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The Effects of Combined *Aloe vera* Gel and Blended Antioxidants on Cooked Chicken Meat Quality

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Abstract: The effects of the inclusion of *Aloe vera* gel mixed with blended antioxidants on cooked chicken meat quality have been evaluated. This study was designed in five different treatments, where *Aloe* gel at level 5% was mixed into all treatment meat batches, including (1) control (without antioxidant additives); (2) blend 1 [90 ppm oregano essential oil (OE), 150 ppm rosemary extract (RE), and 60 ppm of germander extract (GR)]; (3) blend 2 (150 ppm OE, 120 ppm RE, and 30 ppm GR); (4) 200 ppm nitrite of sodium (E-250); and (5) 14 ppm of *butylatedhydroxyanisole* (BHA). The cooked patties of meat were refrigerated for a duration of one week. For meat quality evaluation, proximate composition, oxidation indicator for lipid and protein, total volatiles, and sensorial traits were tested at different times. Across all parameters, the treatment additives showed a considerable ($p < 0.05$) antioxidant effect compared to the control samples. No considerable variations ($p > 0.05$) were observed among treatment samples in relation to their proximate composition. However, the second blend exhibited the strongest antioxidant effect for all the parameters tested. Blend 1's antioxidant effect was very comparable to 200 ppm of sodium nitrite (E-250) additive. Among all the additives, BHA showed the least significant antioxidant effect. Overall, blend 2 was classified as the most preferred treatment by the panelists. The recommendation that could be summarized is that blend 2 was an excellent natural alternative where the *Aloe vera* gel enhances and prolongs its antioxidant activity using cooked chicken meat.

Keywords: oregano; germander; lipid and protein oxidation; plant extract; volatiles

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Citation: Al-Hijazeen, M. The Effects of Combined *Aloe vera* Gel and Blended Antioxidants on Cooked Chicken Meat Quality. *Appl. Sci.* **2024**, *14*, 10897. https://doi.org/10.3390/app142310897

Academic Editors: Juana Fernández-López and Nuria Muñoz-Tebar

Received: 23 October 2024
Revised: 12 November 2024
Accepted: 16 November 2024
Published: 25 November 2024

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1. Introduction

Food security is currently one of the major and top priority goals that all governments are trying to achieve. This must always be linked with food availability in sufficient quantities, safety, and a suitable quality [1,2]. In low-income countries, poultry meat is considered a crucial component of food security since it is the most inexpensive meat protein source [3]. Improving the quality of this source was very challenging for all researchers by adding natural plant-derived antioxidants. In addition, having good meat quality without using synthetic antioxidants was also very interesting in the field of organic/natural food products, which also reflects people's overall health [4–6]. Herbs and natural plant extracts are still under consideration, but they have many limitations in terms of their uses, for example, dose, sensorial characteristics, availability, cost, and partial or full replacement with synthetic antioxidants [6–9]. In Jordan, several medicinal plants are available in *wild* and cultivated forms such as oregano, rosemary, sage, and germander. These plants have several beneficial effects on human health and immunity, and they can improve human resistance to various foodborne diseases. These plant extracts were evaluated in different studies and showed an improvement on both food quality and safety. This effect was due to its distinct composition of polyphenols, which are responsible for their antioxidant effect and also for prolonging meat shelf life [10–13]. However, no research studies have managed to assess this kind of combination (oregano essential oil, rosemary, and germander extract) as a natural antioxidant alternative. Generally, previous studies

evaluated other combinations (e.g., oregano and rosemary) or the individual effect of each extract. In addition, using these extracts may have presented some difficulty in terms of stabilization when they are mixed into the food system, for instance, losing polyphenols before and during the storage period due to the high volatility and reactivity of an extract's components [14]. This property causes an increase in the number of total phenols escaping from the meat system and decreases its antioxidant effect. *Aloe vera* gel is considered an excellent edible barrier/coating layer for this unique blend (oregano, rosemary, and germander extracts), which is used in food preservation and packaging applications [13,15]. Therefore, the use of *Aloe vera* gel not only extends the antioxidant activity of these additives but also improves this effect throughout all the antioxidant constituents. This *Aloe* gel has many pharmaceutical applications, medicinal uses, and food preservation beneficial effects [15,16]. The objectives of the present study were to (1) evaluate the effect of adding various concentrations of blended antioxidants into *Aloe vera* gel on meat quality and (2) compare this blend of antioxidants with the commercial synthetic antioxidant used in meat preservation.

2. Material and Methods

2.1. Sample Preparation for Treatments

Meat patties (100 g/each) were prepared, packaged, cooked, and stored in compliance with the procedure documented in [17]. Inside the department's meat lab, the experiments were carried out (Mutah University; Agriculture Collage/Animal Production Department) and analyzed. Fresh chicken meat was obtained from the National Poultry Company (Slaughtering facility) located in Al Qatrana (South of Jordan, around 45 km from the Agriculture Collage), where all the chicken was observed and evaluated by the company's veterinary specialist. After the harvesting process, all meat carcasses were packaged and transferred to the meat laboratory in a refrigerator. Once the carcasses reached the meat laboratory, they were kept inside a large plastic container with a mixture of water and ice at 4 °C for up to one hour before use. The meat laboratory team (Meat Specialists) separated the thigh meat of all the chicken carcasses, deboned them, and removed the skin, fat, and any other hard connective tissues. Afterwards, the chicken thigh meat was packaged inside plastic bags that are impermeable to oxygen and then frozen at −20 °C in the meat laboratory. On the experiment's first day, the chicken thigh meat was defrosted and prepared for a two-ground step using 8 mm and then 3 mm plates (Type DKA-1, Moulinex®, Écully, France). The ground thigh meat was mixed with treatment additives, and an equal number of meat patties and replications were prepared. The treatments included (**1**) the control (without extract); (**2**) blend 1 (BL_1) (90 ppm essential oil of *Origanum syriacum* L. (OE), 150 ppm extract of *Rosmarinus officinalis* L. (RE), and 60 ppm extract of *Teucrium polium* L. (GR)); (**3**) blend 2 (BL_2) (150 ppm OE, 120 ppm RE, and 30 ppm GR); (**4**) 200 ppm of sodium nitrite salt (E-250); and (**5**) 14 ppm of synthetic *butylatedhydroxyanisole* (BHA). All treatment extracts and essential oils were bought from a Jordanian certified local business (Green-Field Factory for Oils, Amman, Jordan). Raw *Aloe vera* triangular leaves (*Aloe barbadensis miller*) were collected from different dry and semi-dry regions in the wild in Jordan. In the meat lab, *Aloe vera* gel (internal *Parenchymatous* colorless gel) was gathered, cleaned, and filtered with distilled water (DDW) and then kept in plastic bags that were oxygen-impermeable until needed. Nitrite of sodium (Gainland International Ltd.; Chemical Co-GCC, Factory Road; Deeside, UK) solid powder was first solubilized in deionized water and then combined with crude *Aloe vera* gel (nearly 98.5% water (Raw *pulp*)) to create its working solution. All other additives (blend 1 and 2 of plant extracts and BHA) were solubilized using 15 mL of pure ethanol and combined with 50 mL of *Aloe vera* gel to prepare their stander carrier. Using a rotary evaporator (Heidolph Laborota 4001 Efficient Rotary Evaporator; Water bath Glassware, The Lab World Group, Hudson, MA, USA) at a temperature of 70 °C and 175 millibar vacuum pressure, pure ethanol only was removed from the gel prior to combining the stock solution with the ground meat. All treatment additives that were incorporated with *Aloe vera* gel were combined with

ground meat for three minutes using a bowl mixer (KENWOOD Limited, KM-331; Food Processor and Mixer parts, Havant, UK). The meat batches of all the treatments had the same amount of *Aloe vera* gel (5%) and water. However, there was no need to prepare a negative control (*without Aloe gel*) in the current study since it was measured and evaluated in previous research [13]. In addition, the preliminary study also showed that adding *Aloe* gel to the ground meat has a positive effect on its quality and freshness. The fresh raw meat samples were checked for their proximate composition, pH, and cooking loss values. The raw chicken patties were placed inside oxygen-impermeable bags (Mohammed Tahseen Al-Baalbaki and Partners Co., Amman, Jordan) at 95 °C using a water bath (Memmert Water Bath *WNB 14*; GMbH Co. KG, Schwabach, P. O. Box 1720, Germany) to attain an inside-central temperature of 75 °C. After cooking, the meat patties were moved to a clean oxygen-permeable bag (poly-ethylene, size 15 × 30 cm), cooled, and kept at 4 °C for up to seven days for lipid and protein oxidation, obtaining total volatiles. However, for the sensory part, raw meat patties (thigh meat) were left at 4 °C for three days prior to cooking and running each estimation panel meeting.

2.2. Proximate Analysis, Ultimate pH, and Cooking Loss %

The proximate composition (fat, water, ash, and protein percentages) of the raw thigh meat batches was examined. These analyses were important to check if all treatments had a similar and univariate content before cooking. Meat samples (two sub-samples from each batch; $n = 4$) of all treatments were tested using the Association of Official Analytical Chemists (AOAC) [18] standard method.

2.3. Raw Meat Acidity

The number of pH values was reported using Sebranek et al.'s [19] methodology. The ground meat samples (1.0 g of raw meat) were placed in 9 mL of deionized distilled water (DDW) and then homogenized and measured by a digital pH meter (PL-600, Lab pH/mV/Temp; Taiwan) that was available in the meat laboratory. The analysis involved four replicates from each sample tested.

2.4. Cooking Loss Percentage

Water loss values of the cooked meat were measured and evaluated using the methodology described by Al-Hijazeen and Al-Rawashdeh [17].

2.5. Lipid Oxidation: Measured by TBARSs Method

The number of malondialdehyde (MDA) per kg of meat samples was measured using the TBARSs (*thiobarbituric acid-reactive substances*) method [20]. This method is considered the most accurate and widely used at the laboratory to evaluate lipid oxidation degree in the meat.

2.6. Protein Oxidation by DNPH (DNPH: 2.4-Dinitophenylhydrazine) Method

With a few small modifications, the total carbonyl content, which is commonly used to estimate protein oxidation in the meat, was obtained using the method outlined by Lund et al. [21]. The total carbonyl formation was expressed as nmol/mg protein, using an absorption coefficient of 22,000/M/cm, as it was described by Levine et al. [22].

2.7. Total Volatiles Analysis

Cooked meat samples were made according to Ahn et al.'s [23] methodology to measure the total volatiles profile for all treatments on the seventh day of storage. The volatiles (aldehydes, sulfuric, alcohols, hydrocarbons, ketones, etc.) of cooked thigh meat were measured using GC-MS (QP2010nc System, Shimadzu; Kyoto, Japan) which was linked to a purge and trap concentrator (O.I. Analytical, Eclipse; Model 4660). In addition, the total volatiles were taken at the *Royal Scientific Society* (RSS) with the assistance of a specialist team working at the institution. Samples of cooked meat (3 g/each) were

individually placed in a small glass vial from each patty for the GC-MS analysis. The GC-MS computer unit was programed to recognize all compounds (volatiles and semi volatiles) stored in its detection unit (Stander Library Software). The final data (peak area, diagram, qualitative and quantitative data) of each sample were printed, and the total ion counts were reported according to the method of AL-Hijazeen [11].

2.8. Selected Sensorial Analysis

Using a hedonic scale (line scale without numbers pointed from 0 to 9), specific meat quality attributes (egg-like odor, oxidation smell odor, spice odor, and its general acceptability) were evaluated. The cooked meat samples (10 g/each) were sealed inside 20 mL glass vials and kept until needed for the evaluation. Panelists of 10 professional students and staff were trained and participated in the current analysis. The details of all the preparation protocols and sample measurements of the cooked thigh meat were described by Al-Hijazeen [11].

2.9. Experimental Design

All experimental raw data were filled through Microsoft Excel and then imported into the SAS program to construct a generalized linear model (Proc. GLMs, SAS program, version 9.3, [24]) for further analysis. Furthermore, standard error of the means (SEMs) and mean values are also provided. "The Significance was defined at $p < 0.05$, and Tukey test (HSD), or Tukey's honestly significant difference test, was used to determine the significant variations among the mean values". However, this study was not a repeated measurement performed on the same sample.

3. Results and Discussion

3.1. Proximate Analysis, pH, and Cooking Loss %

Overall, the analysis revealed that no considerable variation ($p > 0.05$) was found between the treatments' mean values in relation to raw (thigh) meat proximate composition, *ultimate* pH values, and its cooking loss percentage (Table 1).

Table 1. Ultimate pH [1], pA [2], and cooking loss % of treated thigh meat samples.

TRT *	Proximate Analysis					
	pH Value	***Protein %***	***Fat %***	***Water %***	***Ash%***	**Cooking Loss %**
Control	5.975 [a]	18.508 [a]	6.715 [a]	73.870 [a]	0.907 [a]	0.200 [a]
BL_1	5.972 [a]	18.545 [a]	6.760 [a]	73.790 [a]	0.905 [a]	0.197 [a]
BL_2	5.980 [a]	18.502 [a]	6.653 [a]	73.938 [a]	0.908 [a]	0.202 [a]
E-250	5.973 [a]	18.548 [a]	6.755 [a]	73.760 [a]	0.938 [a]	0.199 [a]
BHA	5.968 [a]	18.645 [a]	6.705 [a]	73.735 [a]	0.915 [a]	0.204 [a]
SEM [b]	0.028	0.099	0.097	0.136	0.019	0.009

[a–b]-Values with distinct letters within a row are significantly different ($p < 0.05$). * Treatments: control; BL_1; BL_2; E-250: sodium nitrite; and 14 ppm BHA; $n = 4$. [1]: Ultimate pH values. [2]: pA: proximate analysis of fresh meat prior to cooking.

These findings were also in agreement with previous research studies that tested oregano and rosemary extract [11,12]. However, using *Aloe vera* gel resulted in a decrease in the pH and cooking loss values of ground meat compared to non-incorporated meat samples [13,25–27]. The outcome indicated that any significant differences that appeared between treatments were attributed to their antioxidant efficiency.

3.2. Lipid Oxidation of Cooked Meat Samples

The number of *thiobarbituric acid-reactive substances* (TBARSs) observed was low on day 0 for all the cooked samples, and no significant differences ($p > 0.05$) were observed among the treatments (Table 2).

Table 2. TBARSs values of cooked chicken thigh meat at various storage times at 4 °C.

Time	Control	BL_1	BL_2	E-250	BHA	SEM
	---------- TBARSs * (mg/Kg) Meat ----------					
Day 0	1.027 ^{az}	1.023 ^{az}	1.041 ^{ay}	1.001 ^{az}	1.052 ^{ay}	0.043
Day 4	3.287 ^{ay}	1.350 ^{by}	1.214 ^{by}	1.318 ^{by}	1.455 ^{by}	0.073
Day 7	6.957 ^{ax}	2.655 ^{bcx}	2.248 ^{cx}	2.625 ^{bcx}	3.120 ^{bx}	0.152
SEM	0.132	0.065	0.074	0.052	0.145	

$^{a–c}$-Values with distinct letters within a row are significantly different ($p < 0.05$); $n = 4$. $^{x–z}$-Values with distinct letters within a column are significantly different ($p < 0.05$). * *TBARSs value in mg malonaldehyde/kg meat*. Treatments: control; BL_1; BL_2; sodium nitrite: E-250; 14 ppm of BHA.

This is in agreement with several research studies evaluating these plants' extracts [11,12,28]. However, all treatment additives (blend 1, blend 2, E-250, and BHA) demonstrated a clear antioxidant ($p < 0.05$) efficiency in contrast to the control samples on the fourth day. The antioxidant effect of all the treatment additives was very comparable, but the activity of blend 2 was the highest among the other treatments. This is probably due to the unique combination of each oil excited (OE, GR, and RE) in different percentages in the presence of *Aloe* gel. Since the experiment uses different percentages from each plant's extracts for each blend, this will certainly cause different antioxidant effects. In addition, the antioxidant effect of each oil will differ because it contains different ingredients, causing different interactions in the meat system. For instance, thymol and carvacrol represent the most important ingredients that participate in the *Origanum syriacum* L. essential oil antioxidant activity [12,29,30]. In addition, phenolic diterpenes (1: carnosic acid, 2: carnosol, 3: rosmanol, and 4: rosmarinic acid) excited in the *Rosmarinus officinalis* L. extract are considered responsible for its antioxidant effect [11,31,32]. Furthermore, *Teucrium polium* L. (commonly named al Ja'adeh in Jordan) also contains several antioxidant compounds such as 8-cedren-13-ol, B-caryophyllene, germacrene D, sabinene, and luteolin-7-O-glucoside and different flavonoids [10,33,34]. In addition, the antioxidant effect of blend 2 was significantly ($p < 0.05$) higher than that of both BHA and the control treatments. The higher percentages of oregano oil (150 ppm) and a lower percentage of germander (30 ppm) could be the most important reasons behind this superlative effect compared to the other treatments. Based on the available data, it was also observed that the effect of BHA was the lowest among all additives, where the effect of E-250 and blend 1 was very close and comparable to each other during storage. The differences between the antioxidant effects of blends 1 and 2 were due to the difference in the percentage of each plant extract, which will work differently, and their antioxidant mechanism will also differ. In addition, these differences can also be due to how these mixtures interact with each other in the presence of *Aloe* gel. *Aloe barbadensis miller* gel collected from locally cultivated plants was examined, and this gel also contains several phenolic components which contribute to its antioxidant activity [15,26,27]. The maximum antioxidant effect usually depends on how these polyphenols interact and if an additive or synergistic effect may exist. So, the quality and components of blend 2 from these extracts by adding *Aloe vera* gel make this treatment the most effective at reducing lipid oxidation while being stored.

3.3. Protein Oxidation

Similarly, the total carbonyl formation was like the TBARSs response, which showed that no considerable variations ($p > 0.05$) showed up between all treatments on the first storage day. Usually, the overall carbonyl values observed at the beginning of any experiment evaluating cooked meat are very low [35–37]. On the fourth day of storage, all treatment additives incorporated with *Aloe gel* exhibited a clear ($p < 0.05$) anti-carbonyl effect. However, the effectiveness of blend 2 was significantly the highest among all other treatments on day 4 (Table 3).

Table 3. The direct effect of combined antioxidants on total carbonyl of cooked meat.

Time	Control	BL_1	BL_2	E-250	BHA	SEM
	---------- Carbonyl (nmol/mg of Protein) ----------					
Day 0	1.277 ^{az}	1.269 ^{az}	1.269 ^{az}	1.279 ^{az}	1.268 ^{az}	0.044
Day 4	3.579 ^{ay}	2.860 ^{by}	2.196 ^{cy}	2.852 ^{by}	2.988 ^{by}	0.054
Day 7	4.010 ^{ax}	3.169 ^{bx}	2.545 ^{cx}	3.123 ^{bx}	3.307 ^{bx}	0.055
SEM	0.055	0.050	0.049	0.067	0.025	

$^{a–c}$-Values with distinct letters within a row are significantly different ($p < 0.05$). $n = 4$. $^{x–z}$-Values with distinct letters within a column are significantly different ($p < 0.05$). Treatments: control; BL_1; BL_2; E-250; 14 ppm of BHA.

The anti-carbonyl effect could be related to the presence of polyphenols from the oil extract, as reported by several investigation studies [37–39]. On day four of storage, no significant differences ($p > 0.05$) appeared between blend 1, E-250, and BHA. On the last day of storage, blend 2 (BL_2) showed the greatest significant ($p < 0.05$) effect among all additives. However, there were no considerable variations between blend 1, E-250, and BHA on day 7 of storage. In the case of carbonyl formation, the effect of blend 2 was very clear, and this could be related to the effect of a high percentage of oregano oil (150 ppm OE) compared to blend 1 (90 ppm of OE), as well as with the differences in the germander and rosemary oil percentage. The mechanism of the antioxidant effect of these extracts when mixed in combination is still not well understood. However, the poly-hydroxyl group (-OH) found on most of the phenols excited in these plant extracts could be the reason for the reduction in free radicals and carbonyl formation [35,40,41]. In addition, *Aloe* gel also participates in improving plant extract stability and supports its antioxidant effect due to its unique composition. Usually, a high antioxidant effect means that the blend composition and its ingredients work well and interact perfectly with the supporting coating layer of *Aloe gel* during storage.

3.4. Total Volatiles

All treatment additives exhibited a considerable ($p < 0.05$) effect decreasing the total volatiles (ketones, hydrocarbons, aldehydes, sulfuric compounds, and other detectable off-odor volatiles) compared to the control (Tables 4 and 5).

Table 4. Screening of volatiles included in cooked thigh meat with different blended antioxidants on day 4.

	Total Ion Counts × 10^4					
Compounds	**CONT**	**BL_1**	**BL_2**	**E-250**	**BHA**	**SEM**
Pentane	5711 ^{a}	5283 ^{ab}	4892 ^{ab}	5053 ^{ab}	4840 ^{b}	192
Carbon disulfide	3760 ^{a}	2954 ^{ab}	2472 ^{b}	2663 ^{ab}	3018 ^{ab}	275
2-Propanone	12,658 ^{a}	9632 ^{a}	9115 ^{a}	9818 ^{a}	9363 ^{a}	825
1-Pentene	1107 ^{a}	899 ^{a}	768 ^{a}	712 ^{a}	804 ^{a}	164
Hexane	18,016 ^{a}	15,386 ^{ab}	1320^{ab}	13,857 ^{b}	15,456 ^{ab}	605
Butanal	4947 ^{a}	4337 ^{a}	3951 ^{a}	4079 ^{a}	4386 ^{a}	303
Dimethyl disulfide	6498 ^{a}	5055 ^{a}	4624 ^{a}	4957 ^{a}	5528 ^{a}	655
Octane	3841 ^{a}	3433 ^{a}	2892 ^{a}	3023 ^{a}	2886 ^{a}	264
Propanal	9241 ^{a}	8344 ^{a}	7164 ^{a}	7301 ^{a}	8320 ^{a}	703
Hexanal	42,301 ^{a}	37,932 ^{b}	35,161 ^{b}	37,314 ^{b}	36,333 ^{b}	954
Pentanal	7358 ^{a}	5863 ^{ab}	5145 ^{b}	5215 ^{b}	5256 ^{b}	467
Nonanal	5084 ^{a}	3618 ^{b}	2560 ^{c}	2985 ^{bc}	3388 ^{b}	158
α-Pinene	0 ^{b}	45 ^{a}	49 ^{a}	0 ^{b}	0 ^{b}	4
Camphene	0 ^{b}	317 ^{a}	329 ^{a}	0 ^{b}	0 ^{b}	18
Limonene	0 ^{b}	66 ^{a}	70 ^{a}	0 ^{b}	0 ^{b}	3
γ-Terpinene	0 ^{b}	103 ^{a}	105 ^{a}	0 ^{b}	0 ^{b}	7
Sabinene	0 ^{b}	53 ^{a}	57 ^{a}	0 ^{b}	0 b	7

Different letters (a–c) within a row are considered different ($p < 0.05$), $n = 4$. Treatments: control; BL_1; BL_2; E-250; 14 ppm of BHA.

Table 5. Screening of volatiles included in cooked thigh meat with different blended antioxidants on day 7.

	Total Ion Counts × 10^4					
Compounds	**CONT**	**BL1**	**BL2**	**E-250**	**BHA**	**SEM**
Pentane	10,360 ^{a}	7872 ^{a}	7006 ^{a}	7145 ^{a}	7209 ^{a}	1132
Carbon disulfide	2488 ^{a}	2082 ^{b}	2041 ^{b}	2243 ^{ab}	2063 ^{b}	78
2-Propanone	20,669 ^{a}	19,724 ^{a}	18,621 ^{a}	19,513 ^{a}	18,358 ^{a}	1204
1-Pentene	3485 ^{a}	2860 ^{ab}	2667 ^{ab}	2802 ^{ab}	1683 ^{b}	304
Hexane	31,595 ^{a}	28,671 ^{ab}	27,154 ^{b}	28,141 ^{ab}	26,483 ^{b}	834
Butanal	13,612 ^{a}	10,769 ^{b}	9113 ^{b}	9671 ^{b}	9235 ^{b}	574
Dimethyl disulfide	5998 ^{a}	4712 ^{ab}	3845 ^{b}	3924 ^{b}	3931 ^{b}	427
Octane	9776 ^{a}	8499 ^{a}	8224 ^{a}	8479 ^{a}	8132 ^{a}	1367
Propanal	14,945 ^{a}	12,609 ^{ab}	11,266 ^{b}	12,131 ^{b}	11,913 ^{b}	545
Hexanal	60,915 ^{a}	55,607 ^{ab}	53,230 ^{b}	54,202 ^{b}	54,328 ^{b}	1250
pentanal	10,315 ^{a}	7212 ^{b}	7071 ^{b}	6461 ^{b}	6791 ^{b}	700
Nonanal	7156 ^{a}	4426 ^{b}	3952 ^{b}	4232 ^{b}	4197 ^{b}	511
α-Pinene	0 ^{b}	45 ^{a}	49 ^{a}	0 ^{b}	0 ^{b}	2
Camphene	0 ^{b}	281 ^{a}	296 ^{a}	0 ^{b}	0 ^{b}	11
Limonene	0 ^{b}	52 ^{a}	63 ^{a}	0 ^{b}	0 ^{b}	3
γ-Terpinene	0 ^{b}	83 ^{a}	93 ^{a}	0 ^{b}	0 ^{b}	3
Sabinene	0 ^{b}	42 ^{a}	51 ^{a}	0 ^{b}	0 ^{b}	2

Different letters (a–b) within a row are considered different ($p < 0.05$), $n = 4$. Treatments: control; BL_1; BL_2; E-250; 14 ppm BHA.

These secondary lipid oxidation compounds reflect the degree of auto-oxidation occurrence that causes meat deterioration and makes food unhealthy for human consumption [11,12,42]. Based on the volatiles profile, it was also observed that the sulfuric volatiles (carbon disulfide and dimethyl disulfide) were decreased during storage for all treatments, and this was due to their extreme volatility [11,37,43]. In the present investigation, *Aloe vera* gel was an excellent coating layer for the mixture of all plant extracts. However, the significant differences among treatments were due to the differences in the mechanism of how these antioxidants work. Blend 2 showed the highest antioxidant effect delaying volatiles and/or off-odor compounds' formation during storage. The effect of other treatments (blend 1, E-250, and BHA) was also very comparable (day 4 and 7).

The effect of BHA had the least antioxidant impact compared to the other treatment additives. Thus, the new finding indicates that blend 2 could be a good natural alternative for BHA and E-250, especially if it is combined with *Aloe vera* gel. The antioxidant constituents of *Aloe vera* gel enhance this activity and make it very competitive with the synthetic antioxidant. The presence of unique volatiles (*α-pinene, camphene, limonene, γ-terpinene, and sabinene*) that appeared only in particular tested vials was attributed to the composition mixture of these plants' extracts of oregano, rosemary, and germander [11,12,33,44].

3.5. Sensory Analysis of Samples of Cooked Meat

Overall, the sensorial results showed that the egg-like and oxidation odor score values were clearly ($p < 0.05$) higher in the control samples compared to the other additives. This antioxidant ability was due to their composition of several types of polyphenols [11,12]. Furthermore, the control samples exhibited the lowest overall acceptability compared to the other treatments (Table 6).

Numerous earlier studies have demonstrated that the addition of these plant extracts will improve the overall volatile profile and reduce the off-odor that can form in cooked meat. This was linked by the direct significant correlation between TBARSs values and the overall volatile profile formed during storage [11,12,37,45]. We also observed that the treatment with a higher TBARSs number, more aldehydes and sulfuric compounds, and with a more significant oxidation odor was detected by the panelists. The effect

of all the treatment additives incorporated with *Aloe* gel was extremely competitive. In addition, researchers have found that using *Aloe vera* gel as an edible natural additive improved several meat quality characteristics [25,26]. For example, it was found that incorporating *Aloe vera* gel at 2.5 percent to goat meat nuggets improves their quality without compromising their sensory, textural, or nutritional qualities [26]. However, blend 2 nearly displayed the greatest effect decreasing the off-odor volatiles regarding egg-like and oxidation odor attributes. On the other hand, BHA showed the least effect in dealing with off-odor volatiles' formation compared to the other additives. Finally, blend 2 was significantly ($p < 0.05$) the most desirable among the other additives by the panelists relying on the overall evaluation.

Table 6. Sensory evaluation of cooked thigh meat treated by different antioxidants.

TRT *	Sensory Attributes [b]			
	Egg-Like Odor	Spice Odor	Oxidation Odor	Overall Acceptability
Control	7.57 [a]	0.63 [b]	8.03 [a]	3.57 [c]
BL_1	5.67 [bc]	6.06 [a]	5.82 [bc]	5.88 [b]
BL_2	5.02 [c]	6.46 [a]	5.09 [c]	6.87 [a]
E-250	5.67 [bc]	0.66 [b]	5.91 [bc]	5.83 [b]
BHA	6.09 [b]	0.68 [b]	6.38 [b]	5.07 [b]
SEM[c]	0.192	0.112	0.247	0.212

* Treatments: control, BL_1, BL_2, E-250, and 14 ppm BHA; $n = 10$. [b] Sensory attributes: samples were evaluated on day 3. [c] SEM: standard error of the means. [a–b] The means in the same column that have different superscripts differ significantly.

4. Conclusions

All the included additives showed significant antioxidant effects to reduce the oxidation level of lipid and protein. In addition, they showed a significant antioxidant effect on both total volatiles and sensory values compared to the control samples. In the current study, the second blend (BL_2) showed the highest effect on both lipid and protein oxidation; however, the effect of E-250 was comparable. In addition, the second blend showed better sensorial scores compared to the first one, probably due to the GR volatiles affecting the panelists' overall acceptability. Finally, it is highly recommended that the second blend mixed with *Aloe vera* gel is used as a natural replacement for the synthetic one. In summary, the new combination of 5% *Aloe vera* gel with blend 2 will be a great alternative that the meat industry may use instead of BHA or sodium nitrite separately. However, more investigations are still needed to understand if there is a synergistic effect of using *Aloe* gel with these additives.

Funding: This project was funded by the Deanship of Scientific Research at Mutah University (Grant number: 120/14/118).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The raw data supporting the conclusions of this article will be made available by the authors on request.

Acknowledgments: With great gratitude, the author acknowledges the assistance and support provided by the National Poultry Co. (*Del Monte*). In addition, the financial support from a previous project by the Deanship of Scientific Research at Mutah University is much appreciated. The author would like to thank Hanna Madanat for his assistance in providing fresh *Aloe vera* plants from the Jordan Valley Center directed by the National Agricultural Research Center (NARC) in Al-Rabbah; Al-Karak Governorate.

Conflicts of Interest: The author of the current study has no conflicts of interest to declare.

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