Egyptian Journal of Animal Health

P-ISSN: 2735-4938 On Line-ISSN: 2735-4946
Journal homepage: https://ejah.journals.ekb.eg/

Amelioration of Beef Burger Quality with Lycopene and *Aloe vera* Supplements

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Received in 15/4/2025
Received in revised from 18/5/2024
Accepted in 26/5/2024

Keywords:
Beef burger
Herbal extracts
Meat quality

ABSTRACT

Beef burger is one of the most popular and highly demanded meat products. Development of healthier meat products of longer shelf-life is based on innovation of more potent and safe preservation technique. The current study was conducted to evaluate the impact of the combined Lycopene-*Aloe vera* added to beef burger by three concentrations (0.5%:1.0%, 1.0%:2.0% and 1.5%:3.0%, respectively), to beef burger on the sensory, microbiological and physicochemical qualities every three days during refrigerated storage. Results showed that addition of Lycopene-*Aloe vera* combination, with different concentrations, to beef burger revealed significant improvement in the overall sensory quality that was represented by enhanced redness color, with improved texture and higher scores of consumer's appeal with longer keeping quality during refrigeration storage in comparison to the control untreated group. Moreover, results revealed significant enhanced physical characters and productivity of the treated burger samples through higher water holding capacity (WHC). Consequently, the treated samples showed lower degrees of cooking loss (CL) and higher cooking yield (CY). In addition, microbiological quality of the treated groups showed significant reduction in the microbial counts, protein degradation and lipid oxidation in relation to the control group. It is worth noted that there is a direct relationship between the concentration of the additives and their potent effects without major impact on the sensory attributes of beef burger. After all, treatment of beef burger with Lycopene-*Aloe vera* compounds appeared to have higher acceptability, productivity and longer shelf-life through significant improvement of the microbial and chemical quality. Therefore, it can be recommended to use Lycopene-*Aloe vera* combination in improvement the keeping quality with enhanced acceptability of beef burger during refrigerated storage.

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DOI: 10.21608/ejah.2025.431715

INTRODUCTION

Meat products are highly valued for their rich nutritional composition and consumer desire, making them a staple in diets worldwide. They are excellent sources of high-quality protein, which provides all essential amino acids necessary for muscle growth, repair, and overall body maintenance. Also, they contain vital micronutrients such as vitamin B12, iron, zinc, selenium, and phosphorus, which support immune function, energy metabolism, and neurological health **(Stadnik, 2024).**

Beef burger is a quintessential culinary delight, enjoyed globally for its rich flavor and versatility. The quality and consumer appeal of beef burgers are driven by key factors such as freshness, juiciness, taste, and customization options. Natural additives like lycopene and *Aloe vera* can significantly enhance the physicochemical characteristics of beef burgers by addressing oxidative stability, moisture retention, and microbial control **(Angioletti et al. 2024).**

Lycopene, a carotenoid with potent antioxidant properties found in tomatoes and other red fruits, enhances beef burger quality by improving color stability and oxidative resistance. Its active principle lies in its 11 conjugated double bonds, which directly neutralize free radicals improving burger's oxidative stability and keeping quality **(Long et al. 2024).**

Besides that, lycopene supplementation in meat products can increases carotenoid content, which stabilize redness and reduce lightness, mimicking nitrite's color-enhancing effects while enabling nitrite reduction for healthier burger production **(Velasco-Arango *et al.*, 2021)**. This dual action preserves the burger's visual appeal and delays metmyoglobin formation, maintaining freshness during refrigerated storage. Additionally, lycopene reduces lipid peroxidation by interrupting chain reactions in unsaturated fatty acids, lowering thiobarbituric acid (TBA) values and delaying rancidity **(Wen et al. 2022)**.

On the other hand, *Aloe vera* exhibits significant antimicrobial, antioxidant, and quality-enhancing effects in meat products, making it a valuable natural additive **(Mensah et al. 2025)**. Its antimicrobial activity stems from bioactive compounds such as anthraquinones, saponins, and acemannan, which inhibit the growth of different spoilage and pathogenic microorganisms **(Kahramanoğlu et al. 2019).**

This action improves the microbiological safety of meat products during storage. As an antioxidant, *Aloe vera* gel reduces lipid oxidation by scavenging free radicals, thereby lowering thiobarbituric acid reactive substances (TBARS) values and delaying rancidity **(Hęś et al. 2019)**. Additionally, its hydrocolloid properties enhance water-holding capacity, reduce cooking loss, and improve texture in beef burger formulations **(Soltanizadeh and Ghiasi -Esfahani, 2015)**.

The combination of lycopene and *Aloe vera* in beef burgers may yield synergistic benefits for enhancing quality and shelf life by leveraging their complementary antioxidant, antimicrobial, and physicochemical mechanisms. Therefore, the current study was planned to evaluate the physicochemical, microbiological and shelf life of beef burger treated with different concentrations of combined lycopene and *Aloe vera* during refrigerated storage.

MATERIALS and METHODS

2.1. Collection and preparation of the used additives

2.1.1. *Aloe vera* gel preparation

Aloe vera gel was made using the technique outlined by **Saritha et al. (2010)**, with a few modifications. To extract the gel, healthy, fresh leaves were collected from the greenhouse at the National Research Centre and scraped with a sterile spoon. After that, an electric blender was used to blend the gel. The combined gel was preserved and kept at 4°C till usage. Three concentrations were prepared (1, 2, and 3%) to be used. The prepared gel was subjected to estimation of total phenolic content following the Folin-Ciocalteu colorimetric method according to **Tumbarski et al. (2019)**, The results were expressed in milligrams of gallic acid equivalent per gram dry weight of

the extracts (mg GAE/g). In addition, total flavonoid content was estimated using the aluminum chloride colorimetric method, based on the protocols described by **Fattahi et al. (2014).** The total flavonoid content of the sample was calculated by using the calibration curve constructed, and the values were expressed as milligrams of quercetin equivalents per gram of dry weight (mg QE/g). Moreover, total tannin content was also estimated by a modification to the Folin-Ciocalteu method using polyvinyl polypyrrolidone (PVPP) to separate tannin phenols from non-tannin phenols according to **Osoro et al. (2007)**. In mg GAE/g dry weight, the total tannin concentration is calculated by the difference between the total and simple phenol values.

2.1.2. Collection of lycopene powder

Commercial lycopene powder was purchased from Yunbang Pharm, with ≥85% concentration purity, and Lot.No. YB24061106. The product was kept in dark bottle, tightly closed in room temperature until usage.

2.2. Collection and preparation of beef burger

Five kilograms of beef chuck were collected, minced and processed following the recipe that has been recommended on the commercial spices mix **(Allrecipes 2024)**, followed by addition of *Aloe vera*-lycopene combination according the following groups; where **G1**: Control group: burger without additives, **G2**: burger with lycopene (0.5% wt:wt) + *Aloe vera* (1.0% wt:wt), **G3**: burger with lycopene (1.0% wt:wt) + *Aloe vera* (2.0% wt:wt), and **G4**: burger with lycopene (1.5% wt:wt) + *Aloe vera* (3.0% wt:wt).

It is worth noted that each beef burger disc weighted about 50 g and 1.5 cm thickness, packed in food-grade poly ethylene bags, and stored separately in refrigerator (4±1^{o}C) during the experiment.

2.3. Quality and microbiological examinations

All beef burger groups were left for 24h in the refrigerator before starting the zero time of examination; where quality and microbiological assessments were repeated every 48h until appearance of spoilage signs grossly. Experiment was repeated three times, data was collected and recorded.

2.3.1. Physical examinations

Beef burger groups were examined for their sensory characters (including color, odor, texture, taste after grilling and overall consumer appeal) following **Mörlein (2019)** in scores (1 to 5), where ≤1- represented the worst while 5- represented the excellent mark. In addition, samples were examined for their cooking loss after grilling, and cooking yield, and water holding capacity (WHC) according to **Jama et al. (2008), USDA (2014)**, and **Szmanko et al. (2021),** respectively**.**

2.3.2. Microbiological examinations

After preparation of tenth fold serial dilutions according to **ISO 6887-2 (2017),** Beef burger groups were examined for their aerobic plate count (APC), coliform count, and total fungal count according to **ISO 4833-1 (2013), ISO 4832 (2006), and ISO 21527-1 (2008)**, respectively.

2.3.3. Chemical examinations

Beef burger were examined for their pH estimation, total volatile basic nitrogen (TVBN), and thiobarbituric acid (TBA) values according **to EOS 63-11 (2006)** using a calibrated pH meter (Adwa, AD1200) dipped in 50g of mixed beef burger sample**, EOS: 63-9 (2006)** was used, in which ten grams of beef burger was mixed with magnesium oxide and dist. water followed by boiling in a conical flask and condenser; after which, TVBN was calculated against sulphoric acid; and for TBA, **EOS 63-10 (2006)** was followed through mixing of ten grams of well-mixed burger samples to dist. water + hydroaluric acid 4N, followed by heating of the flask containing the mixture to distill about 50 ml of the distillate; from which, 5 ml was mixed with thiobarbituric acid reagent and was kept in a boiling water bath for 35 minutes. Optical density of the overall end products was measured at wavelength 538.

2.4. Statistical analyses

The data was statistically analyzed by two-way ANOVA, where time of storage and type of treatment were the variable, using SPSS program for windows (Version 20) (SPSS Inc. Chicago, IL and USA) and Duncan's post hoc test with $P \leq 0.05$ considered to be statistically significant that was expressed as capital and small superscript letters. In addition, independent sample T test was performed between two groups; where significance was expressed as superscript star.

RESULTS

As shown **Table (1)**, the ethanolic extract of *Aloe vera* gel contained a total phenolic compounds which was 23.63 ± 0.45 mg GAE/ g and total flavonoids (31.96 ± 0.25 mg QE/g), while the total tannin content was found to be 18.28 ± 0.63 mg GAE/g.

Table 1. Total phenolic, flavonoid and tannin content of *Aloe vera* gel ethanolic extract

Aleo vera extract	Total phenol (mg GAE/g)	Total flavonoid (mg QE/g)	Total tannin (mg GAE /g)
	23.63± 0.45	31.96 ± 0.25	18.28±0.63

Results are expressed as Mean ± SD for three separate replicates.

Regarding the effect of Lycopene-*Aloe vera* combination treatment on beef burger quality, **Table (2)** showed that addition of Lycopene-*Aloe vera* combination of different concentrations, to beef burger revealed overall improvement in the sensory quality that was represented by enhanced redness color, with improved texture and higher scores of consumer's appeal with longer keeping quality during refrigerated storage in comparison to the control untreated group. Higher concentration of Lycopene-*Aloe vera* combination **(G4)** showed higher sensory scores with longer shelf-life up to 15 days during refrigeration storage; while, control samples showed signs of spoilage (greyish coloration, with slimy texture and offensive odor) after the 9th day of storage.

Table 2. Sensory profile of different treated beef burger samples in cold storage (4 ±1 ^{O}C).

Groups	Tested parameter	G1	G2	G3	G4
Zero day (after 24h storage)	Color	4.9±0.16	4.9±0.16	4.9±0.16	4.9±0.16
	Odour	4.8±0.3	4.8±0.3	4.8±0.3	4.8±0.3
	Texture	4.9±0.4	4.9±0.4	4.9±0.4	4.9±0.4
	Taste	4.9±0.2	4.9±0.2	4.9±0.2	4.9±0.2
	Consumer appeal	4.87±0.05^{Aa} (VG)	4.87±0.05^{Aa} (VG)	4.87±0.05^{Aa} (VG)	4.87±0.05^{Aa} (VG)
3rd day	Color	4.6±0.16	4.6±0.16	4.7±0.16	4.8±0.16
	Odour	4.5±0.3	4.5±0.3	4.5±0.3	4.5±0.3
	Texture	4.7±0.4	4.8±0.4	4.7±0.4	4.6±0.4
	Taste	4.5±0.2	4.5±0.2	4.5±0.3	4.5±0.1
	Consumer appeal	4.57±0.09^{Ba} (VG)	4.6±0.1^{Ba} (VG)	4.6±0.1^{Ba} (VG)	4.6±0.14^{Ba} (VG)
5th day	Color	3.8±0.16	4.3±0.16	4.5±0.16	4.6±0.16
	Odour	4.0±0.3	4.1±0.3	4.2±0.3	4.3±0.3
	Texture	3.8±0.4	4.4±0.4	4.5±0.4	4.6±0.4
	Taste	3.5±0.2	4.1±0.3	4.4±0.2	4.5±0.1
	Consumer appeal	3.77±0.2^{Cc} (G)	4.2±0.15^{Cb} (VG)	4.4±0.1^{Ca} (VG)	4.5±0.14^{Ca} (VG)
7th day	Color	<1	3.5±0.16	4.1±0.16	4.2±0.16
	Odour	<1	3.4±0.3	3.8±0.3	4.0±0.3
	Texture	<1	3.8±0.4	4.0±0.4	4.1±0.4
	Taste	<1	3.7±0.2	3.9±0.3	4.0±0.2
	Consumer appeal	<1	3.6±0.18^{Dc} (G)	3.95±0.12^{Db} (G)	4.1±0.1^{Da} (VG)
9th day	Color	<1	3.0±0.16	3.5±0.16	3.6±0.16
	Odour	<1	2.8±0.3	3.2±0.3	3.5±0.3
	Texture	<1	3.2±0.4	3.4±0.4	3.5±0.4
	Taste	<1	3.5±0.2	3.4±0.4	3.7±0.2
	Consumer appeal	<1	3.12±0.29^{Ec} (G)	3.37±0.12^{Eb} (G)	3.57±0.1^{Ea} (G)
11th day	Color	<1	<1	3.0±0.16	3.0±0.16
	Odour	<1	<1	2.8±0.3	3.0±0.3
	Texture	<1	<1	3.0±0.4	3.2±0.4
	Taste	<1	<1	2.7±0.07	3.1±0.3
	Consumer appeal	<1 (S)	<1	2.87±0.15^{Fb} (A)	3.07±0.1^{Fa} (G)
13th day	Color	<1	<1	<1	2.7±0.16
	Odour	<1	<1	<1	2.3±0.3
	Texture	<1	<1	<1	2.6±0.4
	Taste	<1	<1	<1	2.4±0.3
	Consumer appeal	<1 (S)	<1	<1	2.8±0.18^{Ga} (A)
15th day	Color	<1	<1	<1	2.0±0.16
	Odour	<1	<1	<1	1.9±0.3
	Texture	<1	<1	<1	2.0±0.4
	Taste	<1	<1	<1	1.8±0.2
	Consumer appeal	<1 (S)	<1 (S)	<1	2.5±0.1^{H*} (A)

The values represent Mean ± SE of three experiments.
Means within the same column (ABCD) followed by different superscript letters are significantly different ($P \leq 0.05$).
Means within the same row (abcd) followed by different superscript letters are significantly different ($P \leq 0.05$).
4.0-5.0 very good (VG) 3.1-3.9 good (G) 2.1-3.0 Acceptable (A) 1.1-2.0 Unacceptable (U)
0.0-1.0 spoiled (S)

Moreover, enhanced physical characters and productivity of the treated burger samples were recorded in **Table (3).** Results revealed that treated beef burger with Lycopene-*Aloe vera* combination showed higher water holding capacity (WHC %), particularly, with higher concentrations (G4). Consequently, the treated samples showed lower degrees of cooking loss (CL %) and higher cooking yield (CY %) revealed the treated samples more palatable, with higher productivity.

Table 3. Mean values of water holding capacity (WHC), cooking loss (CL) and cooking yield (CY) (%) in the beef burger groups at cold storage (4±1^{O}C).

Day		G1	G2	G3	G4
Zero day (after 24h storage)	WHC	63.0±2.0^{Da}	70.0±2.0^{Ca}	71.8±2.0^{Ba}	73.0±2^{Aa}
	CL	30.0±2.0^{Ad}	24.0±1.0^{Bg}	20.0±1.0^{Ch}	18.0±1.0^{Dh}
	CY	70.0±1.0^{Da}	77.0±2.0^{Ca}	77.2±0.6^{Ba}	79.2±1.0^{Aa}
3rd day	WHC	58.4±1.0^{Db}	70.0±1.0^{Ca}	69.6±1.0^{Bb}	70.8±1.0^{Ab}
	CL	31.4±0.6^{Ac}	24.6±1.0^{Bf}	22.8±0.5^{Cg}	21.6±1.5^{Dg}
	CY	70.2±2.6^{Db}	75.4±1.0^{Cb}	76.5±0.5^{Bb}	79.2±1.0^{Ab}
5th day	WHC	52.5±1.0^{Dc}	66.2±1.5^{Cb}	68.0±1.5^{Bc}	69.6±0.6^{Ac}
	CL	38.2±1.0^{Ab}	25.6±1.0^{Bc}	23.5±1.0^{Cf}	22.2±2.0^{Df}
	CY	48.9±1.0^{Dc}	74.8±1.0^{Cc}	76.0±1.5^{Bc}	77.2±1.5^{Ac}
7th day	WHC	S.	65.4±1.5^{Cc}	66.8±1.0^{Bd}	67.2±1.2^{Ad}
	CL	S.	26.6±1.0^{Bd}	24.0±1.2^{Ce}	22.0±0.6^{De}
	CY	S.	73.8±1.5^{Cd}	74.6±0.6^{Bd}	75.2±1.0^{Ad}
9th day	WHC	S.	60.2±0.6^{Cd}	61.1±0.6^{Be}	65.0±1.0^{Ae}
	CL	S.	29.0±0.6^{Ac}	27.2±0.6^{Bd}	25.0±2.1^{Cd}
	CY	S.	66.4±1.5^{Ce}	67.8±1.5^{Be}	70.0±1.0^{Ae}
11th day	WHC	S.	S.	54.2±1.5^{Bf}	61.4±0.6^{Af}
	CL	S.	S.	32.5±0.2^{Bc}	27.8±1.0^{Cc}
	CY	S.	S.	56.1±0.6^{Bf}	66.3±1.0^{Af}
13th day	WHC	S.	S.	S.	58.2±0.6^{Ag}
	CL	S.	S.	S.	31.2±1.5^{Cb}
	CY	S.	S.	S.	58.0±0.6^{Cg}
15th day	WHC	S.	S.	S.	55.5±1.2^{*h}
	CL	S.	S.	S.	34.6±1.5^{*a}
	CY	S.	S.	S.	53.2±0.6^{*h}

ABC Different superscript letters within the same row means significant difference when (P≤0.05)
abc Different superscript letters within the same column for the same parameter means significant difference when (P≤0.05)*-. Superscript star within the same row means significant difference between less than three groups of variance when (P≤0.05) S. means apparently spoiled

Bacteriological quality of the treated groups showed significant reduction in the microbial counts in relation to the control group. Antimicrobial effect of Lycopene-*Aloe vera* combination treatment appeared to be dose-dependent; where higher concentration of Lycopene-*Aloe vera* revealed more potent antimicrobial effect **(Table, 4).**

Table 4. Average values of microbiological counts (log CFU/g) of the treated burger groups at cold storage (4±1^{O}C).

Day		G1	G2	G3	G4
Zero day (after 24h storage)	APC	3.8±0.2^{Ad}	3.7±0.1^{Ae}	3.6±0.2^{Be}	3.6±0.3^{Ba}
	CC	1.9±0.2^{Ad}	1.8±0.1^{Ae}	1.77±0.1^{Ce}	1.6±0.1^{Dh}
	FC	2.0±0.1^{d}	2.0±0.2^{f}	<2	<2
3rd day	APC	4.0±0.1^{Ac}	3.5±0.2^{Bf}	3.4±0.1^{Bf}	3.2±0.1^{Cb}
	CC	2.0±0.1^{Ac}	1.7±0.1^{Bf}	1.69±0.2^{Bf}	1.47±0.2^{Cg}
	FC	2.47±0.2^{c}	<2	<2	<2
5th day	APC	4.6±0.2^{Ab}	3.7±0.3^{Be}	3.3±0.2^{Cf}	3.0±0.3^{Dc}
	CC	2.2±0.1^{Ab}	1.9±0.1^{Be}	1.6±0.1^{Cf}	1.0±0.2^{Df}
	FC	2.69±0.2^{*b}	2.3±0.1^{*e}	<2	<2
7th day	APC	S.	3.9±0.2^{Bd}	3.5±0.1^{Ce}	3.1±0.1^{Dd}
	CC	S.	2.0±0.1^{Bd}	1.77±0.1^{Ce}	1.47±0.1^{De}
	FC	S.	2.6±0.2^{Bd}	2.0±0.1^{Cc}	<2
9th day	APC	S.	4.2±2.6^{Ac}	3.7±0.2^{Bd}	3.3±1.0^{Ce}
	CC	S.	2.14±0.6^{Ac}	1.95±0.2^{Bd}	1.69±0.2^{Cd}
	FC	S.	2.77±0.2^{Ac}	2.47±0.2^{Bb}	2.0±0.1^{Cc}
11th day	APC	S.	S.	4.0±0.2^{Bc}	3.7±0.3^{Cf}
	CC	S.	S.	2.11±0.2^{Bc}	1.84±0.1^{Cc}
	FC	S.	S.	2.69±0.3^{Ba}	2.3±0.1^{Cb}
13th day	APC	S.	S.	S.	4.2±0.3^{Cg}
	CC	S.	S.	S.	1.95±0.2^{Cb}
	FC	S.	S.	S.	2.6±0.3^{Ca}
15th day	APC	S.	S.	S.	4.7±0.2^{*h}
	CC	S.	S.	S.	2.07±0.2^{*a}
	FC	S.	S.	S.	2.69±0.3^{*a}

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abc Different superscript letters within the same column for the same parameter means significant difference when (P≤0.05)
*-. Superscript star within the same row means significant difference between less than three groups of variance when (P≤0.05)
APC: Aerobic plate count, CC: Coliform count, FC: Fungal count S. means apparently spoiled

Consequently, the treated burger samples showed more chemical stability; where significant slow-down raising up of TVN and TBA values, as an indirect effect through the potent antimicrobial and anti-oxidant characteristics of the used additives.

Table 5. Average values of pH, TVN (mg/100gm sample) and TBA (MDA/Kg sample) of the treated burger groups at cold storage (4±1^{O}C).

Day		G1	G2	G3	G4
	pH-	5.95±0.1^{Ad}	5.85±0.2^{ABd}	5.82±0.2^{Be}	5.75±0.3^{Ca}
Zero day (after 24h storage)	TVN	12.4±0.2^{Ad}	12.1±0.1^{Bg}	12.03±0.2^{Be}	12.0±0.2^{Bh}
	TBA	0.34±0.04^{Ad}	0.32±0.02^{Bg}	0.31±0.02^{Be}	0.31±0.01^{Be}
	pH-	6.10±0.1^{Ac}	5.88±0.02^{Bd}	5.85±0.1^{Bf}	5.78±0.1^{Cb}
3rd day	TVN	15.2±0.1^{Ac}	14.2±0.2^{Bf}	13.4±0.5^{Bf}	12.3±0.3^{Cg}
	TBA	0.44±0.02^{Ac}	0.38±0.03^{Bf}	0.34±0.02^{Ce}	0.32±0.02^{De}
	pH-	6.34±0.2^{Ab}	5.92±0.3^{Bd}	5.87±0.2^{Cf}	5.82±0.3^{Dc}
5th day	TVN	17.8±1.0^{Ab}	15.8±1.0^{Be}	15.2±1.0^{Cf}	12.8±1.2^{Df}
	TBA	0.59±0.02^{Ab}	0.42±0.01^{Be}	0.38±0.02^{Ce}	0.35±0.02^{De}
	pH-	S.	6.04±0.3^{Bc}	5.95±0.5^{Ce}	5.87±0.12^{Dd}
7th day	TVN	S.	16.2±1.0^{Bd}	15.8±1.2^{Ce}	13.2±0.6^{De}
	TBA	S.	0.54±0.05^{Bd}	0.42±0.06^{Cc}	0.38±0.02^{De}
	pH-	S.	6.20±0.26^{Ab}	6.0±0.6^{Bd}	5.91±0.1^{Ce}
9th day	TVN	S.	17.8±0.6^{Ac}	16.0±0.6^{Bd}	13.8±1.2^{Cd}
	TBA	S.	0.62±0.05^{Ac}	0.51±0.05^{Bb}	0.45±0.01^{Cc}
	pH-	S.	S.	6.13±0.2^{Bc}	5.98±0.5^{Cf}
11th day	TVN	S.	S.	17.2±0.2^{Bc}	15.3±1.0^{Cc}
	TBA	S.	S.	0.59±0.06^{Ba}	0.48±0.02^{Cb}
	pH-	S.	S.	S.	6.06±0.6^{Cg}
13th day	TVN	S.	S.	S.	16.8±1.5^{Cb}
	TBA	S.	S.	S.	0.53±0.06^{Ca}
	pH-	S.	S.	S.	6.14±0.12^{*h}
15th day	TVN	S.	S.	S.	17.9±1.5^{*a}
	TBA	S.	S.	S.	0.62±0.04^{*a}

ABC Different superscript letters within the same row means significant difference when (P≤0.05) abc Different superscript letters within the same column for the same parameter means significant difference when (P≤0.05) *-. Superscript star within the same row means significant difference between less than three groups of variance when (P≤0.05) TVN: Total volatile nitrogen, TBA: Thiobarbituric acid

DISCUSSION

Meat products are a main component in daily meals all over the world because of their rich nutritional makeup and customer demand. All of the required essential amino acids for muscle development, and general body maintenance due to its high-quality protein. They also provide essential micronutrients, including vitamin B12, iron, zinc, selenium, and phosphorus that promote brain health, energy metabolism, and immunological function **(Stadnik, 2024).**

Beef burger, a classic meat product, has been universally demanded for their palatability and adaptability. Key elements including freshness, juiciness, flavor, and consumer's choices influence the quality and customer attractiveness of beef burgers. So, food quality researchers always seek innovative meat additives which provide higher keeping quality with enhanced organoleptic properties of meat products.

The utilization of *Aloe vera* in meat products has gained attention due to its antimicrobial and antioxidant properties, which enhances both safety and shelf life. *Aloe vera* gel, rich in bioactive compounds such as flavonoids, phenols, and tannins, effectively inhibits microbial growth and reduces lipid oxidation. These compounds contribute to its antioxidant activity, which helps maintain meat quality by preventing rancidity and preserving color and texture changes. Characterization of *Aloe vera* gel is crucial to quantify its flavonoid, phenol, and tannin content, as these components directly influence its efficacy. For instance, higher phenolic content correlates with enhanced antioxidant capacity, making *Aloe vera* a valuable natural additive for improving the sensory, microbiological, and chemical stability of meat products (**Mensah et al. 2025**).

Regarding to the recorded results in **Table (1),** *Aloe vera* gel extract possessed a relatively high content of total phenolic compounds with 23.63 ± 0.45 mg GAE/g and total flavonoids (31.96 ± 0.25 mg QE/g), while the total tannin content is found to be 18.28 ± 0.63 mg GAE/g.

Lycopene is a potent carotenoid antioxidant primarily found in tomatoes, watermelon, and other red fruits. Its primary health benefit lies in its ability to neutralize free radicals, which are linked to chronic diseases **(Shafe et al. 2024)**. Additionally, lycopene has shown antimicrobial properties, making it a valuable component in food preservation and health supplements **(Khan et al. 2021)**.

Adding *Aloe vera* gel and lycopene, from tomato peels, significantly enhances beef burger preservation and sensory attributes. Referring to the present findings, **Table (2)** revealed that addition of Lycopene-*Aloe vera* combination revealed significant enhancement in the physical characters of the treated beef burger samples with longer acceptability scores in comparison with the control group which showed spoilage after the 5th day of storage. It is worth noted that the treated groups kept their sensory acceptance criteria up to the 9th day of storage for G2, the 11th day of storage for G3, and the 15th day for G4 with mean scores of 3.12, 2.87 and 2.5, respectively. The recorded results came in line with the recorded results of **Darwish et al. (2019) and Angioletti et al. (2024)** with some variation where they used lycopene and *aloe vera* gel alone in different storage conditions; whereas they recorded a significant enhancement in the overall sensory quality of the treated beef burger with lycopene (1.0%) and *Aloe vera* (2.0%). They attributed these effects to the potent antimicrobial effect of *Aloe vera* and strong antioxidant effect of lycopene active principles, that help in inhibition of microbial multiplication and keep chemical stability.

Improving water holding capacity in meat relies on careful management throughout production, including animal handling before slaughter, controlling pH and temperature after slaughter, and using effective processing techniques. By focusing on these areas, producers can boost meat quality, reduce moisture loss, increase product yield, and better meet consumer expectations **(Watanabe et al. 2018)**.

The provided current results **(Table, 3)** revealed that the treatment of beef burger with Lycopene-*Aloe vera* combination had a significant enhancement effect on the water holding capacity (WHC), cooking loss (CL) and cook-

ing yield (CY) of the treated groups, particularly with higher concentrations of the studied additives.

Aloe vera alone demonstrates significant impacts on water holding capacity (WHC), cooking loss, and cooking yield. Studies showed that *Aloe vera* gel (2-3% concentration) improves WHC by acting as a hydrocolloid, enhancing water absorption and reducing cooking loss by up to 30% in low-meat burgers **(Soltanizadeh and Ghiasi-Esfahani, 2015)**. This stabilization occurs through its gel-forming properties, which bind water and fat, minimizing moisture loss during cooking and improving yield **(Angioletti et al. 2024)**. Additionally, the antioxidant compounds of *Aloe vera* and lycopene compounds (e.g., polyphenols, polysaccharides) inhibit lipid and pigment oxidation **(Soltanizadeh and Ghiasi-Esfahani, 2015)**, preserving cellular integrity and further supporting WHC. While lycopene's specific role is not addressed broadly in the provided studies, *Aloe vera*'s mechanism involves both physical water retention and biochemical antioxidant activity to maintain product quality.

The microbiological safety of meat products is a critical factor in ensuring both quality and consumer satisfaction. Meat, being highly perishable, is susceptible to contamination by foodborne pathogens, which can cause severe illnesses. Additionally, spoilage microorganisms can degrade meat quality, leading to economic losses and reduced shelf life **(Mafe et al. 2024).**

Regarding the current results **(Table, 4)** Lycopene-*Aloe vera* combination treatment revealed significant reductions in the bacterial counts in comparison with the control group; which appeared to be dose-dependent, where higher Lycopene-*Aloe vera* concentration revealed higher antimicrobial effects particularly against foodborne pathogens and spoilage microorganisms. **Kahramanoglu et al. (2019)** and **Arbab et al. (2021)** revealed that coating foods with ethanolic extract of *Aloe vera* leaves and roots showed broad-spectrum antibacterial activity, inhibiting both foodborne Gram-negative and Gram-positive bacteria, and different fungi such as *Penicillium digitatum* and *Aspergillus niger*. In addition, the antioxidant capacity of *Aloe vera* stems from phenolic compounds like flavonoids, which scavenge free radicals and inhibit lipid peroxidation; besides that, its viscous consistency helps in keeping moisture levels that retain lipid peroxidation inhibition, maintaining partial efficacy against oxidative rancidity in food processing.

On the other hand, lycopene, also, exhibits significant antimicrobial properties against both Gram-positive and Gram-negative bacteria, as well as fungi. Studies have demonstrated that lycopene (2.0%) effectively inhibits different foodborne pathogens depending on the microorganism **(Imran et al. 2020)**. The antimicrobial mechanism of lycopene is attributed to its antioxidant activity, which disrupts microbial cell membranes causing leakage of cellular content and inhibits growth **(Shafe et al. 2024)**. Additionally, lycopene-*aloe vera* combinations have shown enhanced antibacterial and antifungal efficacy, suggesting potential applications in food preservation and pharmaceutical formulations, highlighting its potential as a natural antimicrobial agent in diverse industries **(Divyadharsini et al. 2023).**

The freshness and keeping quality of meat products are closely linked to key biochemical parameters such as pH, total volatile nitrogen (TVN), and thiobarbituric acid (TBA) values **(Ragab, 2011)**. Hydrogen ion concentration (pH) is a critical indicator of meat quality, with ideal values ranging between 5.8 and 6.3; deviations can signal spoilage or improper handling, as pH changes are influenced by lactic acid accumulation or proteolysis **(Hassanin et al. 2017)**. Total volatile nitrogen (TVN), which measures volatile nitrogen compounds like ammonia, increases with microbial activity and protein degradation, serving as a reliable marker of spoilage **(Altissimi et al. 2018**). Values of TBA values reflect oxidative rancidity, which deteriorates fat content and sensory attributes (**Domínguez et al. 2019)**. Together, these parameters provide a comprehensive assessment of meat freshness, with lower TVN and TBA values and stable pH indicating higher quality and extended shelf life.

Referring to the current results, **Table (5)** showed a significant enhancement in the chemical criteria of the treated beef burger with Lycopene-*Aloe vera* combination appeared as chemical stability with significant retardation in raising up of pH, TVN and TBA's values that indicated a significant role of the current treatments on protein deterioration ad lipid oxidation inhibition; which came in line with the recorded results of **Nassar et al. (2016), Ammar and Aboalfa (2017), and Hu *et al.* (2024)** who recorded a potent antibacterial and anti-oxidant effects of lycopene and *Aloe vera* as natural meat additives that keeps chemical stability and enhance the sensory characters of the treated meat products.

Lycopene, a carotenoid found in tomatoes, has been shown to reduce lipid oxidation, incorporating lycopene into chicken burgers significantly decreased TBA values, indicating reduced oxidative rancidity during storage, likely due to its potent antioxidant activity (**Nassar et al. 2016, Ammar and Aboalfa, 2017)**. Similarly, *Aloe vera* has been reported to improve meat quality by stabilizing pH and reducing microbial growth, which indirectly lowers TVN levels in relation to control group, a marker of spoilage (**Ammar and Aboalfa, 2017)**. The combination of these natural additives enhances the shelf life and sensory quality of meat products by mitigating oxidative damage and microbial proliferation, making them effective alternatives to synthetic preservatives (**Dahab et al. 2023; Hu et al. 2024).**

The obtained findings can be attributed to the potent antimicrobial and anti-oxidative effects of lycopene and *Aloe vera* compounds, that indirectly keep the beef burger physico-chemical required quality through its microbial inhibition and scavenging free radical's actions **(Sung et al. 2007; Mensah et al. 2025)**.

The obtained results, also, showed dose-dependent action of the used additives on the physico-chemical and microbial quality of the treated beef burger samples. Higher Lycopene-*Aloe vera* concentrations had direct relationship with the keeping quality and shelf-life of the treated samples based on their observed antimicrobial and anti-oxidant effects without adversely affect the sensory attributes **(Mensah et al. 2025)**.

CONCLUSION

The combination of lycopene and *Aloe vera* has been shown to be significantly enhancing the sensory, microbiological, chemical, and keeping quality of beef burgers during refrigeration storage. Lycopene, when combined with *Aloe vera*, acts as a hydrocolloid, improving water absorption and reducing cooking loss, while also stabilizing lipid oxidation, as evidenced by lower TVN and TBA values. Their antimicrobial properties, inhibited microbial growth, extended shelf life and maintaining sensory attributes like color and texture. Together, these natural additives improve the overall quality of beef burgers, offering a viable strategy for enhancing food safety, oxidative stability, and consumer acceptance.

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