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Exploring the effects of comminution level and natural antioxidant incorporation on the quality and oxidative stability of turkey meat system

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Abstract. This study aimed to explore the effects of different comminution degrees and the incorporation of a natural antioxidant on the quality attributes and oxidative reactions of turkey meat. Four distinctive turkey meat systems were established, namely: 3 mm minced treatment (M), 3 mm minced treatment with the addition of 200 ppm gallic acid equivalent *Aloe vera* (*Aloe barbadensis* Mill.) extract (MA), fine-ground treatment (FM), and fine-ground treatment with the addition of 200 ppm gallic acid equivalent *Aloe vera* extract (FMA). The evaluation encompassed an in-depth analysis of various quality parameters and the assessment of lipid-protein oxidation reactions throughout the storage period. The inclusion of *Aloe vera* extract (AE) increased the pH and b* values while simultaneously decreasing the L* and a* values. Conversely, increasing the degree of comminuting manifested an elevation in L* values, concomitant with a decline in a* values. Increased comminuting degree ratios were found to contribute to an exacerbation of oxidative reactions. Nonetheless, the strategic utilization of AE demonstrated its potential to effectively mitigate oxidative reactions during storage.

Keywords and phrases: turkey meat, comminution, *Aloe vera* extract, oxidative reactions, quality parameters, breast muscle

1. Introduction

Meat has been a fundamental source of nutrition for humans throughout history (*Geiker et al.*, 2021). Nowadays, an increasing number of people recognize that turkey meat, classified as poultry, is more economical and contains less fat than red meat (breast fillet and drumstick approximately 1% and 8% resp.). This has

led to a rise in the consumption of turkey meat as a dietary staple. Due to its high levels of polyunsaturated fatty acids, B vitamins, and low cholesterol, many nutritionists advocate the incorporation of turkey meat into our diet. Consequently, the demand for poultry and chicken products has substantially increased over the last decade (*Bashiry et al.*, 2021).

Global poultry meat consumption has significantly increased in recent years, with poultry meat accounting for over 35% of total meat consumption, according to the FAO. In 2020, global poultry meat consumption reached 134.5 million tons, representing 35.6% of the world's meat consumption (*FAOSTAT*, 2023). Turkey meat, classified as poultry, has gained popularity due to its lower fat content and affordability. Turkey has seen a rise in turkey meat production in line with this trend. However, the per capita turkey meat consumption in Turkey lags behind that of major consumers such as the United States and the European Union (*Koyubenbe & Konca*, 2010). This suggests potential for further growth in the meat industry influenced by cultural and economic factors affecting dietary habits.

Foods derived from animal muscles, including fish, red meat, and poultry, are prone to lipid oxidation. Factors such as size reduction techniques, exposure to oxygen, and the generation of reactive oxygen species during processes such as heating, salting, and high-pressure treatment contribute to this oxidation process (*Estévez*, 2021). Mincing or comminution increases the surface area of the meat, exposing it to more oxygen and potentially accelerating oxidation. Enzyme release triggered by mincing also plays a role in oxidation (*Veberg et al.*, 2006). Various external and internal factors, such as fatty acid profile, fat content, temperature, light, moisture, atmospheric oxygen, and the presence of iron, activators, and inhibitors, also impact lipid oxidation (*Abeyrathne et al.*, 2021). The primary impacts of oxidation processes on meat are often related to its sensory characteristics, including alterations in colour, texture, and appearance, as well as the development of off-flavours and off-odours. These changes can result from colour loss, texture damage, and the formation of undesirable rancid flavours caused by the degradation of lipids and proteins in the meat (*Echegaray et al.*, 2021).

Antioxidants are used to delay or prevent the negative consequences of oxidative changes in food. Concerns over the toxicity of synthetic chemicals have led to a search for natural antioxidant sources. The demand for healthier products has driven the food industry to seek natural alternatives to chemical additives. Plant extracts and essential oils from various sources, such as aromatic plants, leaves, seeds, and spices, can serve as natural antioxidants in meat products. They effectively delay or inhibit lipid and protein oxidation without compromising sensory or nutritional properties. Moreover, they minimize rancidity and extend the shelf life of meat products by preventing oxidative chain reactions (*Kumar et al.*, 2015; *Pateiro et al.*, 2021).

Aloe vera is a versatile plant that has been used for its medicinal properties for thousands of years. It is widely used in the cosmetic as well as food industries due to its numerous benefits. *Aloe vera* is a natural antioxidant that has recently gained popularity in the food industry because it contains bioactive compounds such as polysaccharides, glycoproteins, or vitamins, such as A, C, E, carotenoids and phenolic compounds, delaying lipid oxidation in the food industry as well as providing health benefits to the consumer (*Hęś et al.*, 2019). *Aloe vera* is utilized in various forms of dietary products, including gel, essential oil, leaves, and extracts. As a result of the abundance of bioactive compounds present in *Aloe vera*, numerous food processors are currently focusing on developing functional meat products that incorporate *Aloe vera* (*Biswas et al.*, 2014). *Aloe vera* has been utilized in various meat products such as burger *(Soltanizadeh & Ghiasi-Esfahani*, 2015), nugget (*Bhat et al.*, 2015; *Rajkumar et al.*, 2016), meat rolls (*Rathour et al.*, 2019), and dry fermented sausage (*Uşan et al.*, 2021). While there is a singular study on the utilization of *Aloe vera* extract in turkey meat (*Biswas et al.*, 2014), it does not examine the potential influence of using *Aloe* extract in minced turkey meat prepared at varying degrees of mincing. In the light of this information, the purpose of the study was to take a closer look at the quality parameters and oxidative changes that occur when *Aloe vera* extract is used in the formulation of various mincing degrees of turkey breast meat.

2. Materials and methods

2.1 Materials

Turkey breast meat with a moisture content of 75%, protein content of 21.6%, lipid content of 2.4%, and ash content of 1.1% was procured from Migros Trading Co., Ltd. (Izmir, Turkey) while maintaining the cold chain during transportation to the laboratory. *Aloe vera* extract (2.67 mg GAE/g) was obtained from Nurbal Healing Centre (Istanbul, Turkey). Sous-vide cooking bags were supplied by Fitpak Packaging and Chemistry Trade Inc. in Manisa. All chemical reagents used in the study were procured from Sigma–Aldrich Chemical Co. (St. Louis, USA).

2.2 Experimental design

The present study was designed to investigate the impact of different degrees of comminution and the addition of *Aloe vera* extract on turkey breast meat. Four batches were produced and grouped as follows: the first group (M) consisted of turkey breast meat minced through a 3 mm plate without the addition of *Aloe vera*

extract (control treatment-1). The second group (FM) involved finely grounded turkey breast meat in a Thermomix (Vorwerk, Germany) without the inclusion of *Aloe vera* extract (control treatment-2). The third group (MA) included turkey breast meat minced through a 3 mm plate with the addition of *Aloe vera* extract (200 ppm gallic acid equivalent, 0.75 g/kg breast meat). Lastly, the fourth group (FMA) consisted of finely grounded turkey breast meat with *Aloe vera* extract coded as FMA (200 ppm gallic acid equivalent, 0.75 g/kg breast meat).

2.3 Preparation of turkey meat systems

In this study, turkey breast meat was minced using a household meat grinder (Arçelik, Turkey) equipped with a 3 mm diameter plate. The resulting minced meat was then divided into two equal parts. Half of the samples were treated with 0.75 g of *Aloe vera* extract per kilogram of meat, while the other half served as control-1.

To produce FM (control-2) and FMA (*Aloe vera* extract added), the minced meat was homogenized in a Thermomix (2500 rpm, 45 s) and then divided into two parts. Half of the homogenized samples were treated with 0.75 g of *Aloe vera* extract per kilogram of meat. All experimental batches were divided into smaller portions and shaped with metal plates for sampling at different storage periods and packaging conditions.

The samples were vacuum-packed (PA + PE, 160 cm^3/m^2/day oxygen permeability) and subjected to sous-vide cooking at 70°C for 30 minutes, followed by cooling to ambient temperature. The cooked samples were then stored at 4°C for 3, 6, and 9 days prior to analysis.

2.4 pH

The pH values were measured by immersing them in 3 different points with the dipping tip of the pH meter (WTW pH 330i/SET).

2.5 Colour measurement (L*, a*, b*)

The brightness (L*), redness (a*), and yellowness (b*) colour parameters of the samples were assessed using a portable colour measurement device (CR-400, Konica Minolta, Japan). The surface colour of the samples was measured using a portable colorimeter (CR-200, Konica Minolta, Japan) equipped with a ten-degree observer angle and D65 illuminant. The Chroma (C*) and Hue angle (h*) were determined, and the Euclidean distance (ΔE) between samples was calculated following the guidelines set by the American Meat Science Association (AMSA 2012).

Chroma angle: $C^* = \sqrt{a^{*2} + b^{*2}}$ (1)

Hue angle: $h^* = \arctan\left(b^*/a^*\right)$ (2)

Euclidean distance: $\Delta E = \sqrt{(L^*_S - L^*_T)^2 + (a^*_S - a^*_T)^2 + (b^*_S - b^*_T)^2}$ (3)

S representing standard and T representing treated were calculated according to the American Meat Science Association guidelines (AMSA 2012).

2.6 Water-holding capacity

The moisture retention capacity of the uncooked product was evaluated by *Hughes et al.* (1997) using the method specified by modifications.

2.7 Expressible moisture

The fold wrap method described by *Earl et al.* (1996) was used to determine the expressible moisture (EM) of the samples. This involved placing 1.5 g of the sample onto a thimble of filter papers, which were then subjected to ultracentrifugation at 14,000 rpm (18,407 g) for 15 minutes at 4°C. The amount of moisture absorbed by the filter papers was then used to calculate the EM.

$$\text{EM (\%)} = \frac{Weight\ of\ the\ moisture\ expressed}{Original\ weight\ of\ the\ sample} \cdot 100 \quad (4)$$

2.8 Lipid oxidation

Peroxide number and TBARS (thiobarbituric acid reactive substance) analyses were conducted in accordance with *AOAC* (2012) and *Witte et al's* (1970) methods respectively.

2.9 Total sulfhydryl content

The total amount of sulfhydryl (thiol) of samples was determined according to *Eymard et al.* (2009) and *Ellman*'s (1959) method. Samples were mixed with 0.05 M potassium phosphate buffer and homogenized for 1 min by using ultra-turrax (Ultra-Turrax, IKA, Germany). The resulting mixture was centrifuged (Sigma, 3-30 KS, Germany) at 14,000 rpm (18407 g), and the upper phase was taken. To this, a solution of DTNB was added, and the mixture was incubated at 40°C for 15 min. The absorbance values of the sample and blind were read at 412 nm using a spectrophotometer, and the sulfhydryl amount was calculated using a

molar absorption coefficient of 13.600 $M^{-1}.cm^{-1}$. The results were reported as nmol sulfhydryl/mg protein.

2.10 Statistical analyses

The experiment was repeated on two different days, resulting in two distinct batches. Measurements for the relevant characteristics were conducted three times for each batch, and the average values for the measured parameters were calculated. These average values were compared using analysis of variance (ANOVA) performed with SPSS software for Windows (version 21.0, SPSS Inc., Chicago, IL, USA). The production batches were considered as a random factor, while each treatment was regarded as a fixed factor. To analyse the storage data, a two-way ANOVA was employed, considering treatment and storage time as the main factors. Duncan's multiple range test was applied to compare the means of different groups, with a significance level set at $P < 0.05$.

3. Results and discussion

3.1 Water-holding capacity and expressible moisture

Water-holding capacity (WHC) values of samples ranged from 57.55% to 63.14% (*Table 1*). The interaction between *Aloe vera* extract and the degree of comminution significantly affected the WHC in turkey meat. While reducing the particle size of turkey meat with *Aloe vera* extract had a potentially negative impact on WHC, incorporating *Aloe vera* extract improved the WHC of coarsely ground meat ($P < 0.05$). This can be explained by the fact that as comminution increases, the ability of turkey breast meat to retain water decreases. Myofibrillar proteins, particularly myosin, play a key role in WHC. Denaturation of myosin is suggested to contribute to a decline in WHC (*Bowker & Zhuang*, 2015). Interestingly, the MA group showed the highest WHC value (*Table 1*). *Aloe vera*-derived polysaccharides, alone or in combination with proteins, have been found to enhance water-holding capacity by creating a network structure that effectively retains water. Similar findings have been reported in burger formulations with *Aloe vera* powder (*Soltanizadeh & Ghiasi-Esfahani*, 2015).

Lower water-holding capacity in meat is typically correlated with higher expressible moisture content. The present study provides insights into the expressible moisture values of the meat systems, as presented in *Table 1*. The EM values for the turkey meat systems ranged from 11.65% to 14.59%. Notably, the utilization of *Aloe vera* extract and the degree of comminution exhibited significant effects on

the EM values ($P < 0.05$). Interestingly, the incorporation of *Aloe vera* extract did not induce any substantial changes in the water-holding capacity of coarse ground meat systems. However, in finely ground meat, the addition of the extract led to a decrease in EM. Among the treatments, the M demonstrated the highest EM value ($P < 0.05$), while the MA, FM, and FMA treatments exhibited similar values. The inclusion of *Aloe vera* powder in beef burgers has previously been shown to increase moisture retention, potentially attributed to the extract's ability to enhance the water-holding capacity of the product (*Soltanizadeh & Ghiasi-Esfahani*, 2015). This finding aligns with a separate study on meat analogues, where samples incorporating Spirulina flour exhibited higher expressible moisture content (*Palanisamy et al.*, 2019). In addition, *Bhat et al.* (2015) also showed that nuggets formulated with *Aloe vera* pulp had enhanced emulsion stability and cooking yield.

Table 1. Water-holding capacity and expressible moisture

Treatment	Water-holding capacity (%)	Expressible moisture (%)
M	$59.55^{bc} \pm 1.79$	$14.59^{a} \pm 1.00$
MA	$63.14^{a} \pm 0.82$	$14.51^{a} \pm 1.54$
FM	$59.98^{b} \pm 0.97$	$11.65^{b} \pm 0.13$
FMA	$57.55^{c} \pm 1.09$	$13.59^{a} \pm 0.81$

Notes: $^{a–c}$ – different letters in the same row indicate a significant difference ($P < 0.05$). Data were presented as the mean ± standard deviation. M: 3 mm minced; MA: 3 mm minced + AE; FM: finely grounded; FMA: finely grounded + AE.

3.2 pH

The pH value of the meat systems was significantly influenced by the incorporation of *Aloe vera* extract and the degree of comminution (*Figure 1*). Initially, the pH values ranged from 6.08 to 6.20, and by the end of the storage period, they reached a range between 5.86 and 6.00. Throughout the entire storage period, pH values exhibited an increasing trend with the addition of *Aloe vera* extract ($P < 0.05$). However, *Uşan et al.* (2021), *Bhat et al.* (2015), and *Shahrezaee et al.* (2018) reported a decrease in meat products added with *Aloe vera* extract, *Aloe vera* pulp, and *Aloe vera* gel powder. These controversial results regarding pH can potentially be attributed to the sous-vide cooking technique employed and the presence of the added extract. It is believed that the complex relationship between thermal processing and the structural transformations of the *Aloe vera* extract may explain the divergent pH responses observed in this study compared to prior research. As the degree of comminution increased, the pH value of the meat systems decreased ($P < 0.05$). Remarkably, the FM treatment exhibited the

lowest pH value throughout the entire storage period ($P < 0.05$). After the 6th day of storage, the pH values of all treatments displayed a decline, which could be attributed to the microbial spoilage.

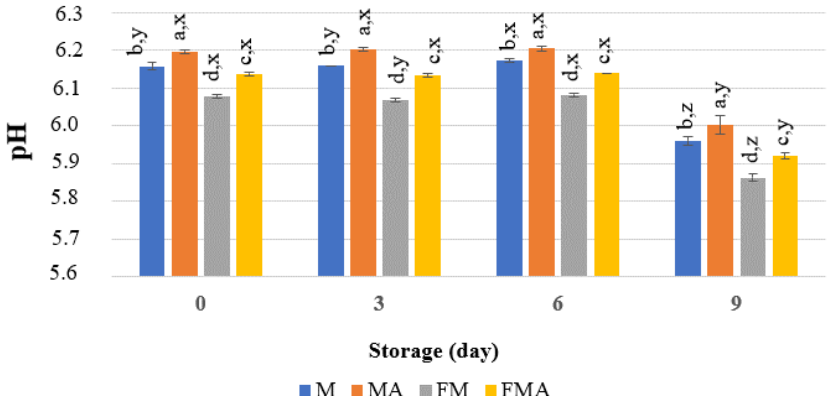

Figure 1. pH values (sample codes are given in *Table 1*)

3.3 Colour

Initially, the L* values ranged between 71.62 and 75.48 (*Figure 2*), with the lowest values measured in the MA group at the beginning of the storage period. The L* values of the other treatments showed similar results. The application of AE resulted in a decrease in the lightness of the meat system on all storage days except the first day. During the storage period, no significant changes in L* values were observed except for a decrease observed in the FMA group on the 9th day. By the end of the storage period, the L* values ranged between 71.52 and 75.36. Furthermore, an increase in the degree of comminution led to an increase in L* values at the end of storage, with the FM group displaying the highest value. This phenomenon can be attributed to the assumption that an increase in the degree of comminution results in a decrease in water-holding capacity. As a result, water tends to rise to the surface, causing enhanced light reflection and increased lightness due to the presence of trapped air bubbles.

On Day 0, the a* values ranged from 1.93 to 3.76 (*Figure 2*). The highest a* value was observed in group M. Both the addition of AE and an increase in the degree of comminution had a reducing effect on the a* values. Throughout the storage period, samples with a higher degree of comminution displayed lower a* values. Among the treatments, the FMA group, which included the addition of AE and fine mincing, consistently exhibited the lowest a* values. This can be attributed to the green colour of AE, which is derived from the whole leaf and has been found

to reduce both the a* and L* values. During the storage period, the a* values of the M and FMA treatments remained unchanged, while those of the MA and FM treatments increased. By the end of the storage period, the a* values ranged between 2.22 and 4.21. A similar trend observed at the beginning of storage was also noted among the groups on the 9th day.

The b* values were influenced by the degree of comminution and the addition of *Aloe vera* extract. Initially, the b* value ranged between 10.59 and 12.85. Throughout the storage period, the MA and FMA groups, which included the *Aloe vera* extract, exhibited the highest b* values. The effect of the comminution degree on b* value was not significant at the beginning of storage. During the storage period, the b* values increased in the M and FMA, while fluctuations were observed in the other treatments. By the end of the storage period, an increase in the degree of comminution led to a decrease in the b* value. The highest yellowness was measured in the FMA where AE was incorporated to the formulation. In a study involving goat meat, it was observed that the addition of *Aloe vera* resulted in an increase in b* values (*Rathour et al.*, 2019). *Uşan et al.* (2021) also stated that the use of *Aloe vera* extract in dry fermented sausage resulted in higher b* values, lower L* and a* values.

Chroma, which represents the saturation or intensity of meat colour, is directly influenced by the concentration and status of myoglobin. The Chroma values observed in this study ranged between 11.05 and 13.20 (*Table 2*). The comminution degree had a significant impact on Chroma values, with higher degrees of comminution resulting in lower Chroma values. Conversely, the use of *Aloe vera* extract had the opposite effect on the meat systems, leading to higher Chroma values ($P < 0.05$). The FM treatment exhibited the lowest Chroma value, indicating greater discolouration in the colour of this treatment ($P < 0.05$).

The Hue angle index (H°) is a measure of colour development from red to yellow, where larger angles indicate lower redness. Our findings indicate that the inclusion of *Aloe vera* extract led to increased Hue angle values (*Table 2*). Specifically, minced turkey meat systems treated with *Aloe vera* extract (MA and FMA) exhibited higher Hue angles compared to other treatments ($P < 0.05$), suggesting that these treatments had less redness due to the natural colour of the extract. The degree of comminution did not significantly affect the redness of the meat systems ($P > 0.05$). Moreover, the M and FM treatments showed similar Hue angle index values, as did the MA and FMA treatments. In a study, where *Aloe vera* extract was added to chevon rolls, lower Hue angles and higher Chroma values were reported (*Rathour et al.*, 2019).

The total colour difference value (ΔE) serves as a useful indicator of the impact of various applications on the colour of meat products. For the human eye to perceive a noticeable colour difference, the threshold value is generally considered to be between 2 and 6 (*Larraín et al.*, 2008). In our study, the total colour differences ranged from 1.34 (FM) to 3.66 (MA). Based on these findings, it can be concluded

that the effect of excessive reduction in the particle size of turkey meat on the colour was almost imperceptible when compared to the addition of *Aloe vera* extract. The differences became detectable when AE was incorporated into the formulation.

Table 2. Turkey meat system colour indices on Day 0

Treatment	Colour indexes		
	Chroma	Hue angle	ΔE
M	$11.80^{d} \pm 0.26$	$71.43^{bc} \pm 1.58$	-
MA	$13.20^{b} \pm 1.57$	$76.80^{a} \pm 0.69$	$3.66^{a} \pm 1.10$
FM	$11.05^{c} \pm 0.13$	$73.44^{c} \pm 0.51$	$1.34^{c} \pm 0.44$
FMA	$12.78^{a} \pm 0.67$	$81.26^{ab} \pm 1.10$	$2.49^{b} \pm 0.42$

Notes: $^{a–d}$ – different letters in the same row indicate a significant difference ($P < 0.05$). Data were presented as the mean ± standard deviation. Sample codes are given in *Table 1*.

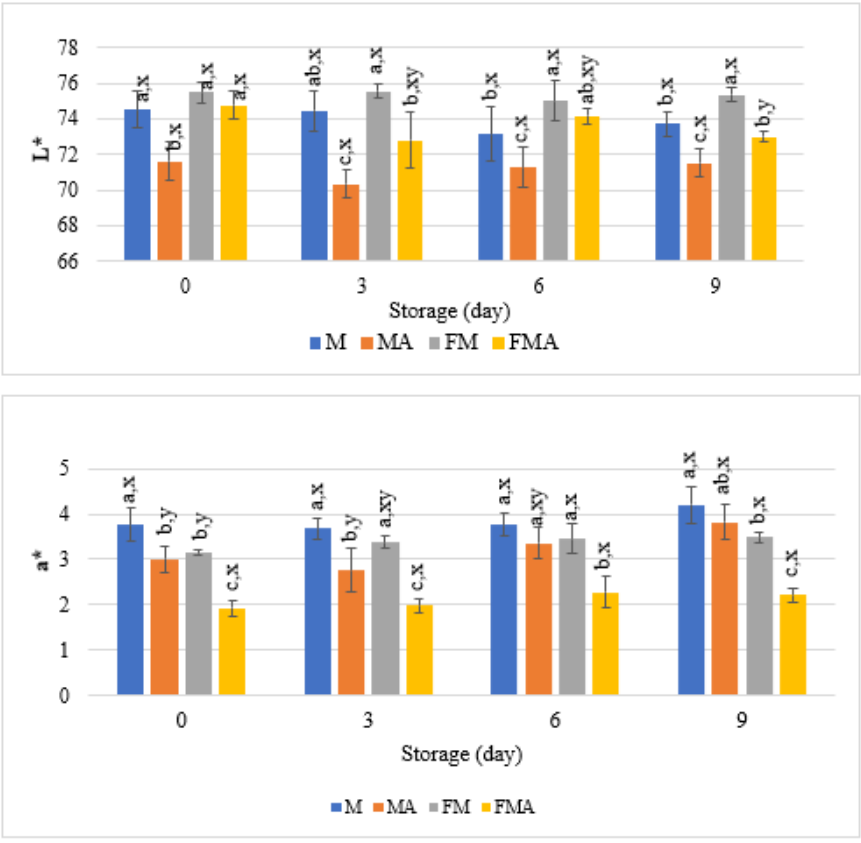

Figure 2a. Colour parameters (sample codes are given in *Table 1*)

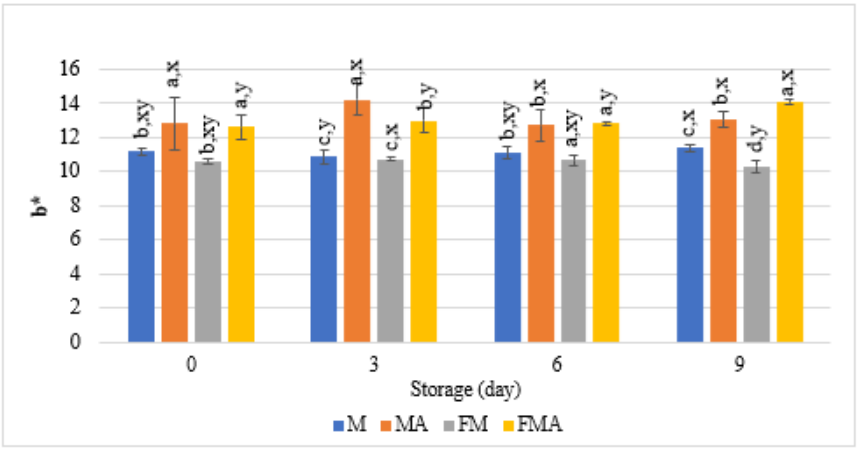

Figure 2b. Colour parameters (sample codes are given in *Table 1*)

3.4 Peroxide value

During the initial stages of lipid oxidation, radical peroxide and hydroperoxides are the compounds primarily responsible for the process of primary oxidation. As the storage period progresses, these compounds undergo transformation into secondary oxidation products (*Serdaroğlu et al.*, 2022). The initial peroxide values of the treatments in our study ranged from 0.78 to 1.96 meqO_2/kg (*Table* 3). The lowest peroxide value was observed in the MA treatment, and no significant differences were observed among the peroxide values of the other treatments. The degree of comminution did not significantly affect the peroxide values during the first 6 days of storage. However, on the 6th day of storage, the highest peroxide values were observed in all samples ($P < 0.05$). The use of *Aloe vera* extract was found to be particularly effective in samples that underwent 3 mm mincing during the later stages of storage. Similarly, turkey meat treated with bioactive compounds from *Aloe vera* gel had lower peroxide values than control groups (*Biswas et al.*, 2014). Also, the inclusion of pomegranate peel extract resulted in a decrease in peroxide values in ground buffalo meat (*Ghimire et al.*, 2022). Fluctuations in peroxide values were observed throughout the storage period, and by the 9th day, the values reached 1.37–2.40 meqO_2/kg. This can be attributed to the accumulation of secondary oxidation products in the environment, as hydroperoxides are converted to aldehydes and ketones (*Ghimire et al.*, 2022). The M treatment exhibited the highest peroxide value at the end of the storage period ($P < 0.05$), while no significant differences were observed among the other treatments.

3.5 TBARS

The initial TBARS values of cooked turkey meat systems ranged from 0.61 to 0.93 mg malonaldehyde/kg (*Table 3*). The comminution degree did not have a significant effect on the initial TBARS values; however, the inclusion of *Aloe vera* extract resulted in a reduction of TBARS in the 3 mm minced treatment. The lowest TBARS value was observed in the MA treatment, while no statistical differences were observed among the other treatments ($P > 0.05$).

During the storage period, the TBARS values exhibited fluctuations. The use of *Aloe vera* extract during the later stages of storage significantly slowed down oxidation ($P < 0.05$) or did not create any significant differences compared to the control treatments. The highest lipid oxidation was observed on the 9th day of storage in all treatments. The accelerating effect of excessive reduction in particle size was more pronounced at the end of the storage period (FM); however, the inclusion of *Aloe vera* extract was able to reduce the TBARS values in this treatment ($P < 0.05$). The presence of antioxidant compounds, such as vitamins C and E, beta-carotene, flavonoids, and phenolic compounds in *Aloe vera*, may be the main reason for the delay in oxidation (*Hęś et al.*, 2019). Similar results were reported by *Bhat et al.* (2015) in chicken nuggets added with 5%, 10%, and 15% *Aloe vera* pulp. *Uşan et al.* (2021) also reported that *Aloe vera* extract could effectively retard oxidation in sausages. Also, different forms of *Aloe vera* have successfully retarded lipid oxidation in goat meat nuggets (*Rajkumar et al.*, 2016), turkey meat (*Biswas et al.*, 2014), and raw meat batter (*Kumar & Langoo*, 2016).

Table 3. Lipid oxidation of turkey meat systems

Peroxide values ($meqO_2$/kg)	**Storage (day)**			
	0	**3**	**6**	**9**
M	$1.77^{a,yz} \pm 0.26$	$1.26^{a,z} \pm 0.30$	$3.05^{ab,x} \pm 0.13$	$2.40^{a,xy} \pm 0.32$
MA	$0.78^{b,z} \pm 0.01$	$1.39^{a,y} \pm 0.20$	$2.17^{c,x} \pm 0.38$	$1.58^{b,y} \pm 0.79$
FM	$1.27^{ab,y} \pm 0.11$	$0.89^{a,z} \pm 0.10$	$3.31^{a,x} \pm 0.30$	$1.37^{b,y} \pm 0.20$
FMA	$1.96^{a,xy} \pm 0.83$	$1.39^{a,y} \pm 0.40$	$2.68^{bc,x} \pm 0.09$	$1.39^{b,y} \pm 0.28$
TBARS (mg malonaldehyde/kg)				
M	$0.86^{a,z} \pm 0.04$	$0.76^{b,z} \pm 0.13$	$1.25^{a,y} \pm 0.07$	$2.85^{b,x} \pm 0.29$
MA	$0.61^{b,y} \pm 0.05$	$0.69^{b,y} \pm 0.09$	$0.36^{d,z} \pm 0.01$	$3.00^{b,x} \pm 0.27$
FM	$0.93^{a,z} \pm 0.01$	$1.49^{a,y} \pm 0.05$	$0.74^{b,z} \pm 0.02$	$4.13^{a,x} \pm 0.38$
FMA	$0.91^{a,y} \pm 0.04$	$0.68^{b,z} \pm 0.11$	$0.56^{c,z} \pm 0.10$	$3.01^{b,x} \pm 0.10$

Notes: $^{a-c}$ / $^{x-z}$ – different letters in the same row/column indicate a significant difference ($P < 0.05$). Data were presented as the mean ± standard deviation (sample codes are given in *Table 1*).

3.6 Sulfhydryl content

Figure 3 represents the loss of sulfhydryl groups in the meat systems during storage. On Day 0, the sulfhydryl concentration of the various treatments varied from 2.93% (FMA) to 15.39% (M). The use of *Aloe vera* extract and the particle size of turkey meat had a significant effect on the total sulfhydryl groups ($P < 0.05$). The lowest total sulfhydryl content was observed in the FMA treatment, which consisted of finely ground turkey meat with *Aloe vera* extract.

Throughout the entire storage period, the samples treated with *Aloe vera* extract showed lower sulfhydryl groups except on the 3rd and 6th days of storage in the coarse-ground samples. The decrease in total sulfhydryl groups can be attributed to the formation of disulphide bonds and tyrosine as a result of oxidation and the cross-linking of sulfhydryl groups both within and between molecules.

By the end of the storage period, the sulfhydryl content ranged from 3.42% (MA) to 19.61% (FM). The highest value was observed in the FM, which consisted of fine-ground turkey breast meat with *Aloe vera* extract. Similarly, pomegranate peel extract, rosemary and lemon balm extracts, clove extract, wild thyme by-products extract, and purslane extract have also been reported to protect sulfhydryl groups in muscle foods due to their bioactive compounds (*Šojić et al.*, 2020; *Wang et al.*, 2021).

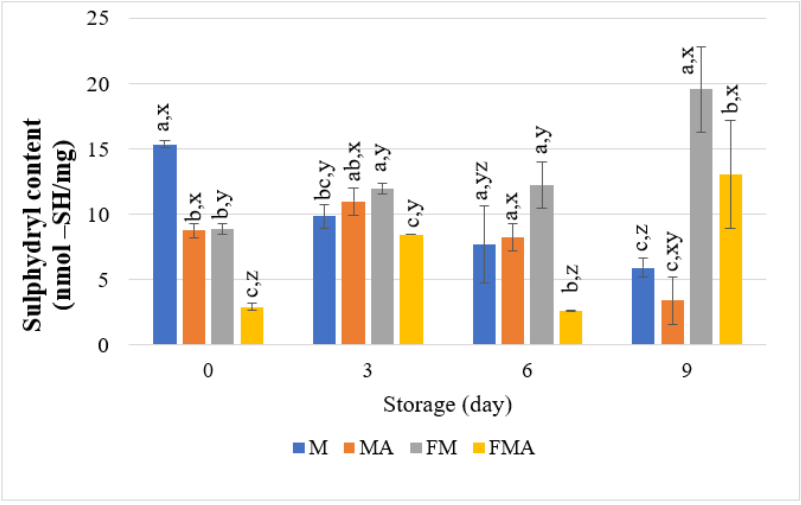

Figure 3. Sulfhydryl content (sample codes are given in Table 1)

4. Conclusions

It can be concluded that there exists a potential risk of progressed oxidation with an escalation in the reduction in the particle size of turkey meat. Nevertheless, the utilization of *Aloe vera* extract in the short-term storage of minced turkey meat demonstrates a promising capability to retard the process of oxidation during storage while concurrently averting the emergence of any discernible quality detriments. Further research in the field should focus on elucidating the specific mechanisms of antioxidant action of *Aloe vera* extract in minced meat products, determining the optimal concentration and application methods for achieving prolonged antioxidant activity and assessing its long-term storage stability. Comparative studies with other natural antioxidants and investigations into consumer perception and acceptance are also necessary to evaluate the potential market viability of *Aloe-vera*-treated minced meat products. By addressing these research areas, we can deepen our understanding of the protective effects of *Aloe vera* extract and develop innovative strategies to enhance the quality and shelf life of minced turkey meat while minimizing oxidative deterioration.

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