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*Corresponding author
Azad Behnan Sabow
azad.sabow@su.edu.krd

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Effect of Pre-and Post-Slaughter Lactic Acid Spray on Microbial Population Reductions and Quality Characteristics of Lamb Carcasses

Mardin Safin Ali[1], Azad Behnan Sabow[1*]

[1]Department of Animal Resources, College of Agricultural Engineering Sciences, Salahaddin University-Erbil, Erbil, Kurdistan Region, Iraq

ABSTRACT

The sheep fleece serves as the primary source of carcass contamination. In this study, before and after slaughter, lactic acid was sprayed for microbial decontamination for lamb carcasses. Eighteen male lambs were randomly assigned to two groups: a treatment and control groups. Each treatment group consisted of six lambs that received sprays of 3% or 6% lactic acid in two distinct phases: (I) applied to a live animal's hide/fleece and (II) was applied to carcass surfaces immediately after slaughter. Remaining six animals, the no-spraying treatment was used as the control group. Microbiological samples were then collected from animal skins or fleece before spraying, and carcass surfaces 24 h after slaughter. The characteristics of the meat quality were also analyzed. Total aerobic counts, coliforms, Escherichia coli, Bacillus, Pseudomonas, and Staphylococcus were detected in both the external hide/fleece and the carcass surface samples. Nonetheless, treatments involving lactic acid sprays markedly decreased counts of all examined microbes on carcass surfaces compared with the non-sprayed control group. Treatments involving 3% and 6% lactic acid sprays reduced Escherichia coli and total coliforms counts by 2.36, 2.51, and 2.67, 2.71 cfu/cm^2 of the carcass surfaces, respectively. Likewise, treatments spraying with 3% and 6% lactic acid treatments led to reductions of 4.20 and 4.31 cfu/cm^2 for the populations of total aerobic count, 1.72 and 2.06 cfu/cm^2 for Pseudomonas, 2.02 and 2.06 cfu/cm^2 for Bacillus and 1.83 and 2.75 cfu/cm^2 for Staphylococcus, respectively. No significant differences were observed in the physicochemical sensory attributes between the control and spray treatments indicating that spraying lactic acid application pre-slaughter did not cause stress to the animals. Spray application of lactic acid pre- and post-slaughter stages is practical and can be used for optimizing food safety as it effectively ensures reduce bacterial contamination of lamb carcasses without negatively impacts the quality.

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1. Introduction

Sheep meat, whether lamb or mutton, has long been a popular choice for consumers, worldwide. This preference is driven by its eating quality, with flavor being the most important factor, followed by tenderness and juiciness (Prache et al., 2022). Changes in meat tenderness, juiciness, flavor, and overall quality are primarily linked to microbial contamination present in the meat (Álvarez et al., 2022). Bacterial contamination levels in sheep carcasses are also influenced mainly owing to variations in the production and processing systems (Rani et al., 2017). Meat contamination during animal slaughter may occur during the killing and dressing processes, either in the field or at the abattoir and can originate from various sources. Main source of microbial cross-contamination on sheep carcasses, according to several research on contamination sources in animal tissues (Morshdy et al., 2023), is the hide or fleece of living animals.

In general, bacterial contamination of the hide or fleece results from interaction with animal excrement. Moreover, several research has indicated that bacterial contamination of animal carcasses mostly happens during dehiding, either from faecal matter splashing back during hide removal or from the knife piercing the hide into the carcass (Bhandare et al., 2007; Milios et al., 2014; Aynewa et al., 2021). Thus, a major issue is stopping bacterial contamination of sheep carcasses from the hides or fleece during slaughter. Responding to this problem, meat industry regulators, researchers, and food safety managers have concentrated on improving food safety by giving raw meat tissues more attention and bacterial decontamination of animal carcasses following slaughter more attention. Improving microbiological safety depends on this since even healthy meat-producing animals may have latent paths for harmful germ cells (Van Ba et al., 2018).

Recent decades have seen research focused on decontamination treatments for animal carcasses, including the application of organic acids, such as lactic acid. This acid is widely used as an antimicrobial agent for carcass decontamination across numerous countries due to its economic advantages and sufficient efficacy in decontamination. Anti-microbial activity of lactic acid could be explained through several factors including: (1) its ability to lower cytoplasmic pH by entering the cell in un-dissociated form and then dissociate by releasing proton (H+), (ii) by physical disruption of microbes and hence immediate decontamination of meat surfaces, and (iii) by free radicals produced in the cell due to perturbation of electron transport chain under acid stress (Manzoor et al., 2020). Additionally, lactic acid is generally recognized as safe (GRAS) natural preservative which allows to be used in food products including mead (Saad et al., 2020). The application of lactic acid at concentrations of 2-5% on carcasses has been demonstrated to improve shelf life and may decrease the likelihood of foodborne illnesses in livestock carcasses (Ben Braïek and Smaoui, 2021; Nkosi et al., 2021). Van Ba et al. (2017) concluded a concentration of 3% lactic acid spray on carcasses produced a greater reduction in a wide variety of pathogen species as compared to the effects of acetic acid. Some studies have examined the reduction of bacterial contamination in animal carcasses through the application of organic acids; however, these treatments were exclusively implemented on sheep carcasses after slaughter in the research conducted (Van Ba et al., 2018; Saad et al., 2020; Roila et al., 2022b). Currently, scientific data on the effects of Carbon-based acids, such as lactic acid, were sprayed before and after slaughter for decontamination of microbes present on the hides of lambs, fleeces, and carcasses, and muscle quality characteristics is limited. Therefore, the objectives of this study was to evaluate the effects pre-and post-slaughter spray application with two different concentrations of lactic acid on carcass microbial population reduction and muscles quality parameters of lambs.

2. Material and methods

The study was conducted following Ethics and Animal welfare committee guidelines at Department of Animal Resources, College of Agricultural Engineering Sciences, Salahaddin

University-Erbil, Kurdistan Regain of Iraq.

2.1 Experimental designs and preparations

Purchased from a commercial fatting lamb farm, 18 male Karadi lambs aged eight months, average body weight of 38.504 ± 2.97 kg, were maintained under similar management practices. One day before the start of the trial, lambs were transported from the farm to livestock government slaughterhouse located in the city of Erbil, Kurdistan Region, Iraq. All the animals stayed overnight without food, but with unlimited access to water. The lambs were randomly divided into three groups (six lambs per group), with one serving as the control group, while the other two were treated with lactic acid spray at concentrations of 3% (pH, 2.35) and 6% (pH, 2.01), respectively. The solution of lactic acid was prepared by diluting lactic acid (90 – 92%) (BDH Chemicals Ltd., Poole Dorset, England) with sterile distilled water to create 3% and 6% acid solution and solution temperature was 21 ± 0.8 °C. The spraying was done twice: the first spray was performed on the external section of the fleece of the live animals after they were transferred into the sheep weighing scale. Each animal at this point was manually sprayed with 500 ml of each lactic acid concentration using one-hand pressure sprayer (Solo® china - 1 bar pressure). After spraying, the animals were allowed to rest for ten minutes before being transported to the slaughtering area. The second spray was performed immediately at the end of slaughter line, after the last washing and before entering the chilling room, by 250 ml of each lactic acid concentration on the overall surface of each carcass. Following the second spray, all carcasses were transferred to a cold chamber at 4 ºC, where they were kept for 24 h before the collection of microbiological samples. To guarantee the elimination of extra blood from carcass, all animals were humanely severed following the halal slaughter technique. A licensed slaughter-man severed the carotid artery, jugular vein, trachea, and esophagus.

2.2 Sampling

Microbiological samples were collected for all the animals used (control and lactic acid treatment) at two different stages: (i) from the external hide or fleece of the live animals before slaughter or spraying at the weighing scale, as well as (ii) from the surfaces of the carcass sides 24 h in a chilling chamber. For both sampling times, samples were collected from six representative locations (3 locations per side x 2 sides): the brisket (between the brisket and limb), hip (along the upper part of the vertebrae column leaning towards the head and to the lower part close to the tail), and round (around the stifle area) of each animal. Using sterile forceps, the sample was gently rubbed with a pre-moistened sterile sponge (3 × 3 cm) across a 25 cm² surface area (5 × 5 cm) of each chosen area. Six microbiological samples were obtained from a 150 cm² surface area on every control or sprayed animals in each sampling phase. Subsequently, every sponge sample was placed in bags, sealed, and forwarded for bacterial examination.

2.3 Microbiological analysis

Following sample, one minute of hand massaging of the bags containing the sponge samples was inside the zip-lock bags. Each sample was serially diluted with peptone water (Accumix, Malaga, Spain). The homogenates' 0.1 ml samples of the successive dilutions (1:10 diluent, and peptone water) were placed on the surface of the dry media for microbiological counting. Ten-fold dilutions were plated in duplicate on petri dishes for enumeration of the total aerobic counts on Nutrient Agar (Scharlau, Barcelona, Spain), Pseudomonas on MacConkey Agar (Merck KGaA, Darmstadt, Germany) and Staphylococcus spp. Yolk emulsions supplemented after 48 hours of incubation at 37 ºC. Following 48 hours of incubation at 37 ºC, total E. coli and coliforms were counted on 3MTM Petri-filmTM E. coli/coliform Count Agar (Merck KGaA, Darmstadt, Germany). After 48h of incubation at 30 °C, Bacillus spp. were counted. Tryptic Soy Agar (Merck KGaA, Darmstadt, Germany). Based on their usual biochemical characteristics including cluster shape and color on the cultivated media E. coli and coliform bacteria were identified. Coliforms were counted from clusters with trapped gas, and red or blue hue. For instance, E. coli was counted from clusters with trapped gas and a blue to red-blue color. Enumeration was performed using a colony counter (Funke Gerber, Germany). Before

statistical analysis, the counts of growth were subsequently translated to log10 of colony forming units/ cm^2 (cfu/cm^2) of fleece or carcass surface. Differences between log10 cfu/cm^2 of live animal's hide surfaces before slaughter or spraying and log10 cfu/cm^2 of carcass surface after slaughter/or spraying were calculated as a log reduction.

2.4 Meat quality analysis

Longissimus lumborum muscle (loin) and semitendinosus muscle (eye of round) were obtained from carcass sides of both control and sprayed animals 24h post-mortem for physicochemical analysis and sensory analysis to find whether the spraying treatments before slaughter caused stress in animals.

2.4.1 pH value

Homogenized approximately 0.5g of longissimus lumborum and semitendinosus muscle samples in 10 ml of ice-cold deionized water for 30s using a homogenizer (Pro Scientific homogenizer PRO250 Willenbrock, Oxford, Connecticut, USA). Acid-based level of resultant homogenates was subsequently measured using an electrode connected to a pH meter, following calibration at pH 4 and 7 (Salaye and Sabow, 2023).

2.4.2 Color

A Color Flex spectrophotometer (Dong wan Technology Innovation Centre, Shenlong Tou, Shenzhen, China) was used to assess color values. Meat color data were expressed by means of the International Commission on Illumination (CIE) Lab system (L*, a*, b*) using a D65 illuminates and a 10° standard observer, thereby determining color values within a specified wavelengths range of 400-700 nm. The tool was tuned against a black-and-white standard before usage. About 12 mm thick, longissimus lumborum and semitendinosus muscle samples were left to bloom for 30 min before positioning the bloomed surface facing the base of the color flex cup (AMSA, 2012). Every sample underwent two measurements of the values of L*(lightness), a*(redness), and b* (yellowness) and then averaged.

2.4.3 Water holding capacity

Water holding capacity was measured following the protocol described by Yu et al. (2021). About 1 g of longissimus lumborum and semitendinosus muscle samples we rewrapped in absorbent cotton and then placed in centrifugal tube. The tubes holding the samples were next centrifuged (Hettich ROTINA 380R, Germany) at 3000 g for 10 min at 4 °C. Express the sample weight after centrifugation to the original sample weight allowed one to determine the water holding capacity (%) using the following formula:

$$\text{Water holding capacity (\%)} = [X1 \div X2] \times 100$$

Where X1 represents the sample weight after centrifugation (g) and X2 represents the original sample weight (g).

2.4.4 Cooking loss

To assess the cooking loss, longissimus lumborum and semitendinosus muscle samples were weighed (X1), placed in polyethene bags, vacuum-sealed, and then transferred to a water bath. The samples were cooked in a preheated water bath (Thermo Haake C10 Water Bath; Crowley Scientific, Agecroft Enterprise Park, Salford, United Kingdom) set to 80 °C. Once the internal temperature of the muscle samples reached 78 °C, as measured using a temperature probe, and cooking for an additional 10 min. The cooked samples were then removed from the water bath and allowed to cool to room temperature. The samples were gently blotted dry and then reweighed (X2). The percentage cooking loss was calculated using the following formula:

$$\text{Cooking loss (\%)} = [(X1 - X2) \div X1] \times 100$$

Where X1 represents the muscle weight before cooking in a water bath (g) and X2 represents the muscle weight after cooking in the water bath (g).

2.4.5 Shear force

Shear force testing was conducted on meat samples for cooking loss assessment utilizing a texture analyzer (CT3 Crunchbase Company Manufacturing Santee, 11423 Woodside Ave Unit C, United States) with a volodkevitch biting jaw. The tool was calibrated 10 mm/s for speed of blade and distance for height was set at 10 mm. Each sample was divided into two 1 × 1 × 2 cm blocks parallel to the muscle fiber direction (Sazili et al., 2005). The volodkevitch bite jaw of the texture analyzer sheared each block at the center and perpendicular to the muscle fibers'

longitudinal orientation. Shear force measurements were taken as the average peak positive force (kg) of all the blocks per sample:

2.4.6 Color stability

Twenty milliliters of 0.04 M phosphoric acid buffer (pH 6.8) were mixed with 5 g of longissimus lumborum and semitendinosus muscle samples, which were then homogenized at high speed for 30 seconds. The mixture was left in an ice bath for an hour before being centrifuged at 3500 rpm for 30 minutes. The homogenate was filtered and diluted to a final volume of 25 ml using aforementioned buffer. The absorbance at 525, 545, 565, and 572 nm was measured with an ultraviolet spectrophotometer (Beckman Coulter DU 800 spectrophotometer; Incorporation Fullerton, California, United States). The following formulae were used to compute methemoglobin (MMb), oxymyoglobin (OMb), and total myoglobin (TMb) contents.

$TMb\ (mg / g) = -0.166A572 + 0.086A565 + 0.088A545 + 0.099A525$

$OMb\ (\%) = (0.882R1 - 1.267R2 + 0.809R3 - 0.361) \times 100$

$MMb\ (\%) = (-2.514R1 + 0.777R2 + 0.800R3 + 1.098) \times 100$

Where R1 = A572/A525, R2 = A565/A525 and R3 = A545/A525.

2.4.7 Determination of thiobarbituric acid reactive substances (TBARS)

TBARS of these muscles' TBARS were tested following the method described by Aminzade et al. (2012). Muscle samples (5 g) were homogenized for 2 min in 48 ml distilled water and 1.25 ml 4N HCl. Distilling the mixture yielded 25 ml. Next, 2.5 ml of distillate and 2.5 ml of TBA reagent (15% trichloroacetic acid and 0.375% thiobarbituric acid) was heated in a boiling water bath for 35 minutes. After cooling for 10 minutes under running tap water, a UV spectrophotometer measured the absorbance at 538 nm with a blank as the reference (Beckman Coulter DU 800; Incorporation Fullerton, California, United States). The TBARS values were determined by multiplying optical density by 7.843. Malondialdehyde equivalents (mg MDA per kilogram of meat) represented oxidation products.

2.4.8 Sensory analysis

The sensory analysis was conducted using the methodology outlined by Xin et al. (2018). The evaluation involved 10-member panel comprised assistant professors, lecturers and postgraduate students of the University. The meat samples from the longissimus lumborum and semitendinosus were cut into steaks 5 cm long, 5 cm wide, and 2 cm high. The internal temperature of the steaks reached 70 °C after 20 minutes of cooking at 180 °C. The steaks were cooked, sliced into 1 cm × 1 cm × 1 cm pieces, and placed in white plastic pans wrapped in aluminum foil, and baked for approximately 10 min at 70 °C before being tasted. Samples were tagged anonymously to keep the panel members unaware of the treatment. The methodology established by Salaye and Sabow (2023) involved recording the scores for lamb tenderness, juiciness, flavor, and overall acceptability on a five-point scale, with 5 indicating strong appreciation and 1 indicating strong dislike.

2.5 Statistical analysis

A completely randomized design was used for the experiment. The General Linear Model (GLM) approach in the Statistical Analysis System (SAS) software, Version 9.1.3 (SAS Institute Inc., Cary, NC, USA), Statistical Analysis System (SAS) was used to analyze collected data for bacterial populations samples before and after spraying and the reduction of control and lactic acid spray treatments. Likewise, meat quality indicators of two different muscle types were evaluated using GLM procedure of SAS. When significant variations between means were found, Duncan's multiple range test was used to compare results. $P<0.05$ was the level of statistical significance. The following mathematical model was used:

$$Y_{ij} = \mu + T_i + e_{ij}$$

Where:

Y_{ij} = observational value of lamb,

μ = overall mean,

T_i = Effect of lactic acid spraying application, and

e_{ij} = Random error associated with each observation.

3. Results and discussion

3.1 Microbial count

Commonly said to be accurate markers of contamination, hygiene standards, and the microbial. The superiority of edibles includes the aerobic plate count, coliforms, and Escherichia coli. Table (1) shows the counts of total aerobic bacteria, Escherichia coli, and total coliforms in the samples taken from lambs' external fleece sections before the neck cut and carcass sections 24 h after the neck cut. Between the treatment groups (3% and 6% lactic acid solutions) and the untreated control group, total aerobic count, Escherichia coli, or total coliform levels did not differ before slaughter or after spraying. However, the findings of this study revealed that the dehiding and washing procedures used during neck cutting were insufficient to eliminate every target bacterium. All samples were taken from the carcass sides; for instance, 24 h after the last washing and chilling, still showed a notable concentration of total aerobic bacteria, Escherichia coli, and total coliforms. Comparatively to the unsprayed control, both spraying treatments produced noticeably reduced levels of total aerobic counts, E. coli, and total coliforms. The unsprayed control only lowered by 1.96 cfu/cm^2, while the spray with 3% and 6% lactic acid considerably reduced the total aerobic count by 4.20 and 4.31 cfu/cm^2, respectively. Likewise, Escherichia coli and total coliforms decreased by 2.36, 2.51, and 2.69, 2.71 cfu/cm^2 of the carcass surfaces, respectively, which got the 3% and 6% lactic acid spray. Spraying with 3% and 6% lactic acid led to reductions of 2.81 and 2.54 cfu/cm^2 for Pseudomonas and 3.54 and 3.853 cfu/cm^2 for Bacillus, respectively. Twenty-four hours after slaughter and spray application, 3% and 6% lactic acid sprays significantly decreased the populations of Bacillus and Pseudomonas bacteria on carcass sections compared to the control (non-sprayed carcasses). The 3 and 6% lactic acid treatments resulted in a reduction in 1.72, 2.02, and 2.06, 2.85 cfu/cm^2 of carcasses for Pseudomonas and Bacillus, respectively. The control carcasses exhibited reductions of 0.82 and 1.38 cfu/cm^2 for Pseudomonas and Bacillus, respectively. The 6% lactic acid spray substantially reduced Staphylococcus bacteria compared with the 3% spray.

Table 1: Quantification and reduction levels of total aerobic count, coliforms, Escherichia coli, Bacillus, Pseudomonas, and Staphylococcus in lambs before and after slaughter influenced by acetic lactic acid application

Parameter	[1]Sampling time	Treatment groups		
		Control	3% LA	6% LA
Total aerobic count	Before	5.12 ± 0.48	5.26 ± 0.43	5.20 ± 0.51
	After	3.16 ± 0.06^a	1.06 ± 0.24^b	0.89 ± 0.26^b
	Reduction	1.96 ± 0.54^b	4.20 ± 0.41^a	4.31 ± 0.75^a
Total coliform	Before	3.59 ± 0.23	3.66 ± 0.21	3.59 ± 0.12
	After	2.49 ± 0.17^a	1.15 ± 0.29^b	0.88 ± 0.07^b
	Reduction	1.10 ± 0.18^b	2.51 ± 0.07^a	2.71 ± 0.04^a
Escherichia coli	Before	3.12 ± 0.01	3.28 ± 0.15	3.48 ± 0.17
	After	2.11 ± 0.04^a	0.93 ± 0.06^b	0.62 ± 0.08^b
	Reduction	1.01 ± 0.03^c	2.36 ± 0.09^b	2.87 ± 0.10^a
Bacillus	Before	3.75 ± 0.17	3.54 ± 0.01	3.85 ± 0.09
	After	2.37 ± 0.11^a	1.52 ±0.06^{ab}	1.01 ± 0.18^b
	Reduction	1.38 ± 0.05^b	2.02 ±0.08^{ab}	2.5 ± 0.35^a
Pseudomonas	Before	2.67 ± 0.02	2.81 ± 0.14	2.54 ± 0.28
	After	1.85 ± 0.18^a	1.09 ± 0.02^b	0.48 ± 0.02^c
	Reduction	0.82 ± 0.13^c	1.72 ± 0.17^b	2.06 ± 0.31^a
Staphylococcus	Before	3.82 ± 0.42	3.77 ± 0.91	3.69 ± 0.08
	After	2.24 ± 0.09^a	1.94 ± 0.14^b	0.95 ± 0.14^c
	Reduction	1.57 ± 0.33^b	1.83 ±0.33^{ab}	2.75 ± 0.22^a

Results in the same row for each parameter that has different letters differ considerably(*P<0.05*).
LA – Lactic acid.
Before slaughter or spaying, the number should be equal to ten log10 cfu/10 cm^2.
[1]Following slaughter or spaying is equal to ten log10 cfu/10 cm^2.
[1]Reduction equals (Log10 cfu/10cm^2) minus (Log10 cfu/10cm^2) following slaughter or spaying.

According to Saad et al. (2020), a spray with a higher concentration demonstrated greater efficacy in reducing gram-positive bacteria counts, such as Staphylococcus, in comparison to lower concentrations on sheep carcasses. Organic acids demonstrated a superior capacity

to reduce gram-negative bacteria compared to gram-positive bacteria (Ben Braïek and Smaoui, 2021). Research indicates the antimicrobial effects of lactic acid is due to the lipophilic characteristics of its und associated form, enabling it to penetrate the cell membrane of gram-negative bacteria. This modification impacts proton and associated anion concentrations in the cytoplasm, consequently influencing purine bases and essential enzymes, this ultimately diminishes bacterial viability (Roila et al., 2022a; Ji et al., 2023). In meat and meat products, the significance of the microbial reduction and extending its shelf life or foodborne illness reduction consider as crucial factors for ensuring product safety and enhancing economic benefits for industries (Zuo et al., 2024).

3.2 Meat quality characteristics

Sensory and physicochemical characteristics of meat are usually considered as major factor addressing the needs of the consumers and affecting their purchasing decisions. Changes in quality characteristics and shelf life of meat are largely linked to the microbial contamination present on the meat. In order to meet the consumer requirements, new approaches are currently being developed for reducing bacteria in meat. Physicochemical properties, including pH, water holding capacity, shear force, and color, were evaluated in two muscles, the longissimus lumborum and semitendinosus, to ascertain whether spraying lactic acid on external fleece sections of live lambs causes short-term stress that could affect meat quality. It is well known that several factors, particularly those related to stress induced by pre-slaughter practices plays a significant role in the development of rigor mortis and, ultimately, in determining the quality of meat (Cam et al., 2021; Álvarez et al., 2022). As indicated in Table (2), the pH of both muscle types did not change significantly following application of lactic acid. Based on these results, it can be concluded that spraying lactic acid on the lamb's hide or fleece surfaces before slaughter did not appear to cause stress that would deplete muscle glycogen reserves. Biochemical alterations in muscle, especially in glycogen metabolism, are affected by the animals' reactions to various handling situations before slaughter (Kumar et al., 2023). The absence of notable variation in the water holding capacity, cooking loss, and shear force among the treatments was expected, given the eventual pH of the muscles from carcasses of both the control and treatment groups was comparable. This assertion was corroborated by Sabow et al. (2017). It has asserted that water holding capacity is affected by the reduction in muscle pH post-mortem. A comparable shear force, indicative of meat tenderness, was noted between the muscles from both the non-sprayed carcass group and those sprayed with lactic acid can be attributed to concomitant absence of fluctuation in pH levels. The pH is significant since it influences endogenous cysteine endopeptidases, perhaps calpains, which are essential for meat tenderization (Bhat et al., 2018).

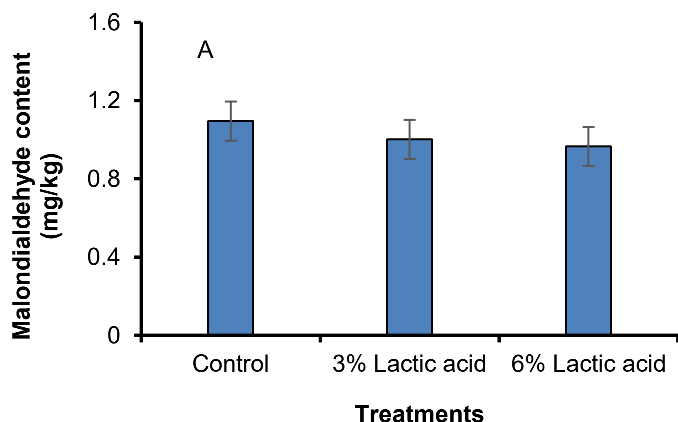
Since meat color is the main sign of freshness, it is a crucial quality factor that influences consumer decisions before purchase (Prache et al., 2022). The basic CIE Lab outputs including lightness, redness, yellowness, Chroma, and hue of the muscles under study were measured. It was found that lactic acid spray did not affect them, as shown in (Table 2). The similarity in the post-mortem pH difference between the control and spray treatments could be the reason for this discovery. Meat color is known to be correlated with final pH, which influences myoglobin oxidation and causes methaemoglobin to accumulate (Bekhit et al., 2019). Meat discoloration is primarily caused by accumulation of methaemoglobin (Gan et al., 2022). There was no discernible difference in the amount of methaemoglobin in samples of the semitendinosus and longissimus lumborum muscles in the spray and control groups (Table 2). These findings also implied that lactic acid-sprayed animals were not under any stress. The chemical and physical characteristics of various muscles treated with organic acid sprays were comparable to in the non-spray group, according to a trend similar to that described by Van Ba et al. (2018) and Rodríguez-Melcón et al. (2017).

Table 2: Quality attributes of two distinct lamb carcass muscles sprayed with varying concentrations of lactic acid

Trait	LL muscle			ST muscle		
	Control	3% LA	Contr ol	3% LA	Control	3% LA
pH	5.41 ± 0.06	5.46 ± 0.03	5.43 ± 0.03	5.56 ± 0.08	5.63 ± 0.17	5.60 ± 0.05
WHC, %	71.72 ± 1.63	69.32 ± 4.44	69.30 ± 1.81	74.49 ± 2.10	75.9 ± 2.71	75.01 ± 8.85
CL, %	26.83 ± 1.17[a]	27.17 ± 3.52	26.49 ± 3.26	26.32 ± 0.69	26.73 ± 3.16	26.52 ± 4.76
SF, kg	1.63 ± 0.01	1.66 ± 0.01	1.67 ± 0.01	1.60 ± 0.04	1.65 ± 0.01	1.65 ± 0.01
L*	44.23 ± 0.51	43.26 ± 2.22	44.02 ± 0.92	52.43 ± 3.52	52.24 ± 1.65	53.44 ± 1.04
a*	26.52 ± 0.51	25.57 ± 0.79	25.62 ± 2.67	22.43 ±1.62[a]	23.51 ± 1.75	22.74 ± 2.57
b*	15.24 ± 0.57	14.53 ± 0.82	14.45 ± 0.49	11.55 ± 0.71[a]	12.33. ± 0.66	12.47 ± 0.41
C*	31.43 ± 1.13	30.05 ± 0.65	31.07 ± 0.92	23.78 ± 1.48[a]	26.94 ± 2.47	26.84 ± 2.90
h*	31.12 ± 0.91	29.89 ± 1.03	29.92 ± 3.15	28.90 ± 0.63	28.57 ± 0.51	29.09 ± 0.84
Met-Hb, %	28.16 ± 0.28	29.67 ± 0.39	29.52 ± 0.09	31.04 ± 0.17	31.99 ± 1.38	32.47 ± 0.92

LA – Lactic acid.
LL muscle - longissimus lumborum, ST muscle - semitendinosus muscle.
L* - Lightness. a* - Redness. b*- Yellowness. C* - Chroma. h* - hue. WHC - Water holding capacity. CL - Cooking loss. SF – Shear force Met-Hb – Met myoglobin.

Lipid oxidation is another quality characteristic that is tested; this is usually done with thiobarbituric acid-reactive substances (TBARS) (Sabow et al., 2016). Improper management of animals during slaughter might affect the rancidity levels in meat and meat products since lipid oxidation is directly associated with pre-slaughter stress (Linares et al., 2007). Figure (1) displays the results of lipid oxidation. There were no discernible variations in TBARS levels between the control and spray treatments.



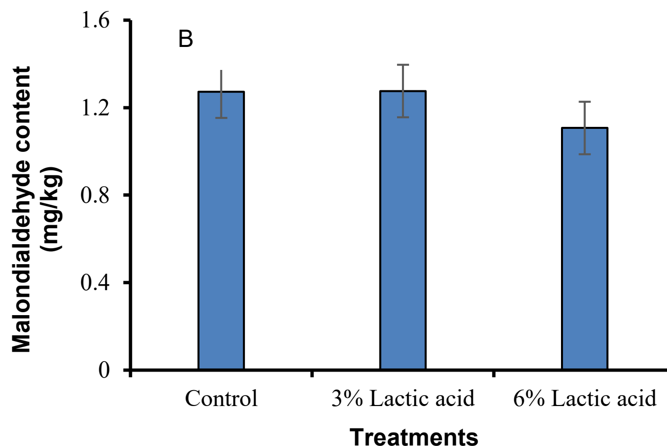
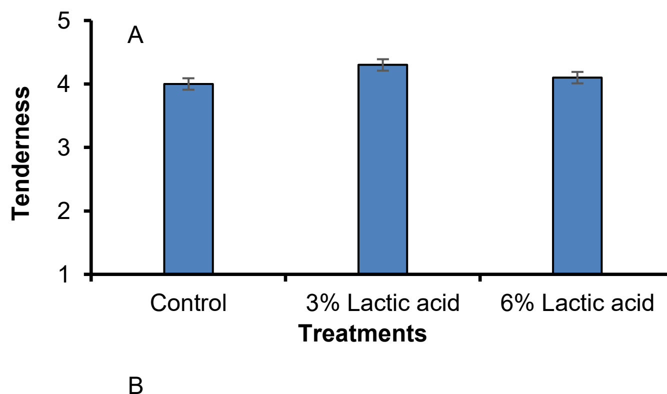


Figure 1: The amount of malondialdehyde (mg/kg) in the lamb carcasses' longissimus lumborum muscle (A) and semitendinosus muscle (B) after lactic acid spraying.

3.2 Meat quality characteristics

Usually seen as essential for customer approval, meat palatability qualities are shaped by several elements, including events that occurred shortly before slaughter. Tenderness, juiciness, and flavor defines panelists' main criteria (Salaye and Sabow, 2023). Lactic acid spray treatment did not influence the sensory quality values of either the longissimus lumborum (Figures 2) or semitendinosus muscles (Figures 2). Similar findings were obtained for beef (Rodríguez-Melcón et al., 2017) and buffalo meat (Manzoor et al., 2019), showing that 4% lactic acid decontaminating carcasses have no appreciable effect on their sensory qualities. Furthermore, lack of taste, smell, or general acceptability of the 6% lactic acid-treated samples compared to the untreated control samples.



B

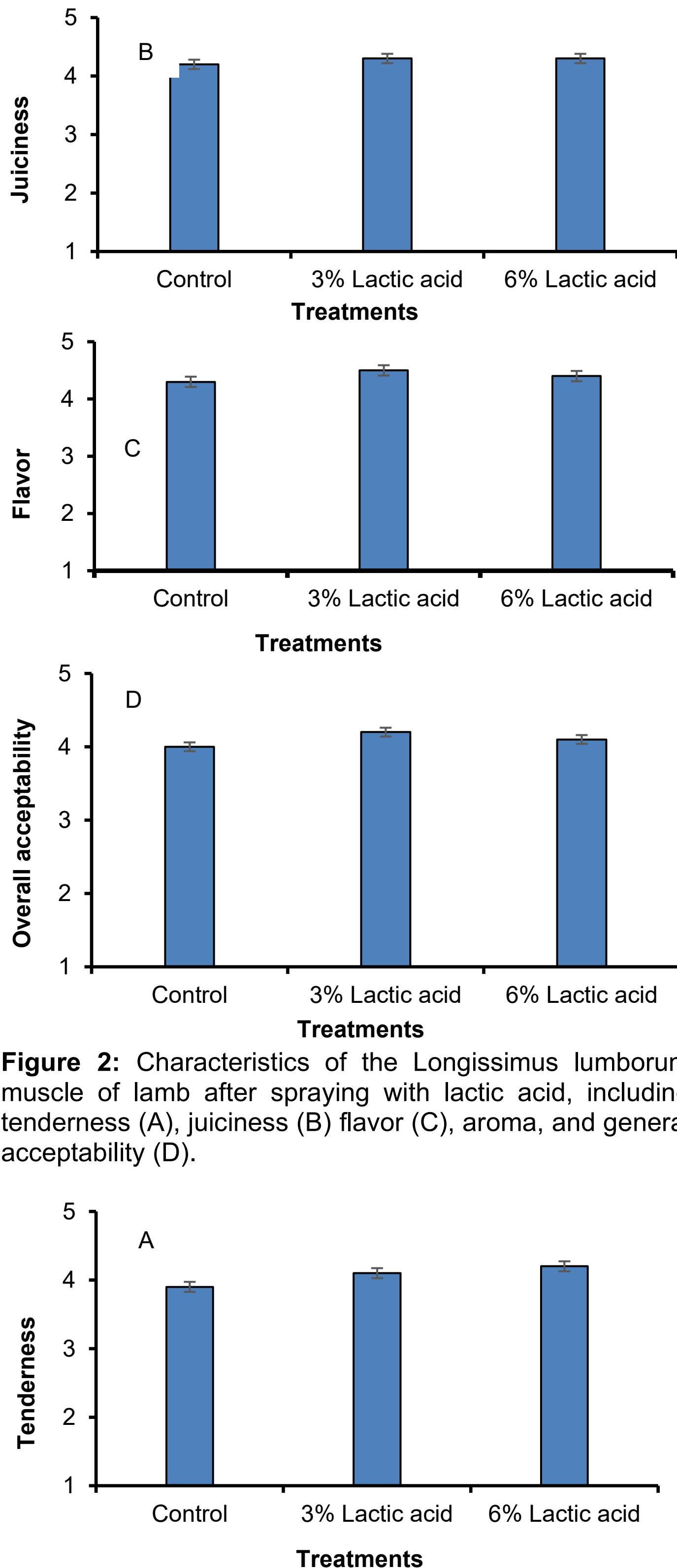


Figure 2: Characteristics of the Longissimus lumborum muscle of lamb after spraying with lactic acid, including tenderness (A), juiciness (B) flavor (C), aroma, and general acceptability (D).

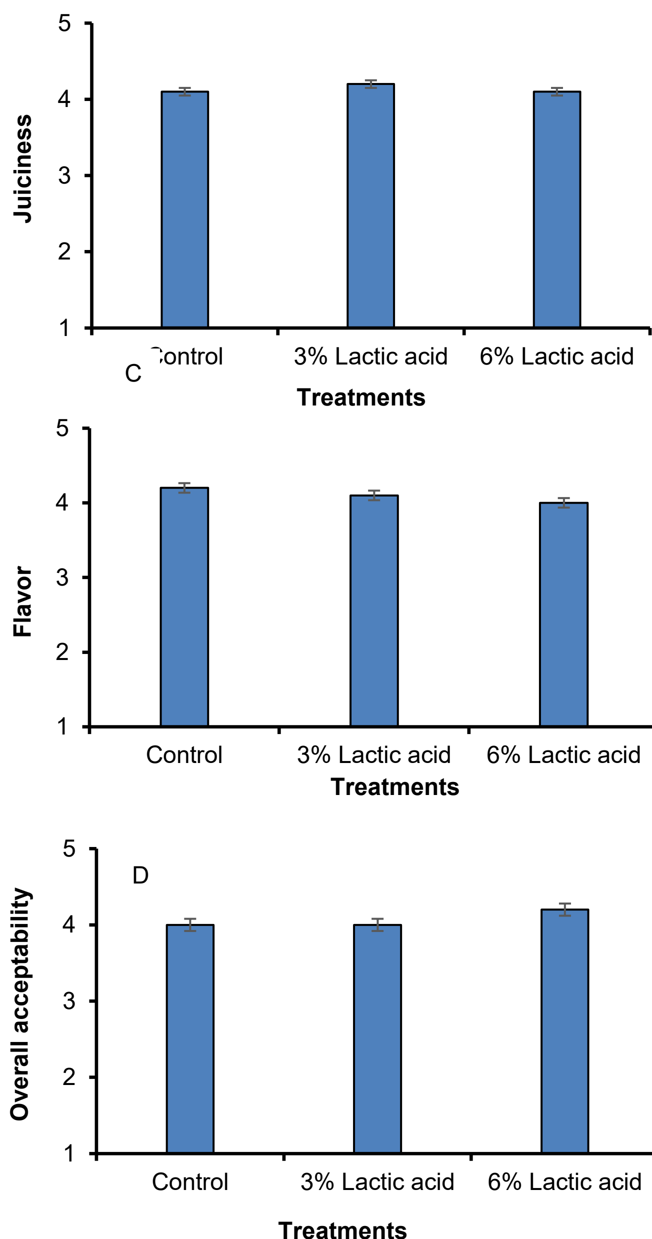


Figure 3: Characteristics of the Semimembranosus muscle of lamb after spraying with lactic acid, including tenderness (A), juiciness (B) flavor (C), aroma, and general acceptability (D).

Conclusions

The current results show that natural bacterial contamination during the slaughter process was indicated by the detection of microbial contaminants, including total aerobic count, coliform, Escherichia coli, Bacillus, Pseudomonas, and Staphylococcus on lamb exterior or fleece surface before slaughter and on the carcass surfaces following a 24-hour slaughter/spraying treatment. However, after spraying with 3 and 6% lactic acid, a notable

decrease in the densities of the investigated bacterial communities were observed on the carcass surfaces. Additionally, muscles from lambs slaughtered after spraying treatment have similar chemical and physical characteristics of lambs slaughtered before the non-spraying control. Lambs' meat quality attributes were unaffected by the two spray treatments using 3 or 6% lactic acid, but they might be a helpful tool for lowering carcass microbial contamination. Application of lactic acid spray showed high anti-bacterial, therefore, this strategy is recommended to improve safety of sheep carcasses and hygiene management during the animals' slaughtering.

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