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QUALITY EVALUATION OF FRESH CAMEL MEAT DIPPED IN EDIBLE CITRIC ACID

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Abstract

This study investigates the impact of dipping in food-grade citric acid on the shelf-life extension of fresh camel meat stored at refrigeration temperature. Fresh camel meat slices were treated with citric acid at concentrations of 0.5%, 1.0%, and 1.5%. The samples were then drip-dried packed into the vinyl acetate packs (VAP) and stored in a refrigerator at 5 °C for 15 days. The parameters studied included pH, water activity, Hunter color values, thiobarbituric acid reactive substances (TBARS) values, and total plate count (TPC). The pH of the treated samples decreased in comparison with the initial value of 5.30 (untreated sample) to a range within 4.20–4.47. The treated samples showed lower water activity values (0.95–0.99) than the control samples (0.97–0.987), especially the samples treated with 1.5% citric acid (0.95). The water activity (a_w) values did not significantly differ among the treated samples. The control sample had an initial a (a* — redness as per the colour chart) value of 16.4. Dipping the samples in citric acid significantly reduced the a* values to a range of 7.3 to 11.6. The red colour values in the control sample decreased during its storage to a range of 12.8 to 14.3. On the first day of treatment, the control sample exhibited a TBARS value of 0.26 mg/kg MA, which was significantly higher than that of the treated samples. The samples dipped in a 1.00% acid solution demonstrated the lowest TBARS values at 0.12 mg/kg MA. The TBARS values levels for the samples treated with 0.5%, 1.0%, and 1.00% citric acid were generally low, peaking at 0.23 to 0.29 mg of malondialdehyde/kg after 15 days. The control sample exhibited a total plate count (TPC) of 5.3 CFU/g, with no significant difference observed between the control sample and the sample treated with 0.5% citric acid. No microorganisms were detected on the first day in camel meat samples treated with citric acid at concentrations of 1.0% and 1.5%. At the end of the storage period, the TPC levels in acid-treated samples remained below 10^7 CFU/g on days 5th, 10th, and 15th. The shelf life of the treated camel meat was extended to 15 days.*

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Introduction

Camel is a viable meat source in climate-affected areas, such as Saudi Arabia, when other animal production efficiency is reduced. The demand for camel derived products, particularly meat in various forms, is increasing among the majority of the population in the Kingdom of Saudi Arabia (KSA) due to the shifts in dietary habits and the population growth. Camel meat is rich in animal protein and is a popular source of meat in many African and Asian countries. In certain regions, especially in Arabian countries, camel meat is preferred over that of other animals, particularly for cooking traditional dishes, due to its perceived medicinal benefits. It is often considered a healthier alternative compared to other meats, as it contains low levels of fat and cholesterol. Furthermore, camel meat is an excellent source of essential minerals, vitamins, bioactive compounds, and important fatty acids, including omega-3 fatty acids [1,2]. Camel can provide high-quality meat. Its meat provides significant therapeutic benefits due to its lower fat and cholesterol content compared to other livestock. It contains a higher level of polyunsaturated fatty acids. Consuming camel meat may help reduce the risk of various diseases in humans, including hypertension, pneumonia, hypersensitivity, and respiratory disease [3,4,5]. The demand for camel meat seems to be increasing due to health considerations, as camels produce carcasses with lower fat content, less cholesterol, and relatively higher levels of polyunsaturated fatty acids than other livestock according to Djenane and Aider [6]. Camel meat is highly susceptible to microbial contamination, which can result in spoilage and foodborne infections, thus leading to significant economic and health losses [7,8]. To prolong the shelf life period, antimicrobial compounds can be added to

fresh camel meat to inhibit the growth of pathogenic bacteria without reducing the quality of the product. Djenane et al. [9] investigated the impact of biopreservation treatment using *Olea europaea subsp. laperrinei* leaf extracts (laper.OLE) and nisin on the quality of camel steak during long-term refrigerated storage at 1±1°C in high O_2 (80%) and low CO_2 (20%) atmospheres. After 30 days of storage, the levels of psychrotrophic bacteria and *Pseudomonas* spp. were significantly lower in camel steaks treated with laper.OLE and nisin compared to untreated steaks. This treatment can extend the shelf life of the meat by up to 30 days. However, in the study conducted by Maqsood et al. [10], the addition of 200 mg/kg of tannic acid or catechin to camel meat reduced total mesophilic and psychrophilic bacterial counts down by one order of magnitude after 9 days of refrigeration. Consequently, the shelf life of the meat can be extended to 9 days. While artificial antimicrobials can be effective, there is a growing demand for natural preservatives. It was observed that herbs such as thyme, rosemary, and cinnamon significantly increased the shelf life of meat, with thyme exhibiting the most pronounced effect, extending the shelf life by up to 60 days [11]. Furthermore, it was found that mixtures of herbs had more effect on the storage stability of meat than individual herbs. It has been demonstrated that incorporating oregano essential oil into modified atmosphere packaging (MAP) extends the shelf life of various animal products, including beef and chicken [12]. Additionally, research has revealed that terpene and terpenoid compounds, such as menthol, geraniol, carvacrol, and thymol, exhibit strong antibacterial properties against *Enterobacter aerogenes*, *Listeria monocytogenes*, *Escherichia coli*, *Shigella flexneri*, *Shigella sonnei*, and species of *Aspergillus* [13,14]. Teshome et al. [15] reported that meat composition, processing techniques, and storage conditions are among the variables that influence the effectiveness of natural antibacterial agents in food industrial applications. They also reported that natural antimicrobials such as parsley, olive leaves, garlic, rosemary, pepper, thyme, sage and grape seeds are considered safe because they can reduce microbial resistance and align with consumer demand for healthier products. Many research works have been conducted to develop various preservation techniques to enhance the shelf life of fresh camel meat. Atika et al. [16] investigated the combined effect of a 2% lactic acid solution and refrigeration temperature on the shelf life of fresh camel meat. The meat samples were immersed in the acid solution and stored at a refrigeration temperature of 4 °C. They found that the shelf life of the meat could be extended by up to nine days. Benyagoub et al. [17] asserted that using a traditional preservation method, specifically drying combined with salt covering, for camel meat could enhance consumer demand for products that promote health and environmental sustainability. This approach not only raises the potential for developing a camel meat drying industry but also encourages the promotion of camel breeding. On other research work it was found that storing fresh camel meat in a refrigerator at 4 °C for 12 days extended the product's shelf life without negative affecting its sensory acceptability. Moghimi et al. [18] applied 0.2% *Cuminum cyminum L.* essential oil as a natural preservative and stored it at 4 °C for 15 days to extend the shelf life of fresh camel sausage. The results indicated that *Cuminum cyminum L.* essential oil can significantly prolong the shelf life of fresh camel sausage by 15 days. Tag et al. [19] found that treating fresh camel meat with gingerol at a concentration of 1.5% and nisin at a concentration of 2.5% can reduce the total microbial plate count (TPC) by 58.35% and 47.76%, respectively, while also enhancing the quality of the meat. Edible organic acids have the potential to prolong the shelf life of meat by controlling harmful bacteria and preventing oxidative spoilage, thus enhancing the overall quality of various types of meat. Bhagath and Manjula [20] reported that the application of organic acids in edible coatings for meat can reduce microbial counts in fresh meat. Similar findings were observed earlier by Siragusa and Dickson [21], who noted that the incorporation of edible organic acids, such as lactic acid at a concentration of 1.7% and acetic acid at 2%, into edible coatings can reduce microbial counts by 1.5 and 0.25 log units, respectively. However, incorporating 0.5% citric acid into an edible coating has proven its ability to enhance the shelf life of chicken meat, which should be stored at a refrigeration temperature of 4±1°C for 7 days [22]. To extend the shelf life of blood sausage, Diez et al. [23] conducted an independent investigation into the use of organic acids (L-potassium lactate, L-potassium lactate/sodium lactate, or L-potassium lactate/sodium acetate) and high-pressure treatments (300, 500, or 600 MPa for 10 minutes). The shelf life achieved was 15 days. Dipping fresh beef in 1 and 2% lactic acid, 1 and 2% acetic acid, 2.5 and 5% sodium lactate and 2.5 and 5% sodium acetate solutions then chilling at 4 °C could extend the shelf life of fresh beef up to 21 days [24]. According to Teshome et al. [15], the effectiveness of natural antimicrobial compounds, such as edible organic acids, in meat covering applications is influenced by various factors, including food composition, processing methods, and storage conditions. However, Yu et al. [25] reported that to enhance the applicability of natural preservatives, several strategies should be implemented. These include combinations of various preservatives and food preservation methods, such as active packaging systems and encapsulation. Moreover, grapefruit seed extract, cinnamaldehyde, and nisin used in active packaging (AP) can delay lipid oxidation and protein deterioration in beef by up to 14 days. Edible organic acids and their salts are commonly used as food additives due to their safety for human consumption and are generally recognized as safe (GRAS) and can be safely applied in food [26]. The objective of this study is to investigate the use of citric acid to extend the shelf life of fresh camel meat.

Materials and methods

Materials

Fresh camel meat was purchased from a slaughterhouse in Buraidah, Al-Qassim region, Kingdom of Saudi Arabia (KSA), and transported immediately to the meat laboratory.

The meat was covered with crushed ice and placed in ethylene-vinyl acetate (EVA) bags and delivered to the laboratory within 30 minutes. All organic acids used in the experiment were the food-grade materials purchased from Sigma Chemical Company.

Preparation of camel meat samples

The fresh camel meat samples were sliced into pieces measuring roughly 15 cm by 10 cm by 1 cm (length × width × diameter), and each piece weighed about 200 g. Solutions of acetic acid, lactic acid, and citric acid at concentrations of 0.5%, 1.0%, and 1.5% were prepared using distilled water. The camel meat samples were dipped in these solutions, soaked for 5 minutes, drained, packaged in polyethylene bags, and stored in a refrigerator for 15 days. The samples were evaluated at 5-days intervals.

pH value

The pH was measured during storage periods (0 to 15 days) at a temperature of 5 ± 0.2 °C using pH meter, the model HI2211 — pH Meter (Hanna instruments, Germany) was used in the measurement.

Water activity (a_w)

The water activity was determined using the method of Abd Elgadir et al. [27]. AquaLab model 3TE, Pullman, WA, USA was used in the measurement. The device was warmed for 30 minutes, after which one gram of each sample was chopped and spread onto the plate. The samples were then placed in the drawer. The device measured the water activity of the samples in approximately 40 seconds at 25 °C, recording three readings for each sample.

Colour measurement

HunterLab Ultrascan Sphere spectrocolorimeter Minolta Chroma Meter CR-300, Japan was used to measure colour. Three standard colour charts for L* (lightness), a* (redness), and b* (yellowness) were employed to calibrate the device. Prior to measurement, each sample was placed separately in disposable Petri dishes. The average of three replicates was calculated and recorded as results for each color measurement value.

Thiobarbituric acid (TBARS) value

A 90% glacial acetic acid solution was utilized to prepare TBARS by diluting 0.2883 g of TBRS in 100 mL. Ten grams of meat were macerated with 50 mL of distilled water and combined with 2.5 mL of hydrochloric acid. The mixture was boiled for 10 minutes, and 50 mL of distillate was collected. Five mL of the distillate was mixed with TBRS and heated for 35 minutes. Absorbance was measured at 538 nm using a UV-spectrophotometer, model Novaspec 11, Biochrom Ltd, England. The malonaldehyde value was calculated in mg/kg, corresponding to 7.8 × D. Each sample was analyzed in triplicate.

Total plate count (TPC)

The anaerobic bacterial count of the samples was determined using the method described by Insausti et al. [28]. Sterilized peptone was prepared by diluting 15 g of peptone in 1 L of distilled water and autoclaving the mixture at 120 °C for 15 minutes. TPC agar was prepared with 22.5 g/L of agar in distilled water, then autoclaved, cooled, and poured into sterilized Petri dishes. Serial dilutions were performed, and 0.1 mL of each dilution was spread onto the agar substrate. The plates were incubated for 48 hours at 37 °C in an anaerobic environment. Total counts were obtained from plates containing 30 to 300 colonies, analyzed in triplicate, and the results were reported as $\log_{10}$ colony-forming units (CFU). The quantity of bacterial colonies is expressed in colony-forming units per milliliter (CFU/mL) and is calculated using the following equation:

$$\text{CFU/mL} = \frac{\textit{Number of colonies} \times \textit{Dilution factor}}{\textit{Volume Plated}\ (\text{mL})}, \quad (1)$$

where:

Number of colonies = The count of visible colonies on the plate;
Dilution factor = The reciprocal of the dilution used;
Volume plated = The volume of diluted sample spread on the plate.

Statistical analysis

Two-way analysis of variance (ANOVA) was conducted using Minitab software version 17. The results are presented as mean ± standard deviation (SD). Dunn's multiple range test was conducted to compare the samples' differences at a significance level of $p \leq 0.05$.

Results and discussion

pH value

The pH values of the control sample and acid-treated samples are presented in Figure 1. All samples exhibited significant decreases in pH ($p < 0.05$) when dipped in citric acid, with concentrations of 0.5%, 1.0%, and 1.5%. Specifically, the pH of the acid-treated samples decreased considerably ($P < 0.05$) to 5.1, 5.0, and 4.7, respectively, while the pH of the control sample (0.00% citric acid) remained the highest at 5.8. Notable ($p < 0.05$) reductions in pH were observed as the concentration of citric acid in the dipping solution increased [29]. All samples exhibited an increasing pH trend, reaching values of 5.6, 5.5, and 5.2 along with the addition of 0.5, 1.0, and 1.5 grams of citric acid, respectively. The control sample showed the highest pH value of 6.2 after 15 days. It was

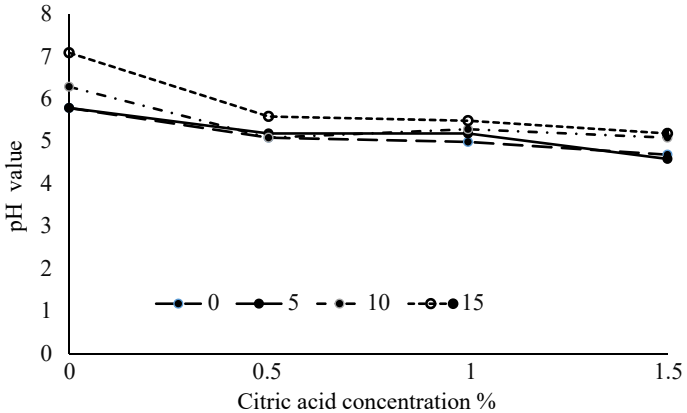

Figure 1. pH values of control sample and citric acid treated camel meat during storage at 5 °C for 15 days

reported that typically, the pH of fresh meat ranges from 5.5 to 6.5 [30]. However, when citric acid is applied to meat, it lowers the pH value. Edible citric acid, when applied to fresh camel meat, can influence its quality and preservation in several ways, mostly due to its acidic nature (pH ~2.2). The acidic environment caused by citric acid treatment can inhibit the growth of various bacteria and other pathogens, slowing down spoilage and thus extending the meat's shelf life. Citric acid disrupts microbial cell walls and interferes with essential metabolic processes, making it an effective preservative against bacteria like *E. coli* and *Salmonella*.

Water activity (a_w)

The water activity (a_w) values for the samples presented in Figure 2 indicate that the treated samples (0.95–0.99) exhibited lower values than the control samples (0.97–0.987), with the most significant reduction observed at 1.5% citric acid (0.95). This might indicate that dipping samples into the citric acid in the above-stated concentration featured more rapid penetration in meat muscle compared with the others. The water activity (a_w) values did not differ significantly ($p > 0.05$) among the various concentrations of citric acid in the treated samples. At the end of the storage period, the a_w values of the samples gradually increased, ultimately reaching 0.99. It was reported that the addition of edible acids such as citric acid can reduce the water activity of fresh meats by binding water molecules more tightly, decreasing pH, and thereby controlling microbial growth [31,32]. This can enhance the meat's shelf life and food safety [33]. By adding citric acid, which is hygroscopic, water molecules may become more tightly bound to the acidic compounds [34]. This interaction reduces the overall free water in the meat, effectively lowering its a_w. Lower a_w helps inhibit microbial growth and spoilage [35]. It was reported earlier that there is a strong correlation between microbial growth and the water activity of the food [36]. It was also revealed that higher water activity values correspond to increased and accelerated microbial growth [37]. Therefore, the lower value of a_w in the acid-treated samples may have contributed to a decrease in microbial growth.

Colour

Table 1 illustrates the changes in colour values of acid-treated samples at various concentrations. The control sample exhibited reddish colour with an initial a* value of 16.4. Dipping the samples into citric acid at various concentrations resulted in significant ($p < 0.05$) decrease in the values of a* values to the range between 7.3–11.6, which caused the camel meat samples to appear pale. The same finding is reported in the studies conducted by Awad et al. [38] and Osazuwa et al. [39]. The red colour also decreased significantly in the control sample during storage period to the values within the range of 12.8–14.3. Hunter L* values increased significantly ($p < 0.05$) after dipping in the acid in the first days (day 0) and after 5 days of storage in the control sample and the sample treated with citric acid in the concentration of 0.5%. However, L* values decreased significantly ($p < 0.05$) during the storage in the samples treated with acid at concentrations of 1.0% and 1.5%. The treated samples appeared lighter throughout the storage period. This finding agreed with those of Bernardez-Morales et al. [40]. The L* value of the control sample was 33.5 at the first; this value increased significantly to 36.1–48.1, 34.7–40.5 and 35.9–42.2 when the meat was treated with the acid in the concentrations of 0.5%, 1.0% and 1.5%. A significant ($P < 0.05$) decrease in a* values ($p > 0.05$) was observed. The a* values in the control group ranged from 12.8 to 16.4 but significantly decreased to 7.3–11.6, 7.8–10.4, and 7.6–8.8 when treated with acid at concentrations of 0.5%, 1.0%, and 1.5%, respectively. A similar trend was noted in the b* values. Treatment with acid at a concentration of 1.0% resulted in a significant ($P < 0.05$) decrease in both a* and b* values.

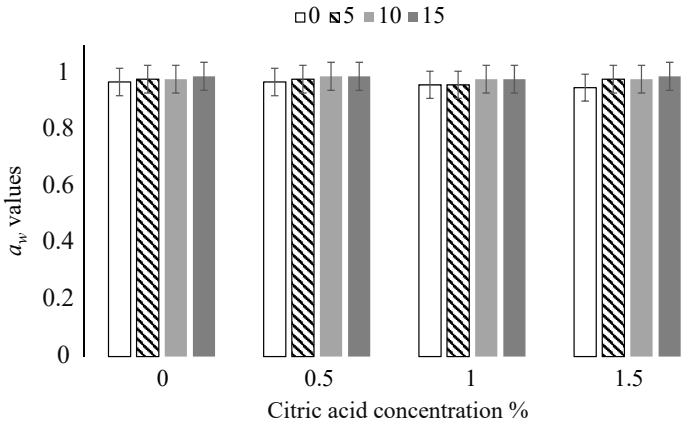

Figure 2. Water activity values of camel meat samples treated with citric acid during storage period

Table 1. Colour values of control sample and citric acid treated camel meat during storage at 5 °C for 15 days

	Storage period (days)	Control sample (0% citric acid)	Citric acid treated samples		
			0.5%	1.0%	1.5%
L*	0	33.5 ± 0.3^{Cd}	37.3 ± 0.2^{Bd}	38.5 ± 0.3^{Ab}	38.7 ± 0.1^{Ab}
	5	37.9 ± 0.1^{Db}	47.4 ± 0.3^{Ab}	40.5 ± 0.1^{Ca}	42.2 ± 0.1^{Ba}
	10	46.3 ± 0.2^{Ac}	36.1 ± 0.1^{Bc}	34.7 ± 0.1^{Dd}	35.9 ± 0.1^{Cd}
	15	42.4 ± 0.1^{Ba}	48.1 ± 0.1^{Aa}	35.8 ± 0.1^{Dc}	37.6 ± 0.3^{Cc}
a*	0	16.4 ± 0.3^{Aa}	11.6 ± 0.1^{Ba}	10.4 ± 0.1^{Ca}	8.8 ± 0.4^{Da}
	5	14.3 ± 0.1^{Ab}	10.4 ± 0.2^{Bb}	9.1 ± 0.2^{Cb}	8.3 ± 0.1^{Da}
	10	12.8 ± 0.1^{Ad}	$8..2 \pm 0.6^{Bc}$	7.8 ± 0.3^{Cc}	7.6 ± 0.1^{Cc}
	15	13.8 ± 0.1^{Ac}	7.3 ± 0.3^{Bd}	7.8 ± 0.4^{Bc}	7.7 ± 0.1^{Bc}
b*	0	11.1 ± 0.2^{Dd}	12.6 ± 0.1^{Aa}	14.4 ± 0.2^{Bb}	13.1 ± 0.1^{Cd}
	5	16.6 ± 0.3^{Ab}	16.3 ± 0.2^{Ab}	15.3 ± 0.3^{Ba}	12.6 ± 0.3^{Ca}
	10	15.4 ± 0.4^{Ac}	10.9 ± 0.2^{Cd}	11.3 ± 0.4^{Bc}	11.1 ± 0.1^{Bc}
	15	20.6 ± 0.1^{Aa}	14.3 ± 0.3^{Bc}	12.5 ± 0.1^{Cd}	12.1 ± 0.2^{Cb}

[a, b, c, d] **Means with different lowercase superscripts within the rows are significantly different ($p < 0.05$).**
[A, B, C, D] **Means with different uppercase superscripts within the column are significantly different ($p < 0.05$).**

Thiobarbituric Acid (TBARS) Value

Table 2 shows the various levels of TBARS in both fresh and treated samples during the studies along the storage period. On the first day of treatment, the control sample exhibited an initial TBARS value of 0.26 mg/kg MA, which was significantly higher ($p < 0.05$) than that of the treated samples. Among the treated samples, those dipped in a 1.00% acid solution consistently showed the lowest TBARS values. Under

storage conditions, there was a significant decrease ($p < 0.05$) in TBARS readings for camel meat that had been treated with organic acids. TBARS levels gradually increased during storage, with control samples exhibiting significantly higher levels ($p < 0.05$) than the treated samples. In this study, the level of lipid oxidation in samples treated with 0.5%, 1.0%, and 1.00% citric acid was generally modest, peaking at 0.23–0.29 mg of malondialdehyde/kg after 15 days of storage. It was observed that a rancid flavor had been initially detected in meat with a TBARS value of 2.0 mg of malondialdehyde/kg [41]. Citric acid is expected to significantly reduce the development of rancidity in camel meat based on this cut-off value [42]. Citric acid can also act as antioxidant, it can donate hydrogen atoms to free radicals, thus stabilizing them and preventing them from interacting with fatty acids in animal products such as meat [43]. This slows down the oxidation chain reaction, reducing the development of malondialdehyde and other TBARS compounds [44, 45]. When used in combination with other antioxidants (like ascorbic acid), citric acid may exhibit synergistic effects, enhancing the overall antioxidant activity [46]. This can be particularly beneficial in fresh meats, where a blend of natural antioxidants can more effectively reduce TBARS and preserve meat quality. In summary, citric acid serves as an effective antioxidant in fresh camel meat by reducing lipid oxidation through chelation, acidification, and radical scavenging. This intervention can play an important role in extending the freshness and quality of camel meat, making it more desirable in the markets where meat quality preservation is essential.

Table 2. TBARS values of control sample and citric acid treated camel meat during storage at 5 °C for 15 days

Storage period (days)	Control sample (0% citric acid)	Citric acid treated samples		
		0.5%	1.0%	1.5%
0	0.26 ± 0.01^{Ba}	0.18 ± 0.03^{Bb}	0.13 ± 0.01^{Bc}	0.18 ± 0.01^{Bb}
5	0.19 ± 0.01^{Cc}	0.23 ± 0.01^{Aa}	0.29 ± 0.01^{Ab}	0.16 ± 0.01^{Bd}
10	0.22 ± 0.02^{Ca}	0.23 ± 0.01^{Aa}	0.12 ± 0.02^{Bb}	0.27 ± 0.02^{Aa}
15	0.36 ± 0.01^{Aa}	0.28 ± 0.03^{Bb}	0.23 ± 0.01^{Bb}	0.29 ± 0.01^{Ac}

[a, b, c, d] Means with different lowercase superscripts within the rows are significantly different ($P < 0.05$).
[A, B, C, D] Means with different uppercase superscripts within the column are significantly different ($P < 0.05$).

Total plate count (TPC)

The TPC values of the control sample and the treated samples during storage are shown in Table 3. The control had a TPC of 5.3 CFU/g. There was no significant difference between the control sample and the sample treated with 0.5% citric acid. However, no microorganisms were detected on the first day when the camel samples were treated with citric acid in the concentrations of 1.0 and 1.5, respectively. Citric acid treatments at all concentrations (0.5, 1.0 and 1.5%) provided significantly lower ($p < 0.05$) for citric acid treatments at all concentrations (0.5%, 1.0%, and 1.5%) compared to untreated samples over the same storage period. It is widely recognized that meat approaches deterioration and becomes unsalable at a level of 10^7 CFU/cm² [47,48]. Previously, it was proposed that the shelf life of fresh meat is influenced by time and the development of off-odor as well as storage temperature and the initial microbial load on the meat [49]. In this research, the samples treated with 1.0% and 1.5% citric acid were below the target count on the day 15th. On days 5th and 10th, the control sample and those treated with 0.5% citric acid exhibited microbial counts exceeding 10^7 CFU/g.

Table 3. TPC values of fresh camel meat during storage at 5 °C for 15 days

Storage period (days)	Control sample (0% citric acid)	Citric acid treated samples		
		0.5%	1.0%	1.5%
0	5.3 ± 0.1^{Da}	5.2 ± 0.1^{Ca}	ND	ND
5	6.2 ± 0.3^{Ca}	6.2 ± 0.1^{Ba}	6.5 ± 0.1^{Aa}	5.5 ± 0.2^{Aa}
10	8.4 ± 0.3^{Ba}	6.1 ± 0.1^{Ba}	6.7 ± 0.1^{Aa}	5.6 ± 0.3^{Aa}
15	9.5 ± 0.1^{Aa}	8.2 ± 0.2^{Aa}	6.8 ± 0.1^{Aa}	5.6 ± 0.2^{Aa}

[a, b, c, d] Means with different lowercase superscripts within the rows are significantly different ($p < 0.05$).
[A, B, C, D] Means with different uppercase superscripts within the column are significantly different ($p < 0.05$).

Conclusion

In conclusion, higher concentrations of citric acid significantly inhibited bacterial growth, thereby reducing spoilage and enhancing microbial safety of the camel meat. The citric acid treatment minimized lipid oxidation, preventing the formation of off-flavors and preserving the sensory qualities of the camel meat. Despite the acidic treatment, pH levels remained within the acceptable range, ensuring that the camel meat's natural texture and quality were maintained. These findings suggest that citric acid can serve as an effective natural preservative for extending the freshness of camel meat, thereby decreasing the reliance on the artificial preservatives. The quality of fresh camel meat can be preserved for a longer time when treated with citric acid. Higher concentrations of citric acid inhibit bacterial growth and reduce the rancidity values of the camel meat. The study found that pH levels remained within normal ranges, and the shelf life of the camel meat increased to 5, 10, and 15 days with citric acid concentrations of 0.5%, 1.0%, and 1.5%, respectively.

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