UC group, while the group coated with EC solution containing 0.1 or 0.5% AVLS extract (AVLS-0.1, AVLS-0.5) had the lowest pH values ($P < 0.05$). The edible coating (with or without extract) may have reduced the deterioration of chicken meat texture by reducing microbial growth and hence the microbial load of the meat products (Samani *et al.,* 2022). Furthermore, AVG or AVLS extracts may have raised the gas concentration inside the coating by reducing the carbon dioxide permeability of the coating. This

Table 2. pH values in cooked ground chicken meat during 14 days of storage at 4 °C

Groups	pH Storage days			
	0	1	7	14
UC	6.30 ± 0.03^{aC}	6.32 ± 0.00^{aC}	6.46 ± 0.00^{aB}	6.62 ± 0.01^{aA}
C	6.22 ± 0.01^{bD}	6.26 ± 0.00^{bC}	6.40 ± 0.00^{cB}	6.51 ± 0.00^{bA}
AVG-0.1	6.22 ± 0.02^{bC}	6.26 ± 0.00^{bB}	6.43 ± 0.01^{bA}	6.41 ± 0.00^{dA}
AVG-0.5	6.19 ± 0.01^{bD}	6.22 ± 0.00^{cC}	6.39 ± 0.00^{cB}	6.44 ± 0.00^{cA}
AVG-2	6.22 ± 0.00^{bC}	6.22 ± 0.00^{cC}	6.40 ± 0.01^{cA}	6.37 ± 0.00^{eB}
AVLS-0.1	6.20 ± 0.00^{bD}	6.22 ± 0.01^{cC}	6.33 ± 0.00^{eB}	6.36 ± 0.00^{fA}
AVLS-0.5	6.21 ± 0.00^{bB}	6.20 ± 0.00^{eC}	6.36 ± 0.00^{dA}	6.36 ± 0.00^{fA}
AVLS-2	6.20 ± 0.01^{bC}	6.21 ± 0.00^{dC}	6.32 ± 0.00^{eB}	6.40 ± 0.00^{dA}

a-f (↓) Different letters within a column are significantly different according to Tukey's test ($p < 0.05$). A-D (→) Different letters within a row are significantly different according to Tukey's test ($p < 0.05$) (two replicates and in duplicate for each replicate).

might have slowed the increase in chicken meat pH and reduced the microbial load (Kiarsi *et al.,* 2020). Similarly, Khare *et al*. (2016) observed lower pH values for edible coated chicken fillets stored under refrigeration. Previous studies documented that applying an edible coating to chicken meat samples could help to maintain the pH value throughout the storage period, and that coated samples had lower pH values than uncoated ones (Apriliyani *et al.,* 2021). Our results also indicated that the group coated with EC solution without extract had higher pH values than the groups coated with the EC solution containing AVG or AVLS extracts ($P < 0.05$). This could be due to *Aloe vera*, which has an acidic pH of 4.1, which lowers the pH of the meat or poultry meat products (Rajkumar *et al.,* 2016). In addition, the group coated with the EC solution containing 2% AVG extract had lower pH values than the other groups containing AVG extract (AVG-0.1, AVG-0.5; $P < 0.05$). However, the group coated with the EC solution containing 2% AVLS extract had higher pH values than the other AVLS extract-containing groups ($P < 0.05$).

Table 3 shows the results of the water activity analysis during the cold storage of cooked ground chicken meat. The water activity values changed from 0.910 to 0.917 on manufacturing day. The highest water activity values were obtained for the AVG-2 group at the beginning of storage; whereas the lowest water activity values were found for the C and AVLS-2 groups ($P < 0.05$). The water activity values for cooked ground chicken meat decreased in the UC, C, AVG-0.1 and AVG-2 groups during the storage period ($P < 0.05$). The obtained results are in agreement with those of Suput *et al.* (2019) who indicated that water activity decreased in fresh pork coated with a starchy edible coating containing oregano essential oil after 2 months' storage at 4 °C. However, a slight increase in water activity values was determined for all groups containing AVLS extracts during 14 days of storage ($P < 0.05$). At the end of the storage period, the group coated with the EC solution containing 2% AVLS extract had the highest water activity values, while the uncoated group had the lowest water activity values ($P < 0.05$). The lower water activity values in the uncoated group may be explained by the greater susceptibility of this group's surface to dehydration during the storage period (Saricaoglu and Turhan, 2019). In addition, the results of this study showed that EC application with or without the use of AVG or AVLS extracts increased the water activity of cooked ground chicken meat ($P < 0.05$). This could be the result of the absorption of water from the EC solution into the coated samples. Furthermore, the group coated with the EC solution containing 2% AVG extract had a higher water activity value than the other groups containing AVG extracts ($P < 0.05$). Similarly, the group coated with the EC solution containing 2% AVLS extract also had a higher water activity value than the other AVLS groups ($P < 0.05$). These results showed that water activity increases when the concentration of AVG or AVLS extracts is increased in the EC solution. However, this increase was lower in groups coated with the EC solution containing AVG extract. This could be due to higher water vapor permeability

Table 3. Water activity (a_w) values in cooked ground chicken meat during 14 days of storage at 4 °C

Groups	a_w			
	Storage days			
	0	1	7	14
UC	0.912 ± 0.01^{eA}	0.905 ± 0.00^{fC}	0.908 ± 0.02^{cB}	0.900 ± 0.01^{fD}
C	0.910 ± 0.00^{fC}	0.911 ± 0.01^{cB}	0.912 ± 0.01^{aA}	0.904 ± 0.00^{eD}
AVG-0.1	0.912 ± 0.01^{eA}	0.912 ± 0.01^{bA}	0.910 ± 0.00^{bB}	0.910 ± 0.00^{dB}
AVG-0.5	0.915 ± 0.02^{bA}	0.911 ± 0.01^{cB}	0.906 ± 0.01^{dC}	0.915 ± 0.01^{cA}
AVG-2	0.917 ± 0.04^{aA}	0.912 ± 0.03^{bC}	0.908 ± 0.01^{cD}	0.916 ± 0.01^{bB}
AVLS-0.1	0.913 ± 0.01^{dC}	0.916 ± 0.02^{aA}	0.905 ± 0.02^{eD}	0.915 ± 0.02^{cB}
AVLS-0.5	0.914 ± 0.02^{cB}	0.908 ± 0.00^{dC}	0.906 ± 0.03^{dD}	0.916 ± 0.02^{bA}
AVLS-2	0.910 ± 0.01^{fB}	0.906 ± 0.01^{eD}	0.908 ± 0.01^{cC}	0.917 ± 0.03^{aA}

a-f (↓) Different letters within a column are significantly different according to Tukey's test ($p < 0.05$). A-D (→) Different letters within a row are significantly different according to Tukey test ($p < 0.05$) (two replicates and in duplicate for each replicate).

Table 4. Oxidation-reduction potential (ORP) values in cooked ground chicken meat during 14 days of storage at 4 °C

Groups	ORP Storage days			
	0	1	7	14
UC	-100.45±0.13^{aD}	-2.62±0.09^{aC}	0.70±0.08^{cB}	49.82±0.22^{bA}
C	-122.25±0.21^{gD}	-13.10±0.08^{bC}	5.60±0.08^{aB}	46.65±0.13^{cA}
AVG-0.1	-114.55±0.13^{eD}	-34.32±0.09^{cC}	-6.72±0.17^{fB}	56.35±0.17^{aA}
AVG-0.5	-133.47±0.09^{hD}	-40.65±0.13^{dC}	0.30±0.08^{dB}	32.62±0.65^{fA}
AVG-2	-107.62±0.05^{cD}	-55.45±0.13^{eC}	-6.10±0.08^{eB}	45.45±0.13^{dA}
AVLS-0.1	-120.67±0.09^{fD}	-68.55±0.14^{fC}	-7.15±0.06^{gB}	56.90±0.08^{aA}
AVLS-0.5	-106.27±0.05^{bD}	-79.25±0.12^{gC}	3.85±0.21^{bB}	45.40±0.08^{dA}
AVLS-2	-108.80±0.01^{dD}	-90.47±0.15^{hC}	-8.80±0.08^{hB}	34.92±0.30^{eA}

a-h (↓) Different letters within a column are significantly different according to Tukey's test ($p < 0.05$). A-D (→) Different letters within a row are significantly different according to Tukey's test ($p < 0.05$) (two replicates and in duplicate for each replicate).

features of the coating formulated with AVG extract (Tural and Turhan, 2017).

ORP values (Table 4) ranged between -133.47 and -100.45 mV at the beginning of refrigerated storage; whereas ORP was raised to range between 32.62 and 56.35 mV at the end of the storage period. The results indicated that the ORP values determined in all groups increased during the storage period ($P < 0.05$). Tenderis *et al*. (2021) also reported increased ORP values when storage time increased in cooked ground beef. This may be a result of the accumulation of lipid oxidation products throughout storage. The results indicated that the highest ORP values were obtained for the uncoated group on manufacturing day; whereas the group coated with EC solution containing 0.5% AVG had the lowest ORP values ($P < 0.05$). At the end of the storage period, the highest ORP values were found for the uncoated group and the groups coated with the EC solution containing 0.1% AVG and 0.1% AVLS extracts ($P < 0.05$). On the other hand, the lower ORP values were determined for the group coated with the EC solution containing 0.5% AVG ($P < 0.05$). The addition of 0.5 or 2% AVG or AVLS extracts into the EC solution decreased the ORP values ($P < 0.05$). Because oxidized environments provide aerobic conditions for microbial growth, decreasing the oxidation-reduction potential in muscle foods is critical for controlling microbial load in the final product. Moreover, low ORP values indicate a lower probability of oxidation reactions. The redox potential of meat is affected by its composition (amino acid, peptide, protein, reducing sugar, and salt content), temperature, packaging type, microbial activity, and, most importantly, dissolved oxygen concentration. Furthermore, the additives that influence pH may also affect ORP values for muscle foods (Bhunia *et al.,* 2017).

3.3. Color values

The results showed that EC application and storage time had a significant ($P < 0.05$) impact on lightness (CIE L^* value), redness (CIE a^* value) and yellowness (CIE b^* value) color values for cooked ground chicken meat (Table 5). Generally, an increase in L^* values for all treatment groups was found during the storage period ($P < 0.05$), except the uncoated group. This might be due to effective lipid oxidation inhibition resulting from reduced oxygen penetration by the edible coating and antioxidant effects of incorporated AVG or AVLS extracts (Ruan *et al.,* 2019). The groups coated with the EC solution containing 0.1% AVG and 0.5% AVLS extracts had a higher L^* value than the group coated with the EC solution containing 2% AVG extract at the beginning of the storage period ($P < 0.05$). In addition, there were no significant differences between L^* values in the other groups ($P > 0.05$). At the end of the storage period, the lowest L^* values were identified in the uncoated group ($P < 0.05$). The high L^* values in the coated groups could be attributed to the luminosity and high transparency of the edible coating (Kiarsi *et al.,* 2020). Similarly, Khare *et al*. (2017) reported that chicken fillets samples coated with chitosan and cinnamon oil had higher L^* value than uncoated samples. The results of our study also showed that the AVG-2 group had higher L^* values

Table 5. CIE L*a*b* color values in cooked ground chicken meat during 14 days of storage at 4 °C

Groups	L*			
	Storage days			
	0	1	7	14
UC	78.65±1.73^{abC}	87.03±1.06^{abcA}	83.55±1.04^{bB}	74.97±1.54^{dD}
C	79.94±1.72^{abC}	86.59±0.58^{abcA}	84.27±1.09^{abA}	81.74±1.84^{bcB}
AVG-0.1	81.67±0.86^{aB}	85.39±0.82^{bcA}	82.79±1.92^{bB}	81.35±0.33^{cB}
AVG-0.5	79.27±1.88^{abB}	84.84±1.60^{cA}	83.94±1.14^{abA}	84.63±0.77^{abA}
AVG-2	76.00±1.40^{bC}	87.60±0.20^{abA}	82.05±1.32^{bB}	84.92±0.57^{aAB}
AVLS-0.1	80.00±1.28^{abC}	86.10±1.23^{abcA}	82.71±1.51^{bB}	82.90±0.59^{abcB}
AVLS-0.5	82.31±3.42^{aC}	87.71±1.27^{abA}	86.69±0.30^{aAB}	83.42±0.62^{abcBC}
AVLS-2	80.28±1.55^{abC}	88.23±0.49^{aA}	83.90±0.66^{abB}	83.44±1.51^{abcBC}
Groups	a*			
	Storage days			
	0	1	7	14
UC	4.90±0.88^{aA}	5.03±0.81^{aA}	4.12±0.81^{bA}	4.94±0.45^{aA}
C	4.33±0.89^{aA}	5.06±0.73^{aA}	4.77±0.37^{abA}	4.53±0.32^{bA}
AVG-0.1	4.30±0.36^{aA}	4.76±0.51^{abA}	4.64±0.12^{abA}	2.35±0.56^{dB}
AVG-0.5	4.61±0.49^{aA}	3.48±0.38^{bB}	4.68±0.24^{abA}	2.93±0.26^{cdB}
AVG-2	3.67±0.50^{aB}	4.79±0.36^{abA}	5.33±0.43^{aA}	3.60±0.09^{bcB}
AVLS-0.1	4.54±0.49^{aA}	4.95±0.68^{aA}	5.12±0.49^{abA}	4.30±0.21^{bA}
AVLS-0.5	4.17±0.30^{aAB}	4.13±0.55^{abAB}	4.91±0.42^{abA}	3.56±0.23^{bcB}
AVLS-2	4.63±0.81^{aA}	4.27±0.39^{abA}	4.66±0.61^{abA}	3.92±0.27^{bcA}
Groups	b*			
	Storage days			
	0	1	7	14
UC	10.08±0.28^{aA}	4.93±0.34^{aD}	7.42±0.48^{aC}	8.80±0.37^{aB}
C	9.81±0.48^{aA}	4.54±0.42^{aD}	7.24±0.71^{aB}	5.69±0.26^{dC}
AVG-0.1	9.62±0.50^{aA}	5.28±0.10^{aC}	7.22±0.88^{aB}	6.87±0.42^{bcBC}
AVG-0.5	9.82±0.51^{aA}	4.84±0.47^{aC}	6.91±0.56^{aB}	7.53±0.16^{bB}
AVG-2	11.73±0.70^{aA}	4.51±0.65^{aB}	7.13±0.15^{aB}	7.27±0.34^{bcB}
AVLS-0.1	10.45±0.83^{aA}	4.63±0.38^{aC}	6.64±0.31^{aB}	6.78±0.29^{cB}
AVLS-0.5	10.12±0.79^{aA}	4.53±0.27^{aC}	7.17±0.27^{aB}	7.45±0.16^{bcB}
AVLS-2	10.39±0.87^{aA}	4.72±0.73^{aC}	6.56±0.42^{aB}	7.55±0.39^{bB}

a-e (↓) Different letters within a column are significantly different according to Tukey's test ($p < 0.05$). A-D (→) Different letters within a row are significantly different according to Tukey's test ($p < 0.05$) (two replicates and in duplicate for each replicate).

than the C group ($P < 0.05$). It has been previously reported that extracts possessing antioxidant and antimicrobial capabilities prevented microbial growth and oxidation, thus, the denaturation rate of proteins was able to be reduced (Lashkari *et al.,* 2020).

In general, results demonstrated that there were no significant changes in a* values in all treatment groups except AVG-0.1 and AVG-0.5 groups during the 14-day storage period ($P > 0.05$). The a* values for the AVG-0.1 and AVG-0.5 groups decreased during the same period of time ($P < 0.05$). Even though no significant a* value differences were found among treatment groups at the beginning of storage ($P > 0.05$), there were a significant a* value differences among treatment groups at the end of the storage period ($P < 0.05$). Xiong *et al*. (2020) reported a similar pattern for a* values in pork and the authors indicated that pork samples coated with oregano oil, resveratrol, and pectin did not vary from uncoated samples on manufacturing day in terms of a* values. The re-

sults indicated that the application of coating with or without extract resulted in lower a^* values at the end of 14 days ($P < 0.05$). On the other hand, the addition of AVG extract at the 2% incorporation level or AVLS extract at all tested concentrations did not create any further reduction in a^* values compared to the C group at the end of the storage period.

The b^* values were decreased in the cooked ground chicken meat during the storage period ($P < 0.05$). The b^* values for all treatment groups ranged from 4.51 to 11.73, and there were differences among the groups only on the 14th day of the storage ($P < 0.05$). The highest b^* values were obtained in the uncoated group at the end of the storage period; while the lowest values were found in the C group ($P < 0.05$). Edible coating application could reduce b^* values due to its oxygen blocking capability (Ruan *et al.,* 2019). In addition, AVG or AVLS extracts could reduce oxidation as an antioxidant and this result decreased b^* values. However, the b^* values for the groups containing extracts were higher ($P < 0.05$) than the group coated with the EC solution without extract (C) due to the yellow-green color features of the extracts. No significant differences were found between the b^* values for the groups containing AVG extracts, and all groups showed similar b^* values ($P > 0.05$). On the other hand, the group coated with the EC solution containing 2% AVLS extract had a higher b^* value than the group coated with the EC solution containing 0.1% AVLS extract ($P < 0.05$). This result revealed that the incorporation of higher AVLS extract concentration into the EC solution increased b^* values. These CIE L^*, a^*, and b^* color results suggested that using WPI-based EC containing AVG or AVLS extracts could help to prevent undesirable color changes in cooked ground chicken meat during the storage period.

3.4. TBARS

The TBARS results (Table 6) indicated that the groups coated with the EC solution containing AVG or AVLS extracts had lower TBARS values than the uncoated group on manufacturing day ($P < 0.05$). In addition, the groups coated with the EC solution containing 0.5% AVG, 2% AVG, and all AVLS extract doses had lower TBARS values than the C group ($P < 0.05$). It has been previously reported that *Aloe vera* had a strong antioxidant capacity equal or superior to synthetic antioxidants due to its tannin, flavonoids, ascorbic acid and vitamin E contents (Rajkumar *et al.,* 2016). The antioxidant capacity of *Aloe vera* has also been reported in chicken nuggets (Bhat *et al.,* 2015), chicken bites (Chauhan *et al.,* 2016) and nuggets (Rajkumar *et al.,* 2016).

Results indicated that TBARS values showed an increasing trend from day 0 to day 14 in all cooked ground chicken meat groups ($P < 0.05$). Similar results were reported by Chauhan *et al*. (2016) in chicken bites and by Huang *et al*. (2020) in ready-to-eat carbonado chicken during refrigerated storage. These findings are also in agreement with the findings of Karimi-Dehkordi *et al*. (2021), who observed an increase in TBARS values during storage time in chicken breast slices coated with whey

Table 6. TBARS values (μmol/kg) in cooked ground chicken meat during 14 days of storage at 4 °C

Groups	TBARS			
	Storage days			
	0	1	7	14
UC	6.56 ± 0.41^{aD}	10.30 ± 0.11^{aC}	26.46 ± 0.76^{aB}	35.10 ± 0.22^{aA}
C	6.13 ± 0.16^{abD}	10.01 ± 0.37^{aC}	25.61 ± 0.89^{abB}	34.32 ± 0.28^{abA}
AVG-0.1	5.58 ± 0.47^{bD}	9.75 ± 0.62^{aC}	25.03 ± 0.41^{abcB}	33.24 ± 0.73^{abA}
AVG-0.5	4.21 ± 0.07^{cD}	8.93 ± 0.08^{abC}	24.69 ± 0.61^{bcB}	33.02 ± 0.11^{abA}
AVG-2	4.42 ± 0.25^{cD}	8.85 ± 0.58^{abC}	21.43 ± 0.45^{dB}	29.32 ± 0.14^{cA}
AVLS-0.1	4.46 ± 0.37^{cD}	9.60 ± 0.26^{aC}	24.55 ± 0.12^{bcB}	32.79 ± 0.29^{abA}
AVLS-0.5	4.72 ± 0.11^{cD}	8.74 ± 0.19^{abC}	24.49 ± 0.70^{bcB}	33.38 ± 0.18^{abA}
AVLS-2	4.38 ± 0.23^{cD}	7.69 ± 0.13^{bC}	23.86 ± 0.32^{cB}	32.33 ± 0.43^{bA}

a-d (↓) Different letters within a column are significantly different according to Tukey's test ($p < 0.05$). A-D (→) Different letters within a row are significantly different according to Tukey's test ($p < 0.05$) (two replicates and in duplicate for each replicate).

protein concentrate incorporated with essential oil, bioactive peptides and nanoparticles. There were no significant differences between the uncoated group and the C group during the storage period ($P > 0.05$). This could be due to the reduced resistance of WPI-based edible coating to gas transfer, which causes accelerated lipid oxidation (Bhat *et al.,* 2015). WPI-based edible coating exhibits extremely low oxygen permeability under low relative humidity conditions (Galus *et al*., 2021). Cisneros-Zevallos and Krochta (2003) indicated that WPI coatings are superior gas barriers, but they are influenced by the relative humidity (RH) of the environment, which affects resistance to the permeation of oxygen and carbon dioxide. As RH is increased, it decreases resistance of the coating to gas transfer.

Lower TBARS values were found in the group coated with the EC solution containing 2% AVG extract compared to the other groups on days 7 and 14 ($P < 0.05$). Also, the TBARS results indicated that the groups coated with the EC solution containing 0.5% AVG and 2% AVG extracts had a lower TBARS values than the group containing 0.1% AVG extract ($P < 0.05$). However, there were no significant differences among the groups coated with the EC solution containing AVLS extracts ($P > 0.05$). At the end of the storage period, TBARS values for the groups containing 2% AVG and 2% AVLS extracts were lower than the uncoated group ($P < 0.05$). This finding shows that cooked ground chicken meat coated with the EC solution containing 2% AVG or AVLS extracts had an ability to slow down TBARS formation. This impact could be attributable to the enhanced antioxidant effec of the substances found in *Aloe vera*, such as phenolic compounds, enzymes, vitamins, and organic acids at a high incorporation dose (Boudreau and Beland, 2006). In addition, the incorporation of *Aloe vera* extracts into an EC solution might contribute to having a dense coating structure and increased oxygen barrier feature, which limits the exposure of cooked ground chicken meat samples to oxygen and slows down the development of lipid oxidation (Ruan *et al.,* 2019). Kanatt and Makwana (2020) also reported that carboxymethyl cellulose-poly vinyl alcohol-*Aloe vera* active packaging film had good antioxidant activity in ground chicken meat. As a result of the TBARS analysis, it was determined that the application of EC containing 2% concentration of *Aloe vera* extracts had an antioxidant effect on cooked ground chicken meat during the 14 days of storage.

3.5. TPA

The results (data not shown) revealed that the adhesiveness (mJ), chewiness (N), cohesiveness, gumminess (N), hardness (N), resilience, and springiness values for cooked ground chicken meat were not affected by the EC application containing AVG or AVLS extracts during 14 days of storage ($P > 0.05$). There were also no significant differences in the TPA results for cooked ground chicken meat, with or without coating, because of a stable emulsion created by 1% added NaCl into the formulation as revealed by Tosati *et al*. (2017), who also stated that the texture profile of uncoated and coated sausages was not affected by the turmeric starch and bovine gelatin edible coating application. The results obtained from the TPA analysis confirmed that the application of EC containing AVG or AVLS extracts did not adversely affect the textural quality attributes of cooked ground chicken meat. These results were in accordance with previous research which showed that soy protein coated beef patties maintained their textural quality characteristics for up to 14 days (Guerrero *et al.,* 2015).

4. CONCLUSIONS

The results of this study indicated that the phenolic contents in *Aloe vera* gel and leaf skin extracts used in WPI-based edible coating solution were similar. EC application decreased the pH values in cooked ground chicken meat. The groups coated with the EC solution containing AVG or AVLS extracts had lower pH values than those coated with the EC solution without extracts. This study also demonstrated that EC application with or without AVG or AVLS extracts increased the aw of cooked ground chicken meat. Also, the addition of 0.5% and 2% AVG or AVLS extracts into the EC solution resulted in a decrease in the ORP values. The results revealed that using 2% AVG in the coating formulation created a lighter color in the final product compared to the application of coating without extract incorporation and a higher redness feature in comparison to using coating with 0.1% AVG. Furthermore, the application of EC containing 2% AVG or AVLS extracts decreased TBARS values in cooked ground chicken meat during the storage period compared to the uncoated counter-

parts. The results indicated that the textural characteristics of cooked ground chicken meat were not affected by EC application containing AVG or AVLS extracts. It can be concluded that the application of edible coating containing both 2% AVG or AVLS extracts in cooked ground chicken meat was a successful approach for maintaining physicochemical properties and retarding lipid oxidation in cooked poultry meat products stored under refrigerated conditions.

5. DECLARATION OF COMPETING INTEREST

The authors of this article declare that they have no financial, professional or personal conflicts of interest that could have inappropriately influenced this work.

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