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Assessing the Use of *Aloe vera* Gel Alone and in Combination with Lemongrass Essential Oil as a Coating Material for Strawberry Fruits: HPLC and EDX Analyses

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Abstract: Strawberry is a non-climacteric fruit but exhibits a limited postharvest life due to rapid softening and decay. A strawberry coating that is natural and safe for human consumption can be used to improve the appearance and safeguard the fruits. In this study, 20% and 40% *Aloe vera* gel alone or in combination with 1% lemongrass essential oil (EO) was used as an edible coating for strawberries. After application of all the treatments, the strawberry fruits were stored at a temperature of 5 ± 1 °C at a relative humidity (RH) of 90%–95% for up to 16 days and all the parameters were analyzed and compared to control (uncoated fruits). The results show that *A. vera* gel alone or with lemongrass EO reduced the deterioration and increased the shelf life of the fruit. Treatment with *A. vera* gel and lemongrass EO decreased acidity and total anthocyanins and maintained fruit firmness. Treatment with *A. vera* gel 40% + lemongrass EO 1% led to the lowest weight loss, retained firmness and acidity, but increased the total soluble solids and total anthocyanins compared to uncoated fruits during storage of up to 16 days. The phenolic compounds of *A. vera* gel were analyzed by HPLC, and the most abundant compounds were found to be caffeic (30.77 mg/mL), coumaric (22.4 mg/mL), syringic (15.12 mg/mL), sinapic (14.05 mg/mL), ferulic (8.22 mg/mL), and cinnamic acids (7.14 mg/mL). Lemongrass EO was analyzed by GC–MS, and the most abundant compounds were identified as α-citral (neral) (40.10%) β-citral (geranial) (30.71%), γ-dodecalactone (10.24%), isoneral (6.67%), neryl acetal (5.64%), and linalool (1.77%). When the fruits were treated with 20% or 40% *A. vera* gel along with 1% lemongrass, their total phenolic content was maintained during the storage period (from 4 to 8 days). The antioxidant activity was relatively stable during the 8 days of cold storage of the fruits coated with *A. vera* gel combined with lemongrass EO because the activity of both 20% and 40% gel was greater than that for the other treatments after 12 days of storage in both experiments. Moreover, all the treatments resulted in lower numbers of total microbes at the end of the storage period compared with the control treatment. This study indicates that the use of *Aloe vera* gel with lemongrass EO as an edible coating considerably enhances the productivity of strawberry fruits and the treatment could be used on a commercial scale.

Keywords: edible coatings; *Aloe vera* gel; lemongrass essential oil; shelf life; strawberry fruit

1. Introduction

Strawberry (*Fragaria* × *ananassa*) is an economically important crop worldwide [1,2]. It has a great nutritional value because it contains minerals, vitamins, flavonoids, and phenolic compounds with beneficial biological properties, for instance antioxidant, anticancer, and anti-inflammatory activities [3,4]. Strawberry has tremendous prospects for commercial use, e.g., for the extraction of natural color with great potential for diverse value-added processed products [5]. However, the physiological characteristics of strawberry fruits deteriorate easily, as their softening reduces their postharvest shelf life during cold storage [6,7].

Postharvest losses in produce are a constant struggle for modern agriculture, which makes it urgent to develop new alternatives to reduce the waste [8,9]. To prolong the storage life of fresh and minimally processed fruits and vegetables, several physical, chemical, and biological alternatives and treatments have been proposed [10]. Recently, methods of ozone, electrolyzed water, modified/controlled atmospheric packaging, natural compounds, antifungal edible coatings, and biocontrol agents have emerged as safe alternatives and efficient preservation methods in the fresh produce industry [11–13].

Edible coatings are made up of natural polymers, such as carbohydrates, proteins, waxes, and their composites, that separate fruits from the surrounding atmosphere [14,15]. Coatings with edible films and essential oils (EOs) can also help to maintain the postharvest quality of fruits by reducing transpiration and respiration [16,17]. They also protect fruits and vegetables from deterioration by reducing the microbial growth and enhancing the textural quality [18–20].

Aloe vera (*Aloe barbadensis* Miller) is a succulent plant belonging to the family Asphodelaceae [21]. *A. vera* leaves have been used for many centuries for their therapeutic properties, and over 75 active ingredients have been identified in its gel [22].

A. vera gel is rich in soluble sugars and polysaccharides but has low properties of hydrophobic and lipid levels with gas barrier efficacy, making it an ideal edible coating material [23,24]. Moreover, *A. vera* gel coatings act as a barrier to moisture and O_2, reducing the respiration rate, thereby preventing anaerobic conditions and conserving fruit quality [25].

As a coating material, *A. vera* gel maintains the texture, color, and shelf life of fruits and vegetables [26,27]. It is edible, invisible, odorless, and does not affect the quality of the fruit and vegetables, moreover, it is safe for human health and ecofriendly [28]. Furthermore, it reduces respiration rate, moisture loss, softening of tissues, oxidative browning, and proliferation of microorganisms in fruits, such as strawberry, cherry laurel fruit, and grapes [27,29,30]. Using *A. vera* gel dip coating reduced weight loss, changes in the physicochemical parameters, and decay, extending the shelf life of figs and litchi fruits [30,31].

EOs play an important role in the protection of the plants as they are antimicrobials and insecticides [32]. One of the advantages of plant EOs is their bioactivity in the vapor phase, which makes them possible fumigants to control postharvest rotting fungi in fruits and grains [33]. For example, lemongrass (*Cymbopogon citratus*), one of the important medicinal herbs, belonging to family Poaceae, is known to have strong antimicrobial and insecticidal properties [34–38]. It shows a strong fungicidal effect against microorganisms in fruit juices [39]. Lemongrass EOs are composed of terpenes and phenylpropenes compounds [40]. In addition, they contain other chemical groups like ketones, alcohols, esters, aldehyde, and flavonoid compounds [41]. The major components of Lemongrass EOs are nerol, α-citral, citronellal, β-citral, geraniol, terpinolene, myrcene, geranyl acetate, terpinol, and methylheptenone [34–37,42,43]. Mixtures of *A. vera* gel and EOs are widely studied as edible coatings for fresh-cut and whole fruit [14].

The present research assessed the effect of *A. vera* gel and lemongrass EO to enhance the postharvest quality, bioactive constituents, and shelf life of strawberry fruit.

2. Materials and Methods

2.1. Plant Material

In two successive experiments during 2020, fruits of strawberry (*Fragaria* × *ananassa* Duch.) cv. Winterstar, a short-day genotype adapted to an annual plastic culture growing system, were harvested at commercial maturity (red color on 80% of the fruit surface) at 30°35′34.5″ N, 30°42′58.4″ E, Behira Governorate, Egypt. The plant is compact, upright, and with long pedicels, making the fruit easy to harvest. This variety produces conical and firm fruit that is uniform in shape throughout the season and has low sourness. The mature fruit has red color on about 90% of its surface [44]. Those fruits were chosen that had red color on over 80% of their surface and were free from mechanical damage, blemishes, and disease [27]. On the same day of harvesting, the fruits were delivered to the laboratory of Alex Postharvest Center (APHC), Faculty of Agriculture, Alexandria University. Then, they were washed with fresh water, air dried, and used in the post-harvest treatments.

2.2. A. vera Gel Extraction and HPLC Analysis of Phenolic Compounds

A. vera mature leaves were obtained from the Nursery of Floriculture, Ornamental Horticulture and Garden Design Department, Faculty of Agriculture, Alexandria University (Alexandria, Egypt). The leaves were washed in tap water and then the gel was separated and blended to obtain a homogeneous mixture. The mixture was filtered using a muslin cloth and then centrifuged at $10000 \times g$ for 25 min to remove the fibers [45]. Then, concentrations were prepared for HPLC analysis as follows: 0.5 g of powdered *A. vera* gel was extracted by ultrasound for 30 min at 25 °C using methanol/water (80%, *v/v*) and filtered.

Phenolic compounds were identified by high-performance liquid chromatography equipment (Agilent 1100, pump PU-1580; UV detector UV-1570; injector equipped with a 20 µL loop) (Agilent Technologies, Santa Clara, CA, USA). The samples were separated using a 250 mm × 4.6 mm stainless-steel column Discovery-C18 4 µm (Agilent Technologies, Santa Clara, CA, USA). The flow rate of the mobile phase was kept at 1 mL/min. Solvent A was water containing 0.05% formic acid, and solvent B was acetonitrile/methanol (80%:20%, *v/v*). The gradient conditions were as follows: 0–5 min, 10% B; 5–15 min, 10%–18% B; 15–25 min, 18% B; 25–30 min, 18%–25% B; 30–35 min, 25% B; 35–40 min, 25%–35% B; 40–45 min, 35%–60% B; 45–50 min, 60%–10% B; and 50–55 min, 10% B. The temperature of the column was controlled at 25 °C.

2.3. Extraction and Chemical Analysis of Lemongrass EO

Lemongrass leaves were obtained from the Nursery of Floriculture, Ornamental Horticulture and Garden Design Department, Faculty of Agriculture, Alexandria University. About 100 g of fresh leaves were chopped and put in a 2 L flask and the essential oil (EO) was hydrodistillated using a Clevenger-type apparatus for 3 h. The collected EO was kept in brown bottles at 4 °C until use [46].

The EO chemical composition was determined using a Trace GC Ultra-ISQ mass spectrometer (Thermo Scientific, Austin, TX, USA) with a direct capillary column TG–5MS (30 m × 0.25 mm × 0.25 µm film thickness). To prepare the EO for GC–MS, 5 µL from the pure lemongrass EO was dissolved in 1.5 mL of hexane. Then, 1 µL was injected into GC–MS. The temperatures of column oven, chemical separation and identification conditions can be found in a previous study [47]. The match factor (MF) between the mass spectrum obtained for each compound and the library mass spectra for each compound was measured and reported, where it was accepted if its value $\geq$ 650 [35].

2.4. Preparation of A. vera–Lemongrass EO Coating

A. vera gel solution (20%–40%) + lemongrass EO 1% was mixed by dissolving lemongrass EO in distilled water with a few drops of Tween-80 (0.01% *w/v*) for 2 min, then the gel was added under vigorous shaking for approximately 2 min [12].

2.5. Treatment Application and Analysis

The fruits were separated into five groups (150 fruits per group and 3 replicates/treat -ment). Each group was treated by immersing fruits with the treatments mentioned in Table 1, for 1 min. Then, the fruits were left to air-dry at room temperature for 1 h so that their surfaces were dry [27,48]. The treated fruits were drained, packed in perforated polystyrene bags (1 L), and stored at 5 ± 1 °C under 90%–95% relative humidity for 16 days. The parameters were recorded every 4 days for each treatment.

Table 1. Fruit coating treatments used in the present study.

Treatments	Concentration
1	Control
2	*A. vera* gel 20% (*v/v*)
3	*A. vera* gel 40% (*v/v*)
4	*A. vera* gel 20% + lemongrass EO 1%
5	*A. vera* gel 40% + lemongrass EO 1%

2.6. Physical Parameters of Strawberry

2.6.1. Weight Loss (%)

The fresh weight of fruit of each replicate was measured on the treatment day and at 4, 8, 12, and 16 days of sampling time. The cumulative weight loss was expressed as a percentage loss of the original fresh weight: weight loss (%) = $(F_0 - F_1)/F_0 \times 100$, where F_0 is the initial fresh weight and F_1 is the measured weight on each sampling day.

2.6.2. Fruit Firmness

The strawberry fruit firmness was determined using a texture analyzer for each treatment and storage period using FT011 Fruit Firmness Tester (Wagner Instruments, Greenwich, CT, USA). This instrument consists of penetrating cylinder (1 mm in diameter) to penetrate inside the pulp of fruits up to a constant distance of 5 mm at a speed 2 mm/s. The firmness per Newton (N) was measured.

2.7. Color Fruit Samples

HunterLab Colormeter (HunterLab Labscan 600 spectrocolorimeter, version 3.0; Hunter Associates Laboratory Inc., Reston, VA, USA) was used according to the Granato and Masson [49]. Strawberry fruits from each treatment were measured at three equidis-tant points for L* (lightness), a* (redness), b* (yellowness), while hue angle (h°) was measured [(h° = $\tan^{-1}$(b*/a*)] for each sample.

2.8. Physicochemical and Bioactive Constituents of Strawberry

2.8.1. Soluble Solid Content (SSC)

Firstly, in a mortar, the fruit samples were crushed then squeezed to acquire juice by hand. A digital refractometer (model PR101, Co. Ltd., Atago, Tokyo, Japan) was used to measure the soluble solid content (SSC) in the fruit juice.

2.8.2. Titratable Acidity (TA), pH and Total Anthocyanin Measurements

Fruits titratable acidity (TA) was analyzed using the Association of Official Analytical Chemists' (AOAC) standard [50]. pH was measure by a digital pH meter (Martini, Temper-ature Laboratory Bench meter Mi 150 pH, Da Nang City, Vietnam) according to the AOAC standard [50]. All parameters of fruit samples were determined after 4, 8, 12, and 16 days. Total anthocyanins were extracted and then calculated (mg of cyanidin chloride g^{-1}) [51].

2.8.3. Total Phenolic Content

Phenolic compounds were extracted with methanol (containing 0.1% HCl) as a solvent. One gram of the sample was individually blended with the solvent at a ratio of 1:20 (*w/v*) and the extraction was carried out twice at the room temperature. Then the extract was

stored at -18 °C until use. The total phenolic content was measured at 750 nm by Optizin UV–Vis spectrophotometer model (Thermo Electron Corporation, Waltham, MA, USA) [50] followed by Folin–Ciocalteu reagent and gallic acid (GA) as the standard. The results were expressed as mg of GA equivalent (GAE)/100 g of FW.

2.8.4. Antioxidant Activity

Strawberry fruit samples (10 g) were soaked in 80% ethanol (50 mL) for 1 week at room temperature, filtered through Whatman paper No. 1, and stored at 4 °C in a refrigerator until use [52]. The antioxidant activity was assessed by evaluating the free-radical-scavenging activity of the 2,2-diphenyl-1-picryl-hydrazyl (DPPH) radical according to a modified method as described previously [53] using Optizin UV–Vis spectrophotometer model (Thermo Electron Corporation, Waltham, MA, USA). The radical-scavenging activity was calculated as a percentage of DPPH discoloration using the following equation: scavenging activity (%) = $((A_{Control} - A_{Sample})/A_{Control}) \times 100$, where A_{Sample} is the absorbance of the tested sample and $A_{Control}$ is the absorbance of the control (DPPH solution).

2.8.5. Fruit Extraction and HPLC Analysis of Flavonoid Compounds

From each treatment, about 50 gm of strawberry fruits were soaked in 60 mL of ethanol for 1 week to acquire the extract. The extracts were filtered using filter paper (Whatman No. 1), concentrated, and in brown vials were stored for further analysis. The flavonoid compounds from the extracts were identified by HPLC (Agilent 1100, Santa Clara, CA, USA), composed of two LC pumps, a UV/Vis detector, and a C18 column (250 mm × 4.6 mm, 5 μm) [54].

2.9. Elemental Analysis of Strawberry Fruit EDX Analysis

Elemental analysis of strawberry fruits was performed by scanning electron microscopy (SEM), attached with energy dispersive spectrometry (EDX), and a JFC-1100E ion sputtering device (model JEOL/MP, JSMIT200 Series, Tokyo, Japan) with an acceleration voltage of 20.00 kV (SEM–EDX) [55] to measure the changes in the elemental chemical composition of strawberry fruits due to different treatments.

2.10. Microbiological Analysis

Samples of a specific weight were pacified to decimal serial dilutions in Ringer's solution (Sigma-Aldrich, Milan, Italy), and 25 g of the fruit samples were homogenized in a flask containing 225 mL of Ringer's solution (Sigma-Aldrich, Milan, Italy) using the Bag-Mixer 400 stomacher (Interscience, Saint Nom, France) for 2 min at the highest speed (blending power 4). All test tubes of serial dilutions used contained Ringer's solution (9 mL). Peptone Dextrose agar (PDA) was used for all plate media. A total of 1 mL of the bacterial suspension was pipetted into a dilution tube containing 9 mL of Ringer's solution. This tube was vortexed, and 1 mL of this volume was removed and placed into a second dilution tube containing 9 mL of Ringer's solution. This process was repeated until the sample was sufficiently diluted. These PDA plates are prepared in three replicates, and 100 mL of this suspension was added to the plates and repeated for every tube in the dilution series. The different microbial groups were investigated as follows: total mesophilic microorganisms (TMM) on plate count agar (PCA) incubated at 37 °C for 48 h and total yeasts and molds (TYM) on PDA supplemented with chloramphenicol (0.1 g/L) to avoid the growth of bacteria then incubated for 48 h at 25 °C. Plate counts were achieved by the spread plate method [56] by inoculating 100 μL from each sample's suspension of appropriate dilution. All media were supplied from Oxoid (Milan, Italy). At each collection time, the microbiological counts were performed in triplicate.

2.11. Statistical Analysis

Data were subjected to statistical analysis for calculation of means, variance and standard error using CoStat Software Program Version 6.303 (CoHort Software, Monterey, CA, USA)

using one-factor analysis of variance (ANOVA, general linear model), followed by Duncan multiple range test for $p < 0.05$ [57] was used to test the differences among treatments.

3. Results and Discussion

3.1. Phenolic Profile of A. vera Gel by HPLC

The data in Table 2 and Figure 1 show the six identified phenolic compounds of *A. vera* gel by HPLC. Caffeic acid is the most abundant, followed by coumaric, syringic, sinapic, ferulic, and cinnamic acids, and their percentages are displayed in Table 2. These data were matched with the studies by López et al. [58], who found that *A. vera* gel contains catechin, sinapic acid, and quercitrin; Elbandy et al. [59], who observed that gallic protocatecuic, vanillic, ferulic acids, cinnamic, p-coumaric acids, hesperidin, rosmarinicrutin, quercitrin, narengenin, hesperitin, kampferol, and apigenin are the main components of *A. vera* gel; and Numan [60], who confirmed that the gel contains the phenolic compounds quercetin, catechin, aloe emodin, sinapic acid, and aloin [58,60].

Table 2. Identification of the phenolic compounds in *A. vera* gel by HPLC.

R.T. (min)	Compound	Concentration (mg/mL)
5.00	Coumaric acid	22.4
7.01	Ferulic acid	8.22
8.00	Caffeic acid	30.77
9.00	Syringic acid	15.12
11.10	Sinapic acid	14.05
15.00	Cinnamic acid	7.14

R.T.: retention time.
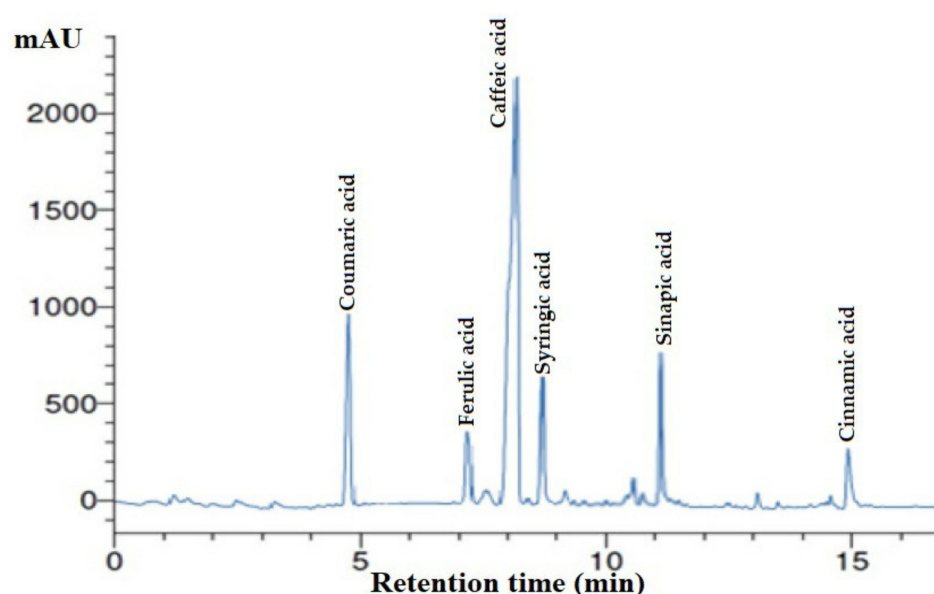
Figure 1. Phenolic profile of *A. vera* gel by HPLC.

3.2. Chemical Constituents of Lemongrass Oil

Table 3 shows the chemical constituents of the EO from lemongrass fresh leaves, where the main components were α-citral (neral) (40.10%), β-citral (geranial) (30.71%), γ-dodecalactone (10.24%), isoneral (6.67%), neryl acetal (5.64%), linalool (1.77%), citral (1.22%), isocitral (0.97%), and geraniol acetate (0.91%). Previous studies have reported that the major constituents of EO are α-citral, β-citral, geraniol, nerol, terpinolene, geranyl acetate, citronellal, myrcene, and terpinol methylheptenone [37]. In one study, α-citral (44.97%), α-citral (33.06%), and myrcene (7.68%) were identified as the major compounds of lemongrass EO [61].

Table 3. Phytochemical constituents of lemongrass EO identified by GC–MS.

| Chemical Compound	Percentage (%)	MF
Linalool	1.77	861
Isocitral	0.97	853
Isoneral	6.67	943
α-Citral (Neral)	40.10	930
β-Citral (Geranial)	30.71	916
Citral	1.22	931
Neryl acetal	5.64	876
γ-Dodecalactone	10.24	912
Geraniol acetate	0.91	897
2-Tridecanone	0.70	867
Nizatidine	0.32	979
β-Caryophyllene epoxide	0.36	917
Selin-6-en-4β-ol	0.40	892

MF: match factor.

In general, lemongrass EO contains greater than 45% of α- or β-citral but the amount can vary widely depending on the factors the plants are exposed to, such as genetic diversity, weather, and extraction techniques [62–64].

3.3. Physical Parameters of Strawberry fruits

3.3.1. Weight Loss (%)

The effects of different treatments on the weight loss (%) of strawberry fruits during the 16 days of storage period in both experiments are shown in Figure 2. During the time in all treatments, the weight loss (%) was significantly ($p \leq 0.05$) increased, but all the edible coating treatments helped to reduce the weight loss of strawberry fruit in the two experiments. At the end of storage (day 16), the highest weight loss (6.11%) was observed for the control sample, while the lowest value (11.87%) was obtained for fruits treated with *A. vera* gel 40% + lemongrass EO 1% coating, followed by fruits treated with *A. vera* gel 20% + EO 1% coating (7.63%), in the two experiments.
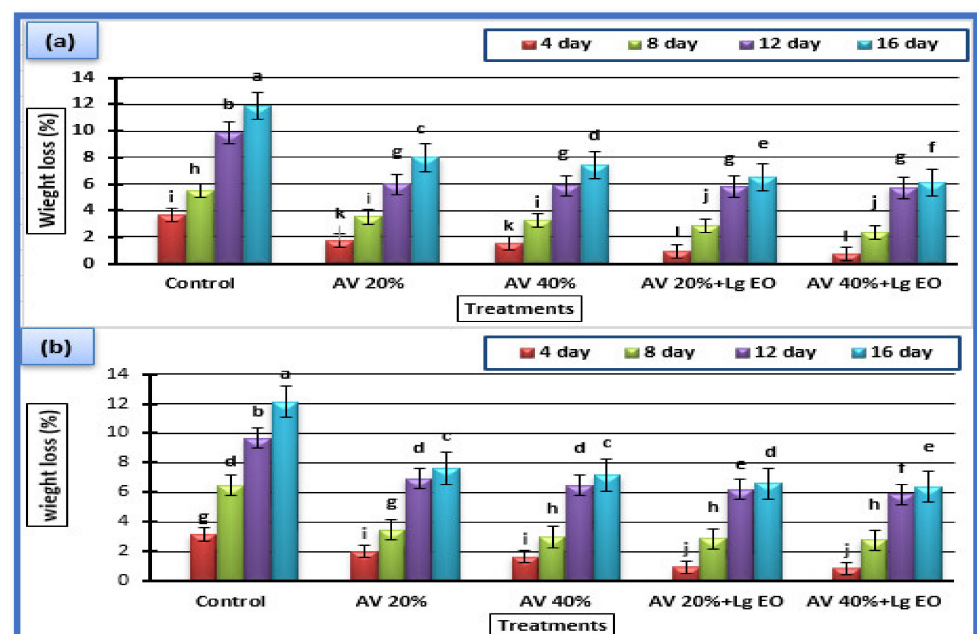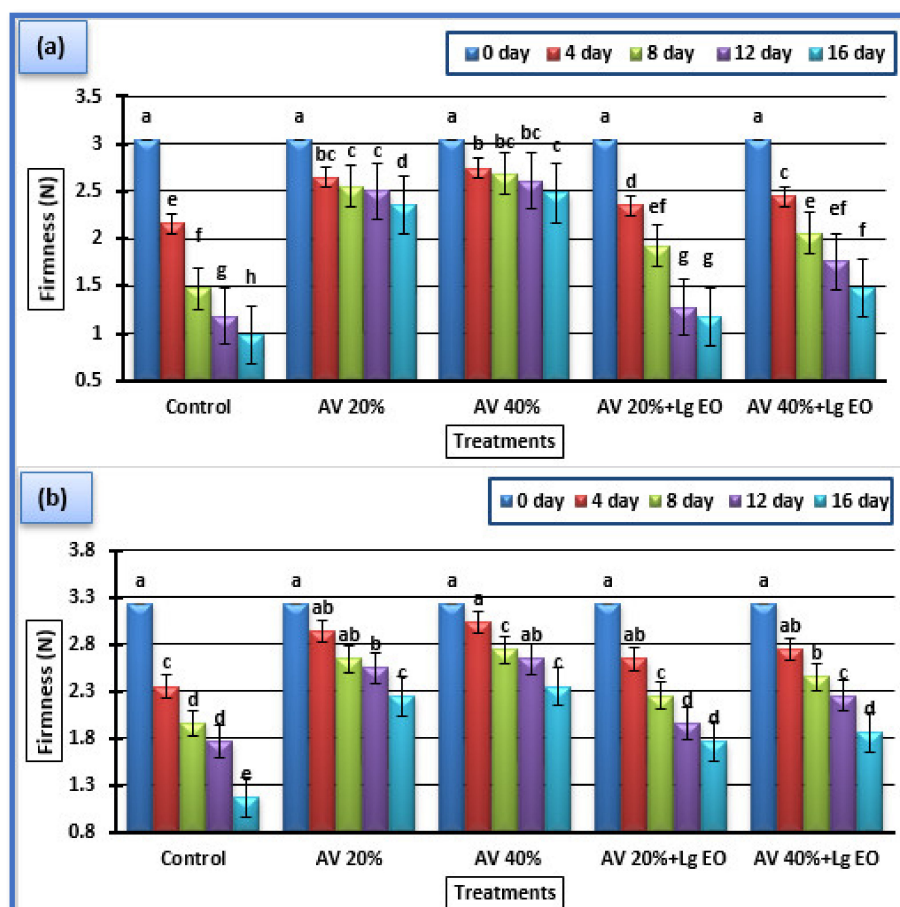

Figure 2. Weight loss (%) (mean ± S.E.) of strawberry fruits stored at 5 °C as affected by coating treatments when stored for different lengths of time in both experiments. The mean ± S.E. of treatments in the figures with the same letter/s shows a nonsignificant difference according to Duncan multiple range test for *p* < 0.05. AV: *A. vera* gel. (**a**) First experiment; (**b**) second experiment.

The reduction in the weight loss in the fruits treated with *A. vera* with EO could be due to composition of polysaccharides in *A. vera* gel, which act as an effective moisture barrier [23,24]. The water loss reduction mechanism is based on the hygroscopic water pressure between the fruit and environment, whereas *A. vera* gel can form a film on the strawberry surface with a thin layer, sealing small wounds and reducing moisture loss [27,65,66].

3.3.2. Fruit Firmness

The firmness of strawberry fruits significantly reduced after all treatments during storage of 4, 8, 12, and 16 days in the two experiments, as shown in Figure 3. The coating treatments showed a higher firmness value than the control strawberry fruits. The firmness of strawberries treated with *A. vera* gel at 20% and 40% was found to be lower than that of other coated samples with *A. vera* gel combined with EO during different days of storage, showing that the treated and control strawberry fruit become less firm due to reaping (Figure 3). Compared to that of the control, the highest firmness value was that of strawberry fruits treated with *A. vera* gel 40%, followed by the fruits treated with *A. vera* gel 20% and those treated with *A. vera* gel with EO 1%. *A. vera* gel coatings retarded the postharvest ripening process and reduced the firmness of table grape and sour cherry [67,68]. Lower water vapor from fruits subjected to *A. vera* gel coating results in maintained turgor pressure of the cell wall [69,70]. The treated fruits with *A. vera* with EO showed slightly higher firmness, that could be due to the higher hydrophobic properties in this treatment. In agreement with this work, the coated strawberry fruits with *A. vera* gel alone and combined with basil EO had a lower softening rate compared to the control treatment [71].

Figure 3. Firmness (N) (mean ± S.E.) of strawberry fruits stored at 5 °C as affected by coating treatments when stored for different lengths of time in both experiments. The mean ± S.E. of treatments in the figures with the same letters shows a nonsignificant difference according to Duncan multiple range test for $p \leq 0.05$. AV: *A. vera* gel. (**a**) First experiment; (**b**) second experiment.

3.4. Color Value

The data in Tables 4 and 5 show that the color value of strawberry fruits was influenced by the different coating treatments. The L* of the strawberry fruits increased in lightness in both coating treatments during the shelf-life study. In other words, a coating of *A. vera* gel or *A. vera* gel with lemongrass EO helped to maintain the lightness of the fruit compared to the control samples (Tables 4 and 5). The chromaticity coordinate a* value, representing the red-green color, was slightly affected by the coatings and remained stable in all treatments during the shelf life. The chromaticity coordinate b* value of strawberry fruits slightly reduced over storage time and coating treatment by *A. vera* gel only. However, *A. vera* gel with lemongrass EO increased this parameter by day 16 in the two experiments. Coated and control fruits showed a significant decrease in hue during the first 8 days of storage and the hue increased as the storage period was increased to 16 days (Tables 4 and 5).

Table 4. Color values of strawberry fruits as affected by coating treatments after 0, 8, and 16 days of storage at 5 °C in Experiment 1.

Experiment 1					
Treatments	**Days**	**L***	**a***	**b***	**h°**
Control	0	43.83 ± 1.21 [b]	43.64 ± 1.89 [b]	21.05 + 2.87 [b]	1.97 + 1.12 [ab]
	8	35.66 ± 2.24 [d]	44.93 ± 2.13 [b]	20.87 + 1.87 [b]	1.57 + 0.87 [d]
	16	33.70 ± 1.54 [e]	45.45 ± 1.97 [ab]	19.16 + 1.22 [cd]	1.90 + 0.58 [b]
A. vera gel 20%	0	43.83 ± 1.21 [b]	43.64 ± 1.89 [b]	21.05 ± 2.87 [b]	1.97 ± 1.12 [ab]
	8	39.40 ± 1.32 [cd]	49.47 ± 2.54 [a]	19.48 ± 2.01 [cd]	1.37 ± 1.02 [ef]
	16	35.61 ± 1.12 [d]	44.63 ± 2.33 [b]	17.07 ± 1.33 [d]	1.57 ± 0.98 [d]
A. vera gel 40%	0	43.83 ± 1.21 [b]	43.64 ± 1.89 [b]	21.05 ± 2.87 [b]	1.97 ± 1.12 [ab]
	8	38.40 ± 2.12 [cd]	44.05 ± 2.01 [b]	18.49 ± 1.21 [cd]	1.45 ± 1.03 [e]
	16	36.84 ± 1.34 [d]	44.87 ± 2.44 [b]	16.28 ± 1.32 [d]	1.15 ± 0.45 [f]
A. vera gel 20% + lemongrass EO 1%	0	43.83 ± 1.21 [b]	43.64 ± 1.89 [b]	21.05 ± 2.87 [b]	1.97 ± 1.12 [ab]
	8	37.80 ± 2.65 [cd]	36.43 ± 2.12 [c]	25.25 ± 1.56 [ab]	2.03 ± 1.11 [a]
	16	49.90 ± 1.67 [a]	36.97 ± 2.03 [c]	28.59 ± 1.12 [a]	2.03 ± 1.01 [a]
A. vera gel 20% + lemongrass EO 1%	0	43.83 ± 1.21 [b]	43.64 ± 1.89 [b]	21.05 ± 2.87 [b]	1.97 ± 1.12 [ab]
	8	44.05 ± 1.78 [b]	35.14 ± 2.43 [c]	22.42 ± 1.65 [b]	1.84 ± 0.55 [cd]
	16	46.80 ± 2.03 [a]	34.57 ± 2.63 [c]	25.93 ± 1.78 [ab]	1.81 ± 0.98 [cd]

The mean values with the same superscript letter/s in the same column show a nonsignificant difference according to Duncan multiple range test for $p \leq 0.05$.

Table 5. Color values of strawberry fruits as affected by coating treatments after 0, 8, and 16 days of storage at 5 °C in Experiment 2.

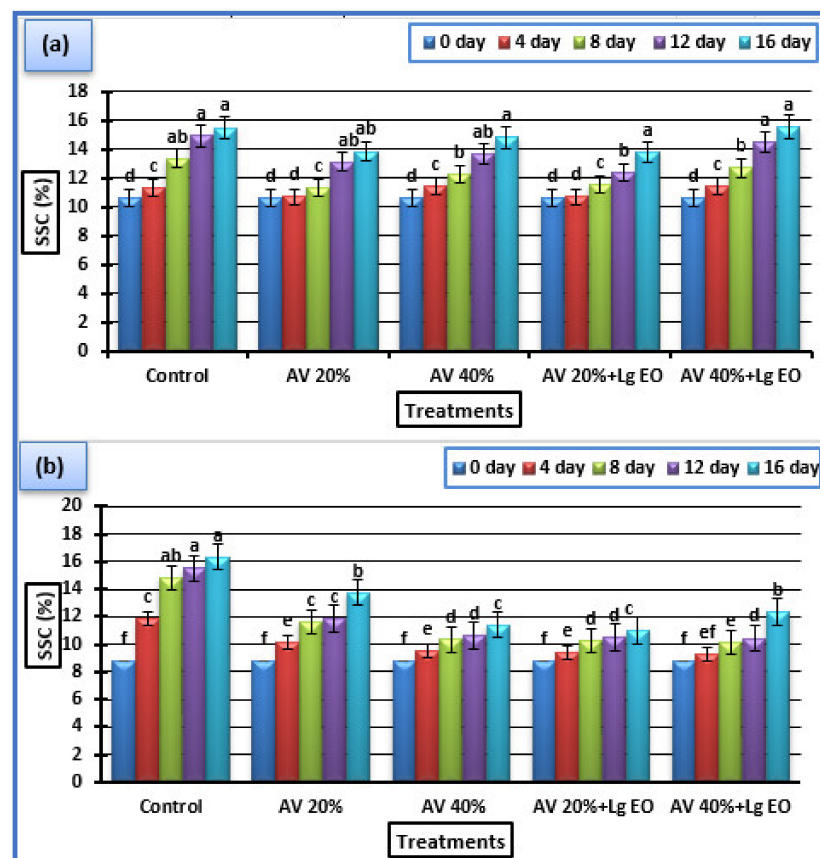| Experimental 2					
Treatments	**Days**	**L***	**a***	**b***	**h°**
Control	0	43.49 ± 2.44 [c]	42.07 ± 2.61 [b]	20.39 ± 1.77 [b]	1.89 ± 0.31 [c]
	8	34.71 ± 2.03 [e]	43.87 ± 2.11 [b]	19.83 ± 1.34 [c]	1.27 ± 0.61 [e]
	16	33.23 ± 1.65 [f]	42.69 ± 1.34 [b]	18.66 ± 1.01 [c]	2.07 ± 0.54 [b]
A. vera gel 20%	0	43.49 ± 2.44 [c]	42.07 ± 2.61 [b]	20.39 ± 1.77 [b]	1.89 ± 0.31 [c]
	8	40.52 ± 2.23 [d]	47.48 ± 2.43 [a]	18.73 ± 1.22 [c]	1.96 ± 1.21 [bc]
	16	34.67 ± 2.01 [e]	43.25 ± 1.87 [b]	17.16 ± 1.02 [d]	2.75 ± 1.32 [a]
A. vera gel 40%	0	43.49 ± 2.44 [c]	42.07 ± 2.61 [b]	20.39 ± 1.77 [b]	1.89 ± 0.31 [c]
	8	39.94 ± 2.46 [d]	46.71 ± 2.21 [a]	18.49 ± 1.67 [d]	1.54 ± 0.64 [d]
	16	35.17 ± 1.78 [e]	43.22 ± 1.44 [b]	20.10 ± 1.25 [b]	1.37 ± 0.67 [e]
A. vera gel 20% + lemongrass EO 1%	0	43.49 ± 2.44 [c]	42.07 ± 2.61 [b]	20.39 ± 1.77 [b]	1.89 ± 0.31 [c]
	8	47.18 ± 2.67 [a]	36.20 ± 1.98 [c]	26.88 ± 1.06 [ab]	1.08 ± 0.23 [g]
	16	48.50 ± 2.43 [a]	37.30 ± 1.66 [c]	29.73 ± 1.33 [a]	1.95 ± 0.35 [bc]
A. vera gel 20% + lemongrass EO 1%	0	43.49 ± 2.44 [c]	42.07 ± 2.61 [b]	20.39 ± 1.77 [b]	1.89 ± 0.31 [c]
	8	45.37 ± 1.56 [b]	35.86 ± 1.78 [d]	26.99 ± 1.89 [ab]	1.16 ± 0.33 [f]
	16	47.08 ± 1.32 [d]	34.19 ± 1.56 [d]	27.19 ± 1.65 [a]	1.86 ± 0.54 [c]

The mean values with the same superscript letter/s in the same column show a nonsignificant difference according to Duncan multiple range test for $p \leq 0.05$.

The color of strawberry fruits is an important property for product reception by the consumer; although the coating did not change the fruit initially color [72], and with the increased storage time, the fruit became redder and darker. This increase was probably due to a reduction in both the respiration rate and some enzymatic processes, maintaining the quality of the fruit and preventing its browning [73]. At the end of storage time, control fruits and those treated with gluten plus CaCl$_2$ had a low L* value (darker color) [74].

3.5. Physicochemical and Bioactive Constituents of Strawberry

3.5.1. Soluble Solid Content (SSC)

The effect of *A. vera* gel and lemongrass EO coating on the SSC content of strawberry fruits during the storage period of 16 days is shown in Figure 4. The SSC content in treated strawberry fruits increased gradually until day 16 of the storage period in the two experiments (Figure 4). Until the end of the trial in the treatments with control and *A. vera* gel 20%, a gradual increase in the SSC was found, which indicates that *A. vera* gel 20% and 40% + lemongrass EO 1% treatments had slowed the respiration rate of strawberry fruits during the storage period. The same result was reported previously, indicating a link between SSC and respiration rate [27]. In both experiments, the maximum increase in the SSC content was found in the control on day 16. In the case of treatment with *A. vera* gel 40% + lemongrass EO 1%, the least SSC content was observed on days 4 and 8 in the second experiment (Figure 4b). The hydrolysis of starch into sugar might cause the initial increase in the SSC and subsequently the decline in SSC could be due to the decreased respiration rate and the metabolism of sugars into organic acids [48]. A lower SSC could be related to the hydrolysis of carbohydrates into sugar [65].
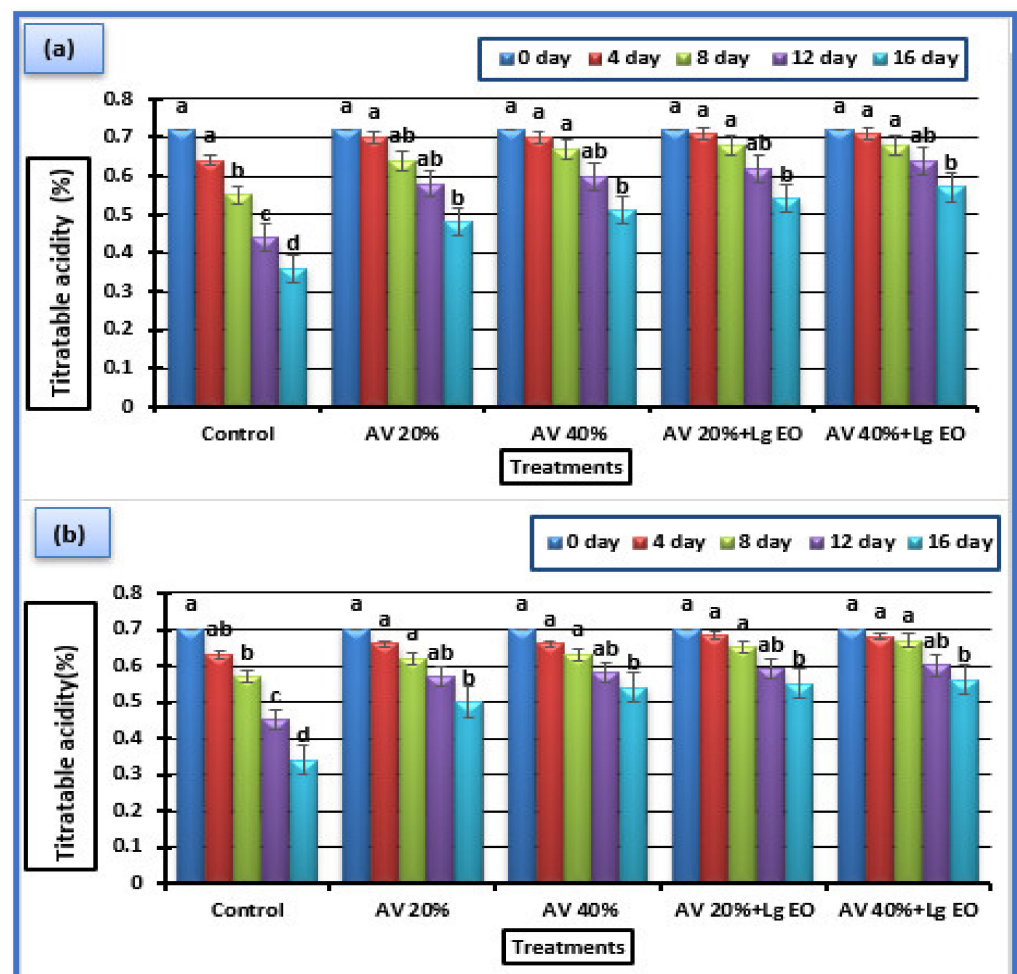

Figure 4. SSC (mean ± S.E.) of strawberry fruits stored at 5 °C as affected by coating treatments when stored for different lengths of time in both experiments. The mean ± S.E. of treatments in the figures with the same letters shows a nonsignificant difference according to Duncan multiple range test for $p \leq 0.05$. AV: *A. vera* gel. (**a**) First experiment; (**b**) second experiment.

3.5.2. Titratable Acidity (TA) and pH

The changes in the Titratable acidity (TA) amount and pH of fruit strawberry in the two experiments during storage are shown in Figures 5 and 6, respectively. The pH of strawberry juices increased in all treatments during the storage period until day 8 in both experiments (Figure 6). Moreover, the coated fruits in both experiments had steadied pH around 3.5. However, coating treatments slowed down the titratable acidity (TA) change in the strawberries during the shelf-life study compared with uncoated fruits (control).

The TA amount in strawberry is directly correlated to fruit organic acids content [48]. The content of fruit acid tends to decrease over time, that could due to the organic acids oxidation as the fruit ripens [75]. The edible coatings of the fruits reduce the respiration rate, decreasing the consumption of organic acids in the respiratory metabolic activities of the fruits [48,76].

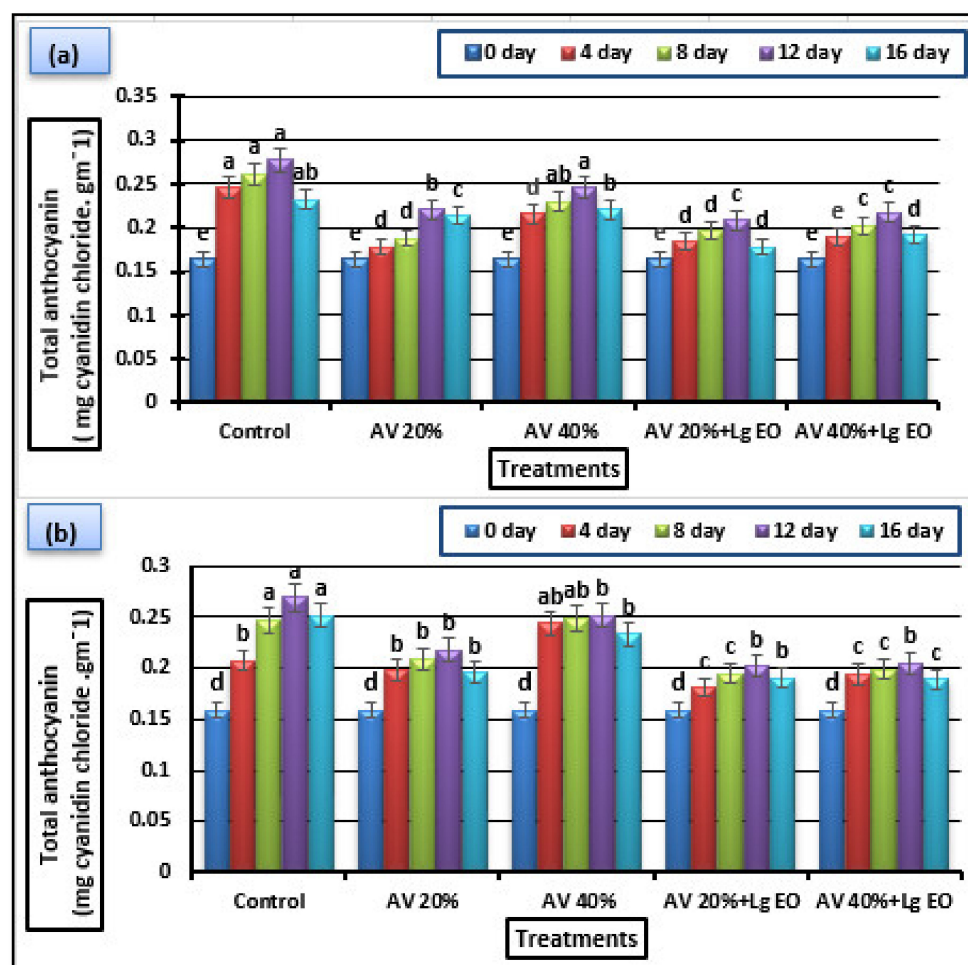**Figure 5.** Titratable acidity (%) (mean ± S.E.) of strawberry fruits stored at 5 °C as affected by coating treatments when stored for different lengths of time in both experiments. The mean ± S.E. of treatments in the figures with the same letters shows a nonsignificant difference according to Duncan multiple range test for *p* ≤ 0.05. AV: *A. vera* gel. (**a**) First experiment; (**b**) second experiment.
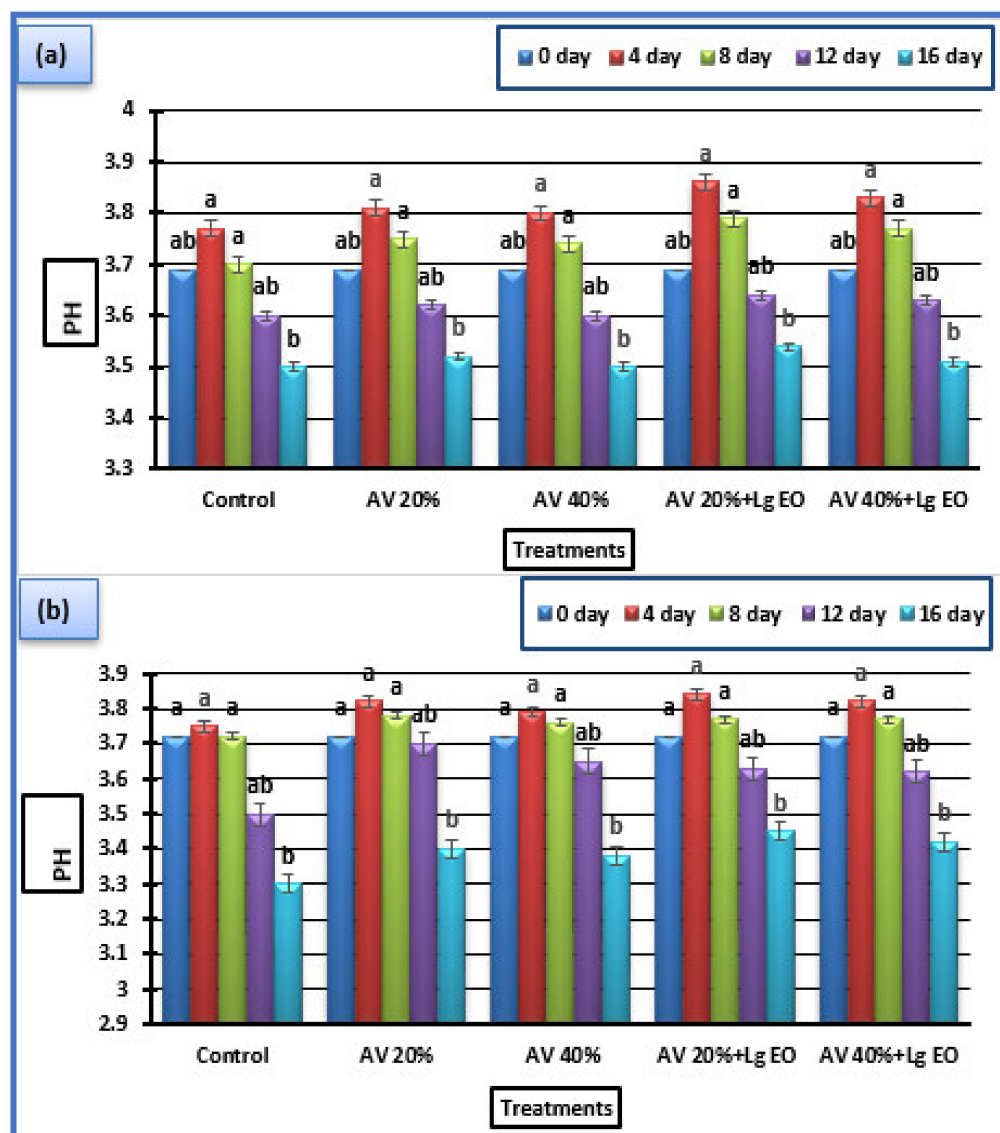
Figure 6. pH (mean ± S.E.) of strawberry fruits stored at 5 °C as affected by coating treatments when stored for different lengths of time in both experiments. The mean ± S.E. of treatments in the figures with the same letters shows a nonsignificant difference according to Duncan multiple range test for $p \leq 0.05$. AV: *A. vera* gel. (**a**) First experiment; (**b**) second experiment.

3.5.3. Total Anthocyanins

The change in the total anthocyanins of strawberry fruits coated with *A. vera* gel and *A. vera* gel with lemongrass EO is shown in Figure 7. The total anthocyanin content in all the treatments increased for the first 12 days of storage in both experiments. Thereafter, it decreased gradually for the remainder of storage. The untreated fruit showed the maximum anthocyanin concentration (277 mg·kg^{-1}) on day 12 of the storage, followed by fruits treated with *A. vera* gel 40% + lemongrass EO 1% (246 mg·kg^{-1}) and those treated with *A. vera* gel 20% + lemongrass EO 1% (221 mg·kg^{-1}) at the end of the storage period, compared to 163 mg·kg^{-1} when the fruits were initially stored.
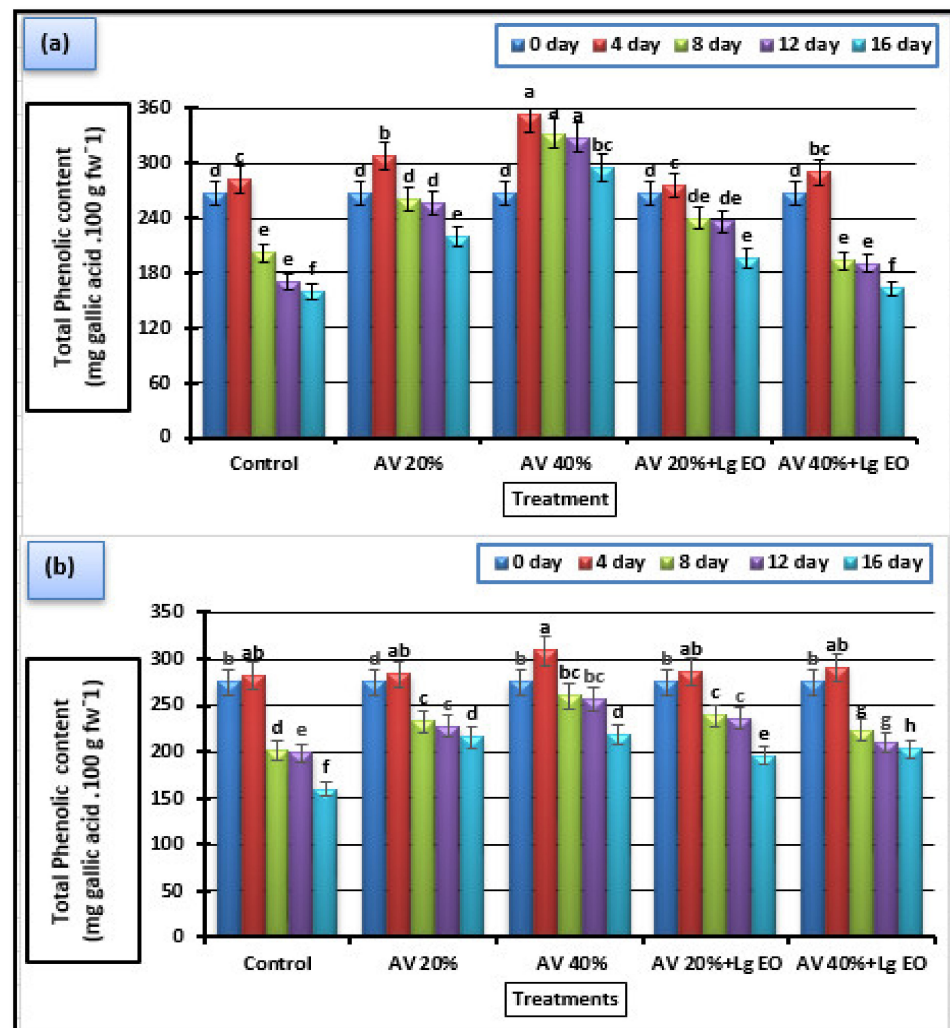
Figure 7. Total anthocyanin (mg of cyanidin chloride.gm^{-1}) (mean $\pm$ S.E.) of strawberry fruits stored at 5 °C as affected by coating treatments when stored for different lengths of time in both experiments. The mean $\pm$ S.E. of treatments in the figures with the same letters shows a nonsignificant difference according to Duncan multiple range test for $p \leq 0.05$. *A. vera* gel. (**a**) First experiment; (**b**) second experiment.

The significant increase in anthocyanin in control treatment could probably be related to the natural process during fruit ripening. However, the fruits treated with EOs showed a lower concentration of anthocyanin than the untreated ones. During cold storage the anthocyanin of treated fruits was increased, similar to those reported previously [77], which may be due to the continued biosynthesis of these compounds after harvest. Furthermore, total anthocyanin showed significant differences among fruits coated with a lemongrass EO and alginate-based edible coating [78].

3.5.4. Total Phenolic Content

It is clear from Figure 8 that all examined postharvest treatments decreased the total phenolic content (TPC) in both experiments. However, the highest TPC was recorded by untreated fruits, followed by fruits treated with *A. vera* gel 20%. The lowest values of TPC were scored by the treated fruits with *A. vera* gel 40% + lemongrass EO 1% and those treated with *A. vera* gel 20% + lemongrass EO 1% during both experiments. Figure 8 also indicates that regardless of the initial reading, the TPC was increased from day 4 to day 8 of storage.
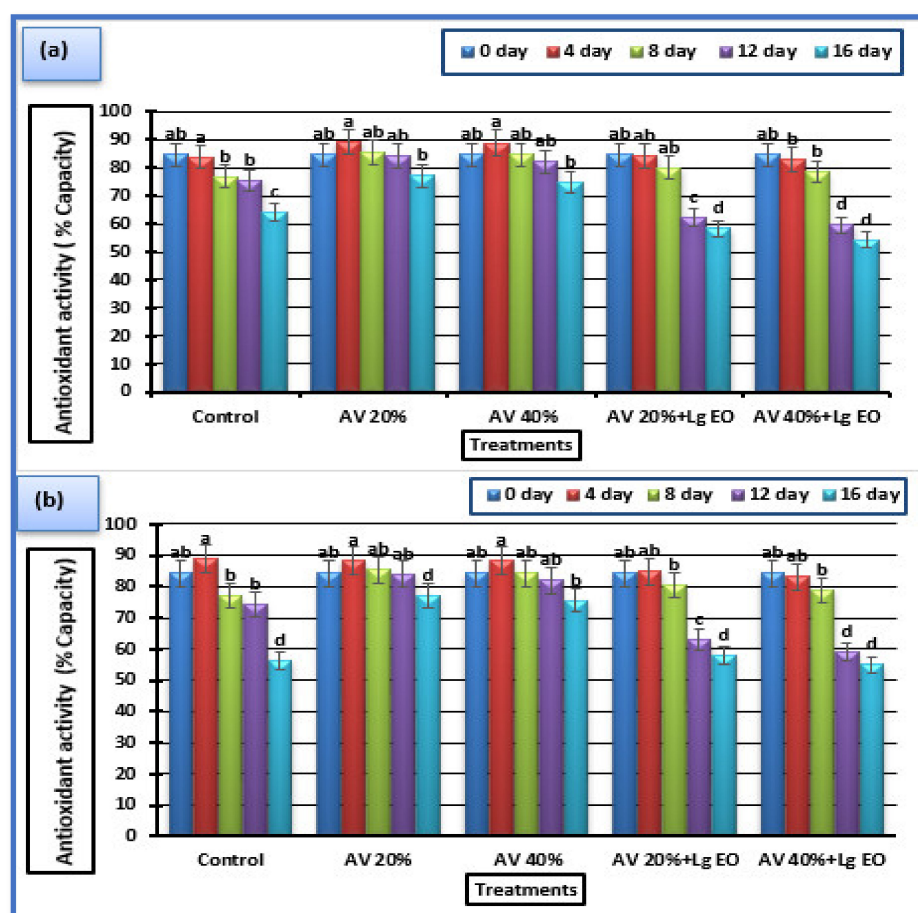
Figure 8. Total phenolic content (mg of gallic acid.100 g fw^{-1}) (mean ± S.E.) of strawberry fruits stored at 5 °C as affected by coating treatments when stored for different lengths of time in both experiments. The mean ± S.E. of treatments in the figures with the same letters shows a nonsignificant difference according to Duncan multiple range test for $p \leq 0.05$. AV: *A. vera*. (**a**) First experiment; (**b**) second experiment.

Anthocyanins are a group of phenolic compounds responsible for the red-blue color of many fruits and are important for human health [79]. The TPC and anthocyanin may be one of their most significant biological properties [80]. In the current study, the TPC decreased while anthocyanin increased in the untreated fruit. It is important for fruits to retain high levels of these compounds during storage and over their shelf life. The anthocyanin and TPC of the treated fruit increased during cold storage (Figure 8), similar to those reported previously [77], which may be due to the continued biosynthesis of these compounds after harvest. The evolution of the TPC of fruits during storage could be different depending on the species, temperature, cultivar, and climactic and environmental conditions during the growth period [48]. The findings indicate that both TPC and anthocyanin content in fruits treated with *A. vera* + ascorbic acid were higher than those in either untreated fruits or fruits treated with *A. vera* alone. Similarly, the use of ascorbic acid as a reducing agent prevented a decrease in the TPC in fresh-cut fruits [14,66].

3.5.5. Antioxidant Activity

The free-radical-scavenging activity (% inhibition) of strawberry fruits' ethanolic extracts was assessed by the DPPH test (Figure 9). Treatments with *A. vera* gel at 20%

and 40% were more effective than treatment with *A. vera* gel with lemongrass EO, since the radical-scavenging activity was 77.04%, 74.58% and 58.22%, 54.29% for *A. vera* gel at 20% and 40% and *A. vera* gel with lemongrass EO, respectively, while it decreased in untreated extract to 64.24% at the end of the storage period. However, antioxidant activity was relatively stable during the 8 days of cold storage in fruits treated with *A. vera* gel and lemongrass EO, and the activity in fruits treated with *A. vera* gel at 20% or 40% was greater than the activity in fruits that underwent other treatments after 12 days of storage in both experiments. Moreover, the antioxidant activity decreased in untreated fruits and fruits treated with *A. vera* gel alone or combined with lemongrass EO. This means that *A. vera* gel at 20% and 40% has powerful potential antioxidant activity and increased the quality and stability of strawberry fruits.

Figure 9. Antioxidant activity (% capacity) (mean ± S.E.) of strawberry fruits stored at 5 °C as affected by coating treatments after being stored for different lengths of time in both experiments. The mean ± S.E. of treatments in the figures with the same letters shows a nonsignificant difference according to Duncan multiple range test for $p \leq 0.05$. AV: *A. vera* gel. (**a**) First experiment; (**b**) second experiment.

Several studies have shown that strawberry is a good source of natural antioxidants [27]. It has been reported that fruits treated with *A. vera* had higher antioxidant capacity than the sample in the case of mango [81], raspberry [77], and table grapes (*Vitis vinifera* L. cv. Yaghouti) [82]. *A. vera* may also increase tissue resistance to decay by enhancing their antioxidant system and free-radical-scavenging capability [83]. Hidayati et al. [84] stated that antioxidant activity can be affected by the phenolic compounds and pigment content. Phenolic compounds and flavonoids as primary antioxidants can play an important role in absorbing and neutralizing free radicals, preventing the progress of diseases such as cancer [85].

3.5.6. Fruit Extraction and HPLC Analysis of the Fruit's Flavonoids

As presented in Table 6, the flavonoid concentration (µg/mL) of strawberry fruit was affected on treatment with *A. vera* gel and lemongrass EO. The highest value of rutin was obtained on treatment with *A. vera* gel 40% + lemongrass EO 1% compared with the initial value in the fruits and the value in the control fruit sample (16.25, 6.14, and 9.14 µg/mL, respectively). Naringin and hesperidin values were the best in the control, with concentrations of 8.16 and 14.56 µg/mL, respectively. Isorhamnetin and genistein were not detected in any treatment except for fruits treated with *A. vera* gel 40% + lemongrass EO 1%, with concentrations of 10.23 and 3.52 µg/mL, respectively. The highest concentration of quercetin was identified in strawberry fruits treated with *A. vera* gel 20% (15.36 µg/mL), the highest value of kaempferol was obtained on treatment with *A. vera* gel 40% (20.47 µg/mL), the highest values for luteolin and catechin were observed in fruits treated with *A. vera* gel 20% (14.66 and 20.56 µg/mL, respectively), and the highest value of 7-hydroxyflavone was obtained in fruits treated with *A. vera* gel 40% (14.16 µg/mL). The best value of chrysoeriol was observed in the initial sample, followed by fruits treated with *A. vera* gel 40%, with concentrations of 25.08 and 17.44 µg/mL. The compound myricetin was not detected in any treatment except in fruits treated with *A. vera* 40%, with a concentration of 2.25 µg/mL. These results are in good agreement with the studies of Hannum [86] and Co and Markakis [87].

Table 6. Flavonoid concentration in strawberry fruit as affected by different treatments of *A. vera* gel and lemongrass EO.

R.T. (min)	Compound	Concentration of Flavonoid Compounds (µg/mL) in Strawberry Fruit as Treated by					
		Initial (0 day)	Control	*A. vera* 20%	*A. vera* 40%	*A. vera* 20% + Lemongrass EO 1%	*A. vera* 40% + Lemongrass EO 1%
4.6	Rutin	6.14	9.14	ND	7.13	7.14	16.25
5.2	Naringin	5.16	8.16	ND	6.19	ND	5.66
6.0	Isorhamnetin	ND	ND	ND	ND	ND	10.23
6.9	Quercetin	10.41	15.23	15.36	8.47	9.56	9.66
8.1	Kaempferol	5.17	6.17	6.15	20.47	22.17	11.43
9.0	Luteolin	7.13	7.46	14.66	ND	8.15	ND
10.0	Hesperidin	13.45	14.56	8.12	ND	ND	22.15
11.0	7-Hydroxyflavone	ND	ND	ND	14.16	12.02	8.14
12.01	Catechin	8.14	9.52	20.56	11.78	16.11	1.13
14.6	Genistein	ND	ND	ND	ND	ND	3.52
15.0	Chrysoeriol	25.08	ND	4.21	17.44	7.66	15.04
15.2	Myricetin	ND	ND	ND	2.25	ND	ND

ND: not detected; R.T.: retention time.

3.6. EDX Analysis for Elemental Composition of Strawberry Fruits

Table 7 and Figure 10 present the EDX analysis to measure the changes in the element composition of strawberry fruits due to different treatments. There was a significant effect of various treatments on element O percentage ($p < 0.05$), the highest value obtained on treatment with *A. vera* gel 20% (56.1%), followed by control (55.61%). There was a significant effect of treatments on element Ca percentage ($p < 0.0001$), with the highest value observed in strawberry fruits treated with *A. vera* gel 40% + lemongrass EO 1% (1.23%), followed by fruits treated with *A. vera* gel 20% + lemongrass EO 1% (0.48%). The rest of the treatments were not significant. However, the highest values of elements C, P, and K in strawberry fruits were obtained on treatment with *A. vera* gel 40% + lemongrass EO 1%, with percentages of 45.06%, 0.17%, and 1.8%, respectively, compared with the other treatments. The highest value of Mg in strawberry fruits was obtained on treatment with *A. vera* gel 40% (0.19%), whereas N was identified only in strawberry fruits treated with *A. vera* gel 40% alone.

Table 7. Elemental analysis of strawberry fruits coated by *A. vera* gel and lemongrass EO.

Treatment	Element (Atom %)							
	C	O	Si	P	K	Ca	Mg	N
Control	42.36 ± 0.26 [ad]	55.61 ± 0.21 [ab]	0.25 ± 0.12 [a]	0.14 ± 0.02 [a]	1.33 ± 0.12 [b]	0.31 ± 0.05 [b]	nd	nd
A. vera gel 20%	41.30 ± 1.35 [b]	56.10 ± 1.11 [a]	0.49 ± 0.49 [a]	0.17 ± 0.05 [a]	1.54 ± 0.16 [ab]	0.25 ± 0.02 [b]	0.15 ± 0.08 [ab]	nd
A. vera gel 40%	41.75 ± 1.12 [b]	55.01 ± 0.17 [ab]	1.04 ± 0.76 [ab]	0.11 ± 0.01 [ab]	1.10 ± 0.06 [b]	0.38 ± 0.13 [b]	0.19 ± 0.04 [a]	0.40 ± 0.40
A. vera gel 20% + lemongrass EO 1%	43.61 ± 0.80 [ad]	53.74 ± 0.56 [b]	0.63 ± 0.41 [b]	0.04 ± 0.01 [ab]	1.48 ± 0.20 [ab]	0.48 ± 0.03 [b]	0.03 ± 0.03 [bc]	nd
A. vera gel 40% + lemongrass EO 1%	45.06 ± 0.66 [a]	51.54 ± 0.56 [c]	0.15 ± 0.15 [a]	0.17 ± 0.02 [a]	1.80 ± 0.07 [a]	1.23 ± 0.14 [a]	0.05 ± 0.03 [abc]	nd
p-value	0.0908 [ns]	0.0030	0.6712 [ns]	0.0652 [ns]	0.0516 [ns]	0.0001	0.0612 [ns]	-

ns: not significant; the mean values with the same superscript letter/s within the same column show a nonsignificant difference according to LSD at 0.05 level of probability. nd: not detected.
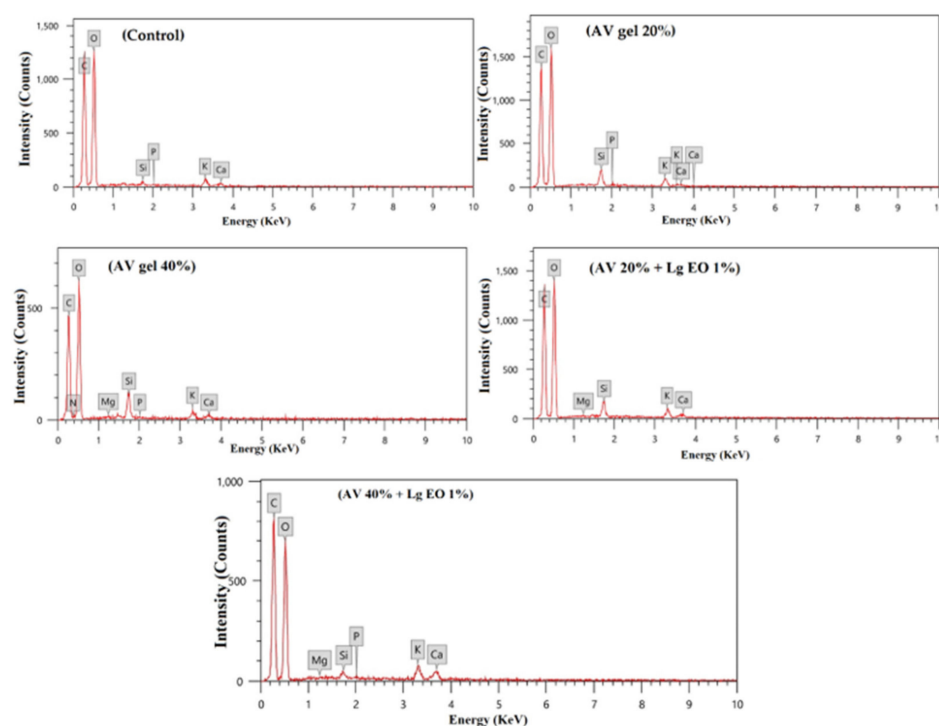
Figure 10. EDX analysis for the elemental composition of strawberry fruits as affected by different treatments; each treatment was measured at three points.

3.7. Microbiological Analysis

Strawberry shows high metabolic activities and sensitivity against pathogens. The bioactive compounds and phytochemicals of the fruit rapidly decrease during storage [88]. Increased soluble sugars and sweetness and decreased acidity and defense metabolites, such as phenolic and antioxidants, make the fruit more susceptible to pathogen attack and postharvest losses [77].

The initial populations of total aerobic mesophilic bacteria and yeasts + molds in the fruit were 80 and 6 CFU g^{-1}, respectively, which increased in the untreated and treated fruit during 16 days of cold storage (Figures 11 and 12), but the samples treated with *A. vera* gel alone or with lemongrass EO showed a strong effect on the total count of microbes in terms of preservation during the storage period, and the counts remained lower than in untreated fruits. These results are comparable with the results of coating with *A. vera* gel and cinnamon EO in modified atmosphere packaging of strawberry. A reduction in microbial populations during storage was observed but there was no change observed in the mold and yeast counts until day 10 of storage; however, on day 15, a decrease in the microbial load was noticed [89].
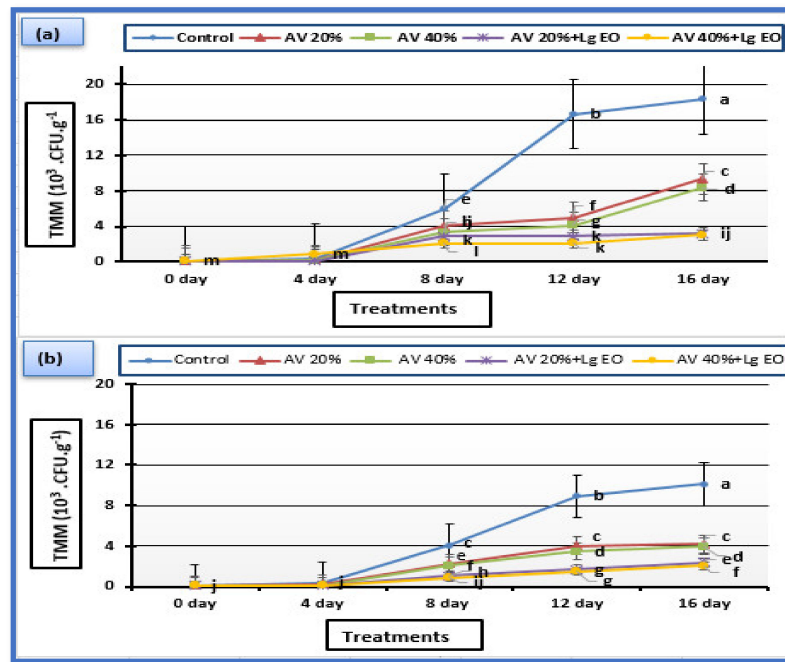
Figure 11. TMM (10^3 CFU.g^{-1}) (mean $\pm$ S.E.) of strawberry fruits stored at 5 °C as affected by coating treatments when store for different lengths of time in both experiments. The mean $\pm$ S.E. of treatments in the figures with the same letters shows a nonsignificant difference according to Duncan multiple range test for $p \leq 0.05$. AV: *A. vera* gel. (**a**) First experiment; (**b**) second experiment.

Figure 12. TYM (CFU g^{-1}) (mean $\pm$ S.E.) of strawberry fruits stored at 5 °C as affected by coating treatments when stored for different lengths of time in both experiments. The mean $\pm$ S.E. of treatments in the figures with the same letters shows a nonsignificant difference according to Duncan multiple range test for $p \leq 0.05$. AV: *A. vera* gel. (**a**) First experiment; (**b**) second experiment.
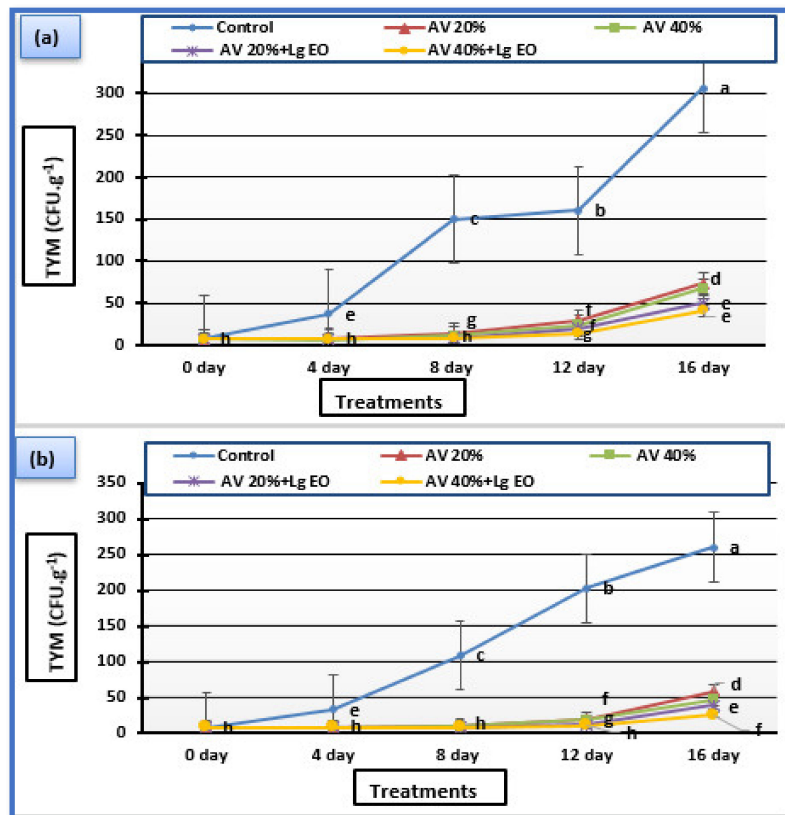
At the end storage, the fruits treated with *A. vera* gel 40% and lemongrass EO recorded a lower microbial count than the fruits that underwent all other treatments. The control sample had the highest microbial count at the end of storage. Therefore, fruits treated with *A. vera* gel at 20% and 40% with lemongrass EO were able to resist fungal growth better than fruits treated with *A. vera* gel alone, and *A. vera* also remarkably reduced aerobic bacteria and yeast and mold counts during the 16 days of storage. In our study, a combination of *A. vera* gel and lemongrass EO seemed to have a synergistic effect on controlling microbial growth in strawberry during storage in a concentration-dependent manner. In a similar study, the effect of coating using *A. vera* gel 20% with 3% starch + 0.1% mandarin EO on physical and mechanical properties of blackberry indicated that this coating is suitable due to its thickness and shows the best mechanical properties observed, providing the fruit with greater thickness and improving its resistance to possible damage [90]. A bioactive coating combined with cinnamon EO significantly reduced mesophilic bacteria and yeast and molds in apple slices during a storage time of 25 days [91].

Coatings of *A. vera* gel with lemongrass EO effectively controlled or inhibited microbial populations (Figures 11 and 12). The present results are comparable with the results when sweet cherries and table grapes were coated with *A. vera* gel, which showed a reduction in the populations of mesophilic aerobic bacteria and yeast and mold during storage. *A. vera* gel compounds such as saponins, acemannan, and anthraquinones derivatives are reported to be responsible for antibacterial activity [92].

Rasouli et al. [93] reported that the inhibition effect of *A. vera* gel on microbial load arises from the presence of ingredients such as aleonin and aloeemodin, which is a possible rationale for the diminishing of germination and mycelial growth of fungi. Antara et al. [94] stated that the compounds responsible for the antimicrobial mechanism of lemongrass EO are a group of terpenoids, e.g., geranial (β-citral) and neral (α-citral).

Certain phenolic compounds are reported to be associated with antioxidant activity, such as radical-scavenging activity [95]. As shown in Figure 8, extracts contain polyphenols and flavonoids, which exhibit not only antioxidant activity but also antimicrobial activity (e.g., ferulic acid, caffeic acid, *p*-coumaric acid, syringic acid, sinapic acid, and cinnamic acid). Therefore, the antioxidant and antibacterial activities of extracts are linked to the activity of individual phenolic and flavonoid compounds. Extracts of *A. vera* gel 40% with lemongrass EO presented higher antimicrobial activity due to their high contents of total phenol content, total flavonoid content, and terpenoids. These results thus suggest that *A. vera* gel with lemongrass EO can be used as a natural antimicrobial.

Strawberries coated with *A. vera* gel 40% + lemongrass EO 1% had increased storage time because this treatment contributed to a decrease in the decay rate. Therefore, *A. vera* gel with lemongrass EO helps maintain the quality of strawberries during storage.

4. Conclusions

The results obtained from this study show that an *Aloe vera* gel coating with lemongrass EO on strawberry fruit has a positive influence on the quality and biochemical properties of the fruit and reduces the microbial growth on the fruit. It was observed that between the two best treatments, treatment with *A. vera* gel 40% followed by *A. vera* gel 20% + lemongrass EO 1% gives better results as compared to treatment with *A. vera* gel (20% or 40%); additionally, for both treatments, significantly higher results were observed as compared to control. Treatment with *A. vera* gel 40% + lemongrass EO 1% enhanced the shelf life of the fruit at 5 °C by maintaining its quality and reducing the spoilage by postharvest pathogens. Thus, this treatment has the potential to be practiced on other different types of strawberry fruits. The present results may show an economical and natural way to improve fruit quality as well as resistance to a wide range of microorganisms.

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