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Original research

Comparison of Peracetic Acid with Organic Acids on Microbial, Chemical and Physical Properties of Red Meat after Slaughtering in Refrigeration

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ABSTRACT

This study aimed to evaluate the effects of peracetic acid compared to lactic acid and citric acid to improve the shelf life of red meat in refrigeration. Sequential concentrations (50, 200, 400 ppm) of organic acids and peracetic acid were sprayed on the meat surface. Then the level and intensity of germicidal impacts on microorganisms were investigated and the effects of these compounds on peroxide value, and sensory evaluation were determined. Mesophilic microorganisms, salmonella, *Escherichia coli* of meat samples were determined during one week in the refrigerator (first, fourth, and sixth day), according to the standard methods. The results demonstrated that all peracetic acid treatments caused a significant difference in microbial counts compared to equivalent dilution of other solutions (p<0.05). Sensory evaluation was performed on color, smell, and general acceptability factors based on the 5-point hedonic method. Comparing the peroxide value in the examined meat samples showed that increasing the peroxide value in treated meat samples (p<0.05) did not lead to undesirable alterations and had no effects on consumer acceptance. The findings of this study demonstrated that using peracetic acid especially at a concentration of 200 ppm immediately after slaughter can extend the shelf life of raw meat.

Keywords: peracetic acid; organic acid; red meat; shelf life

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1. Introduction

Red meat is one of the most critical components of the human diet (Kafili *et al*., 2006). Typically, after slaughter, meat contamination is gradually increased and spoilage occurs during transportation and preparation of products. During slaughter, skin peeling and splitting of the carcass can cause microbes to infect meat through the external parts of the animal (horn, venom, hair) or internal parts such as the intestines (Toldra, 2010; Cutter, 2005). The conditions of slaughter, transportation, storage, packaging, and distribution of raw meat products have many challenges and problems. It is possible to extend the shelf-life of meat during refrigeration using food-grade dietary acids on carcass storage time, contamination control, and finally not increasing initial contamination to ensure the safety of products (Naseri Khalkhali & Rahati Noveir, 2018; Cutter, 2005; de Rezende *et al*., 2023).

Meat fat varies depending on the breed and diet of the animals. Intracellular muscle fats contain large amounts of unsaturated fatty acids and a chain length of 20 to 22 carbon atoms. Unsaturated fatty acids in meat are chemically oxidized under aerobic conditions, and light and copper may catalyze lipid oxidation. Lipolytic bacteria also do some lipolysis processes. Therefore, they accelerate fat oxidation. Some meat fats become rancid by oxidation and hydrolysis, when animal fats are oxidized, rancidity occurs due to oxidation and odor change due to aldehydes and acids production; and reduction of sensory quality which influences consumer acceptance (Domínguez *et al*., 2019). Chemical compounds such as organic acids have been used to prevent or delay the spoilage of meat and meat products (Knipe & Rust, 2009).

Peracetic acid as a disinfectant has the best results in terms of removing microorganisms compared to other dietary organic acids. However, there is no requirement for ultimate rinsing after utilizing this substance, and its effect on average refrigeration temperature can be an advantage of this point in decreasing the expense of red meat deterioration (FDA, 2012). Peracetic acid is approved by FSIS for use on beef carcasses (FSIS, 2023). Currently, the maximum allowance of peracetic acid for use in the beef industry is 1200 ppm (FDA, 2017), but 200–400 ppm is

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normally used for washing and rinsing of carcasses, heads, and primal cuts of fresh beef due to hazardous conditions that the chemical poses to employees (Wheeler et al., 2014).

Peracetic acid is colorless, with a vinegar odor, and is a safe oxidizer in different parts of the world. It is called by names, such as peroxyacetic acid, peracetic acid, and peroxide of acetic acid (Block, 2001; Baldry & Fraser, 1998). Peracetic acid can destroy different kinds of carbohydrates, nucleic acids, lipids, and proteins in the cell walls of microbes, and breaking down the cell wall causes the death of microorganisms. Peracetic acid destroys the outer membrane cell of vegetative bacterial cells, endospores, yeast, and mold spores via oxidation (Jolivet Gougeon *et al*., 2006; FDA, 2012).

The use of peracetic acid, a specific combination of acetic acid and hydrogen peroxide, has been proven to reduce microbial contamination and affect all microorganisms, including molds, yeasts, bacteria, and viruses, and with specific dilutions have the advantages compared to edible organic acids and the US Food and Drug Administration (FDA) has explicitly verified using this substance in food production, food preservation, and fruit and vegetable disinfection (Stopforth, 2002; Ditommaso, 2005; De Rezende *et al*., 2023).

Citric acid is an edible organic substance with the chemical formula CH_3-CH_2-COOH, and exists as a complete molecule in the natural cycle. This organic acid is present in plants and tissues of some animals and is generally called lemon acid and edible citric acid (Apelblat, 2014).

Lactic acid is an edible organic acid with the chemical formula $CH_3CHOHCOOH$. This edible acid is one of the products of changes in sugars in human cells and is present in the body pH in the form of ions, i.e., Lactate ($C_3H_5O_3$-). Excessive increase in this compound in muscle cells causes muscle cramps and pain. In case of oxygen shortage in the body, it occurs as one of the by-products of sugar hydrolysis (Martinez *et al*, 2013).

Abd ellatif *et al*. (2020) showed the effects of lactic acid and acetic acid in reducing the contamination load not increasing the peroxide of meat surface fats, and, not changing the natural taste, and smell of the product can be a good solution for red meat processing industry. Also, by introducing scientific methods with health certifications, it was proved that the storage time of red meat increases during refrigeration, and it was directly shown that reducing the surface contamination of raw meat without affecting other properties of raw meat is an excellent method to reduce waste and costs in meat processing factories and red meat packaging units.

Previous studies have evaluated the use of organic acid solutions to red meat by using different methods. Most of these studies were investigated under laboratory conditions, while few were performed at slaughterhouses, as considered in the present research. Therefore, in this study, the most critical microorganisms of the meat industry (Total count of microorganisms, *Escherichia coli* and *Salmonella* bacteria) were performed on freshly slaughtered sheep carcasses in cold storage with standard humidity and temperature (National Standard of Iran No. 9717, 2007; National Standard of Iran, No. 8923). In slaughterhouses, peracetic acid is utilized, and it has been demonstrated that its immediate application post-slaughter can extend the shelf life of meat (Rossi *et al*., 2023).

The application of antimicrobial compounds to decrease microbial contamination in ground beef has increased recently. The effectiveness of peracetic acid at different concentrations against *E. coli* O157:H7 and *Salmonella* on the surface of beef trimmings was applied at industry operating parameters within the retained water requirement. Peracetic acid spray treatment significantly reduced *E. coli* O157:H7 and *Salmonella* on beef trimmings and subprimals (Kalchayanand *et al*., 2024).

Nowadays, a tendency toward natural preservatives to extend the shelf life of food products has grown. Antimicrobial edible films and coatings containing natural essential oils and extracts are considered a novelty in food packaging. The edible coatings containing some essential oils such as *Mentha pulegium* essential oil (MPEO), *Myristica fragrans*, or citrus lemon essential oil are used as a coating for buffalo or beef meat during the storage period in the refrigerator. Research findings indicate that these coatings effectively reduce the progression of lipid oxidation (peroxide value) and inhibit microbial growth (total viable count, psychrotrophic bacteria, *Escherichia coli*, *Staphylococcus aureus*, and fungi). Moreover, the coating containing the essential oil had no unfavorable effect on the sensory attributes of the samples. (Kiarsi *et al*., 2020; Noshad *et al*., 2021; Tanavar *et al*., 2021).

2. Material and Methods

2.1. Materials

One of the raw meat processing factories in Alborz province in Iran was selected for preparing sheep carcasses. In this study, 12 complete carcasses were treated. Three full carcasses (6 half carcasses) were prepared randomly and separately for microbial tests and three full carcasses (6 half carcasses) for chemical testing and in a separate test, six full carcasses (12 half carcasses) were provided, all from the slaughter of the day.

Materials used in microbial tests such as nutrient agar culture medium (EM-Germany), double green brilliant culture medium (Merck-Germany), and sterile physiological serum (Samen-Iran drug) were prepared. Also, the applied chemicals such as chloroform, potassium iodide, sodium thiosulfate, reagent for starch adhesive and sodium sulfate (Merck-Germany), ethanol (Razi-Iran drug), peracetic acid (Behban chemical drug-Iran), citric acid and Lactic acid (Merck-Germany) were provided.

2.2. Methods

2.2.1. Sample preparation

The required solutions including peracetic acid, lactic acid, and citric acid were prepared for testing and treatment of red meat and stored separately in sealed glass containers. The meat was divided into two halves based on random selection. The carcasses were performed according to Figure 1 in the dimensions of 10-10 and after marking, the material was sprayed. In the symmetrical carcass, the test was repeated, and the mean data were recorded after incubation, and microbial counting (Veterinary Organization of Iran, 2016). To perform the treatment, a complete carcass was divided into two halves according to the industry routine with a pre-disinfected industrial blade. The left half of the carcass was stenciled so that the control sample was considered in one half, and organic acids were sprayed in the same half of the carcass (Figure 1).

To have a uniform distribution of the desired organic solutions on the given surface of the meat, special containers equipped with sprayers with a diameter of fewer than 50 microns were used. Three 1-liter containers were prepared and filled with the required solutions

inside the sprays. Before treatment, sterilized distilled water was sprayed on the relevant half of the carcass in the control group. After 1 hour, sampling was performed with a sterile swab, and this sample was transferred to 10 mL of physiological serum. In this method, sterile cotton swabs soaked in buffered peptone water solution were used. The swap was applied to the mentioned surface (internal area of the stencil) 5 times without applying hand pressure in a vertical and horizontal motion. The obtained samples, or in other words, the same swab dipped in the meat surface, were mixed well in test tubes containing peptone water for one minute using a shaker. Then, 0.1, 0.01, and 0.001 dilutions were poured on the sterile plate using a pipette, and sterile and melted culture medium was poured on it. Then they were moved in a circular motion slowly and were set at the temperature of 37 ℃ after solidification (National Standard of Iran, No. 5272). This method was performed on the fourth and sixth days on the same part of the meat and in the place of the mentioned stencil, and microbial culture was performed accurately. To prevent secondary contamination, stretch, and disinfection films were used to cover the meat surface, and after the test, destruction was performed and the healthy parts of the meat were used.

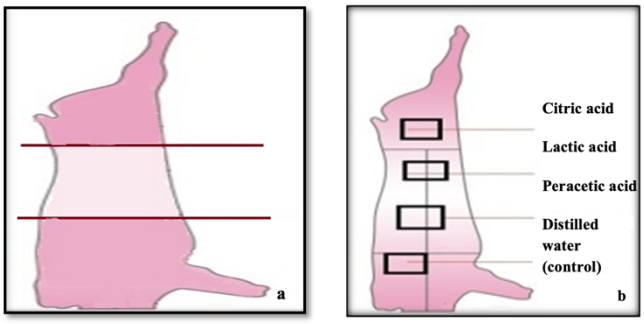

Fig. 1. a) Chemical treatment method on half-carcass; b) Stenciling method on half-carcass.

2.2.2. Microbial tests

The microbial tests of the samples (stored at 4 °C) were performed at specific time intervals (days 0, 1, 4, and 6). The surface of the meat samples was swabbed and microbial cultures were prepared. Subsequent sequential dilutions were prepared using the stock solution. The microbiological tests of red meat during storage were performed according to international standards (FAO/WHO Codex Alimentarius Commission, 1993). Total microbial count using Nutrient Agar medium was performed based on ISO 4833-1:2013/Amd1:2022. To count *Escherichia coli*, the method for counting this bacterium in food was based on ISO 4832: 2006. To count *Salmonella*, the process for finding this bacterium in food was used based on ISO 6579-1:2017. Preparation of initial suspension and decimal dilutions for microbiological tests were performed according to ISO 6887-1:2017.

2.2.3. Chemical test

After spraying organic acids on the surface of meat carcasses, evaluation of meat fat oxidation and chemical changes were performed by sampling of control carcasses and comparison with other carcasses. An oxidation test was conducted based on the peroxide value. The peroxide value is generally considered as the index of the formation of primary products during lipid oxidation reactions. During this treatment, each part of the carcass was divided into three sections (Figure 1-a), and organic acids with a specific dilution were sprayed on the meat parts. In another symmetrical half of the carcass, sterile distilled water was used as a control, and the entire surface of the meat was sprayed with distilled water. After the first, fourth, and sixth day, a layer of meat with fat and skin was separated with forceps and cutting tools and mixed in a clean and sterile flask with chloroform (Rhee & Myers, 2004).

The peroxide index is the milliequivalent gram of peroxide or active oxygen per kilogram of oil or fat sample. It indicates the degree of oxidative damage in oils and fats. 5 g of the sample (prepared solution) was weighed to determine the peroxide value, and saturated potassium iodide (KI) was added. The container was kept in the dark and a few drops of 1% starch adhesive reagent (starch solution) were added. The prepared sample was titrated with sodium thiosulfate (0.01N), to the point when the dark color disappeared. Equation (1) was used to calculate the peroxide value (Steele, 2004; Majdinasab, 2020).

$$\text{Peroxide value} = (V \times 1000 \times N) / W \quad (1)$$

Where: V = consumption volume, N = normality of thiosulfate (0.01), W = sample weight.

2.2.4. Sensory evaluation

The sensory evaluation was performed by seven trained evaluators based on the 5-point hedonic scale method. The results were recorded based on the meat surface's general acceptance sensory test (related to sticky and slimy meat as well as wilting and darkening meat). The appropriate sensory evaluation tests and the stability of the test conditions were performed, in a specific space in the laboratory space, conditions, and facilities such as hand sanitizer, armchair, steel table, and lamp with colored light (ability to change the lamp and select the suitable light). All people evaluated the treated meats only in this place. Latex gloves, forceps, and primary tools were also provided to the evaluators to examine the raw meat better. To avoid the effect of humidity of the environment on the meat and to prevent secondary contamination (based on the possibility of off-odor and off-color due to spoilage), in addition to regulating the humidity of the refrigerator and meat storage, clean films were used to cover the meat surface (Pimentel *et al*., 2015).

2.2.5. Data analysis method

Repeated analysis of variance (Repeated measure ANOVA) was performed according to statistical methods. Also, to compare the data One-Way ANOVA followed by Duncan's test was performed using SPSS software version 22 with p values less than 0.05.

3. Results and Discussion

3.1. The results of microbial tests

Changes in microbial contamination of red meat treated with different concentrations of organic acids and peracetic acids (50, 200, 400 mg Kg^{-1}) during storage are presented in Table 1. The results showed that *Escherichia coli* was significantly deferred between treatments ($p<0.05$). According to the multiple initial tests in the slaughterhouse and after slaughter, as well as the initial tests in the delivery of raw meat, it was indicated that the meat by the primary treatment of this study does not have Salmonella. Therefore,

the report on the effectiveness of peracetic acid and other organic acids on *Escherichia coli* was determined as indicators for the study and shown in Table 1.

Evaluation of the total microbial count (Log CFU g^{-1}) of meat treated with different concentrations of acids during storage was determined as shown in Table 2.

Table 1. Evaluation of meat contamination with different dilutions of organic and peracetic acids during storage. The different small letters in columns show a significant difference between the values ($p<0.05$).

Treatment	Day	Concentration (mg/L)					
		400		200		50	
		E.coli	*Salmonella*	*E.coli*	*Salmonella*	*E.coli*	*Salmonella*
Half-carcass of control	0	N	39±1^{f}	N	45±3^{h}	N	38±2^{g}
Half-carcass dipped in peracetic acid	1	N	11±4^{c}	N	24±0^{f}	N	22±0^{d}
	4	N	9±0^{bc}	N	12±0^{b}	N	17±0^{b}
	6	N	5±1^{a}	N	10±0^{a}	N	15±1^{a}
Half-carcass dipped in lactic acid	1	N	16±1^{d}	N	29±1^{g}	N	26±0^{e}
	4	N	9±1^{bc}	N	15±0^{c}	N	20±0^{c}
	6	N	8±0^{b}	N	15±1^{c}	N	20±0^{c}
Half-carcass dipped in citric acid	1	N	20±2^{e}	N	20±0^{e}	N	28±0^{f}
	4	N	16±1^{d}	N	17±0^{d}	N	22±0^{d}
	6	N	9±0^{bc}	N	14±0^{c}	N	21±0^{cd}

The use of 130–400 ppm reduced E. coli O157:H7 and Salmonella on fresh beef trimmings and skirts compared to untreated control or water-treated, thus improving the microbial safety of beef products during processing. (Kalchayanand et al., 2024). Several studies have reported a significant reduction of E. coli O157:H7 and Salmonella by spraying and dipping inoculated fresh beef tissues with 200 ppm of PAA solution (Acuff, 2017; Ellebracht et al., 2005; Ransom et al., 2003).

Table 2. Evaluation of total microbial count (Log CFU g^{-1}) of meat with different dilutions of organic and peracetic acids during storage. The different small letters in columns show a significant difference between the values ($p<0.05$).

Treatment	Day	**50 mg/L**	**200 mg/L**	**400 mg/L**
Half-carcass of control	0	5.60±0.01^{e}	5.54±0.06^{d}	5.62±0.01^{d}
Half-carcass dipped with peracetic acid	1	4.99±0.04^{a}	5.19±0.11^{a}	5.15±0.13^{a}
	4	5.34±0.02^{c}	5.66±0.03^{e}	5.79±0.01^{f}
	6	5.78±0.01^{f}	5.85±0.01^{f}	5.66±0.04^{e}
Half-carcass dipped with lactic acid	1	5.41±0.00^{d}	5.30±0.00^{b}	5.23±0.00^{b}
	4	5.14±0.00^{b}	5.44±0.00^{c}	5.44±0.01^{c}
	6	5.92±0.02^{g}	5.84±0.01^{f}	5.88±0.01^{g}
Half-carcass dipped with citric acid	1	5.43±0.00^{d}	5.36±0.00^{b}	5.23±0.00^{b}
	4	5.41±0.02^{d}	5.32±0.00^{b}	5.20±0.00^{b}
	6	5.96±0.00^{i}	5.84±0.06^{f}	5.92±0.00^{h}

The use of many organic acids is a general method to extend the shelf life of food. Edible organic acids temporarily lower surface pH and affect surface microorganisms. Adding these acids to food causes a desirable taste and in addition, due to the decrease in pH, has an inhibitory effect on microorganisms, thus, this increases the shelf life of food (Rezweiler, 1999).

Indeed, bacteria sensitivity is due to the pH created by different acids. This difference is related to the pKa of organic and inorganic acids. This means that the higher the pKa of an acid, the higher the antimicrobial properties (Rebelo *et al*., 2023).

The relationship between acid strength (pKa) and its antimicrobial effect is recognized. This means that high-strength acids such as Propionic, acetic acid, and lactic acid (with a strength of 4.87, 4.76, and 3.9, respectively) had the highest inhibitory effect. In contrast, citric acid (with a strength of 3.13) had the lowest inhibitory effect (Braiek and Smaoui, 2021). H^{+} ion of acids interferes with microbial enzymes, and the exchange of substances is disrupted through the cell membrane (Jay, 2005). The organic acids used in this study did not have close acid strength and therefore the changes caused by them were very different.

Table 1 indicates a significant difference between the three test cases and the effectiveness of organic acid solutions in terms of minimum inhibitory concentration. Also, a significant difference was found between the tested solutions in terms of duration of action and increase of treatment days, and a significant difference was shown between the bacterial interaction with all disinfectant solutions or the same as edible organic acids. Also, the interaction of the solution and bacteria during contact with peracetic acid solution was stronger than lactic acid and lactic acid was more potent than citric acid and was significant. The results showed that peracetic acid could have inhibitory and lethal effects on the microorganisms in this test in different dilutions, especially at the dilution of 400 ppm, a limitless than the permissible consumption in food products, compared to other disinfectants.

Muhammad *et al*. (2016) showed that organic acid spraying such as lactic acid and acetic acid in dilutions of 1 to 2% are also effective in reducing the bacteria in chickens, but high concentrations of these acids cause fading and discoloration in the carcass.

On the other hand, hydrogen peroxide with a dilution of 5% as spraying and the use of this solution in dilution of 0.5 to 1.5% in cold water is allowed to maintain and reduce contamination of chicken carcass and reduce the carcass temperature to 4 °C in cold water and immediately after slaughter, the first barrier is to prevent the spread of pathogenic disease in poultry (Loretz *et al*., 2010).

Lactic acid spraying on the carcasses of slaughtered animals to reduce the surface microbial load is a conventional method in foreign countries (Nuryana *et al*., 2019). In some studies, organic acids have been used to reduce microbial contamination in the livestock and poultry slaughterhouse or in processed meats, or a modified atmosphere (Rokni, 1998).

The results of the Hanifian study in 2007 showed that the total count of bacteria, the number of coliforms, and the number of psychrotrophic bacteria in the control and research samples increased significantly ($P<0.01$) during eight days of storage at a temperature of 2-4℃. Also, the use of lactic and acetic acids in comparison with the control sample had a significant impact ($P<0.01$) in reducing the total microbial load. Among them, acetic acid by 1.2 logarithmic units and lactic acid by about 0.42 logarithmic units, decreased the total bacterial count compared to the control sample during eight days (Hanifian, 2007).

In general, the use of organic acids not only inhibits the growth of spoilage microorganisms. Also has no side effects such as increased purge, odor, and unfavorable color in meat (Hajipour *et al*., 2015; Braiek and Smaoui, 2021). Among the acids used, acetic acid has an inhibitory effect on bacterial species. Despite the studies on the use of lactic acid and its antimicrobial effect, in the study conducted, the examination of the antimicrobial effect of this acid was not very significant, and perhaps the reason for this difference was the difference in lactic acid concentrations used in the various studies performed by different researchers (Shebs *et al*., 2019).

Hajipour *et al*., (2015) investigated the impact of the preservation of organic acids on microbial indices of poultry meat. The results showed that the use of organic acids in the lowest concentration (1%) inhibits the growth of spoilage microorganisms, and reduces the microbial load of aerobic mesophiles. Among the acids used, propionic, acetic, and citric acids had the highest inhibitory effect on the different bacterial species, respectively.

These acids are used in the food industry and have no adverse effect on the consumer (Drosinos *et al*., 2006). Today, organic acids are known as healthy antibacterial agents, and their effects on various pathogenic bacteria have been investigated. For example, researchers studied the effect of lactic acid spraying on pork and beef minced meat, and the results showed that their shelf life was doubled (Samelis *et al*., 2012).

In the study by Schirmer and Langsrud (2010), 3% citric acid had a significant impact on the number of anaerobic bacteria, mainly when this acid was used in combination with CO_2-containing packaging.

Shirvani *et al*. (2017) investigated the antibacterial activity of acetic acid and lactic acid against Listeria monocytogenes and their effect on releasing intracellular compounds. They reported that acetic acid and lactic acid were effective in inhibiting the growth of Listeria monocytogenes and had an anti-acidogenic effect and acetic acid had a more potent anti-bacterial effect compared to lactic acid and acetic acid and lactic acid can be used in food in combination with other preservatives to inhibit disease-borne and spoilage microorganisms. The results are consistent with the results of the present study, which showed a stronger antibacterial effect of acetic acid than lactic acid against bacteria.

3.2. Peroxide value

According to the results presented in Table 3, it was found that the type of treatment is based on the use of peracetic acid, citric acid, and lactic acid with concentrations of 50, 200, and 400 mg/L had a significant effect (p<0.05) on changes in peroxide value. Based on multiple tests, and initial tests, (control samples), it was found that the increase in peroxide value occurred in all samples and can be measured, but according to the range of changes and the allowable limit of free oxygen equivalents, all treatments and its repetition were within the standard limit and are shown in Table 3 in the form of average treatment data.

Table 3. Evaluation of meat peroxide value with different dilutions of edible acids. The different small letters in columns and the capital letters in rows show a significant difference between the values (p<0.05).

Treatment	Day	Peroxide value Meq/Kg		
		50 mg/L	**200 mg/L**	**400 mg/L**
Half-carcass of control	0	0.95 ± 0.04^{Aa}	0.98 ± 0.06^{a}	0.69 ± 0.06^{a}
Half-carcass dipped in Peracetic acid	1	1.05 ± 0.0^{Ad}	1.06 ± 0.01^{Ab}	1.38 ± 0.04^{Bd}
	4	1.09 ± 0.00^{Ae}	1.11 ± 0.00^{Bbc}	1.55 ± 0.00^{Ce}
	6	1.16 ± 0.01^{Af}	1.31 ± 0.01^{Bd}	1.59 ± 0.00^{Ce}
Half-carcass dipped in Lactic acid	1	0.97 ± 0.02^{Aab}	1.06 ± 0.00^{Bb}	1.00 ± 0.00^{Ab}
	4	0.99 ± 0.00^{Abc}	1.06 ± 0.02^{Bb}	1.14 ± 0.02^{Cc}
	6	1.01 ± 0.00^{Ac}	1.07 ± 0.00^{Bb}	1.15 ± 0.01^{Cc}
Half-carcass dipped in Citric acid	1	0.99 ± 0.02^{Abc}	1.07 ± 0.00^{b}	0.99 ± 0.00^{Ab}
	4	0.99 ± 0.00^{Abc}	1.09 ± 0.10^{Cb}	1.00 ± 0.01^{Bb}
	6	1.02 ± 0.01^{Acd}	1.16 ± 0.01^{Bc}	1.09 ± 0.03^{ABc}

The peroxide value of experimental treatments has a significant difference (p<0.05). The minimum lethal concentration of organic acids solution and treatment with the maximum dilution of these solutions increased the peroxide value. In other words (Table 3), it was indicated that there was no significant difference between the three cases of solution and effectiveness in terms of acceptability and desirability of meat in terms of consumption. The results showed that peracetic acid was more potent than citric acid, and also the results showed that citric acid was more potent than lactic acid. In other words, lactic acid had the best conditions in terms of the lowest changes in increasing the peroxide value. The peroxide value of samples treated with peracetic acid revealed a significant difference (p<0.05), without undesirable alterations in sensory properties.

In this study, lactic acid had the most acceptance regarding the lowest effect on increasing oxidation. Indeed, it can be said that if edible acids and even peracids are used, the level of oxidation changes, and the increase in peroxide number has not been so high that it causes unfavorable changes in meat and rejection by the consumer (Kim *et al*., 2019; Ghabraie *et al*., 2016).

3.3. Sensory evaluation

The comparison between raw meat treated with antimicrobial solutions (peracetic acid, lactic acid, and citric acid) showed that increasing the concentration of acids caused to decrease in the sensory aspects of meat (p<0.05); While no significant difference was found between the antimicrobial acids (p≥0.05). The results showed that the sensory attributes (total acceptance) between the disinfected carcass with edible organic acids for different days had no significant differences (p≥0.05).

The results of a recent study show that the total count of bacteria, the number of coliforms, and the number of psychrotrophic bacteria in the control sample and treatment samples increased significantly (p<0.01) during six days of storage at 4 °C. The use of peracetic acid, lactic acid, and citric acid in comparison with the control sample had a significant impact on decreasing the overall microbial load, and a significant difference (p<0.01) was found in the inhibitory effect of different types of acids.

In other words, all organic acids and peracetic acid solutions after use and on consecutive days and after evaluation by evaluators did not have adverse effects on meat and consumer acceptance (Table 4), and all of these solutions can be used to reduce the microbial load of meat without having adverse effects on the appearance and quality of raw meat.

Table 4. Sensory evaluation (total acceptance) of meat treated with citric acid, lactic acid, and peracetic acid. The different small letters in columns and the capital letters in rows show a significant difference between the values (p<0.05).

	Concentration (mg/L)	**Day**		
		1	4	6
Peracetic Acid	5	4.0 ± 0.1^{Aa}	3.7 ± 0.1^{Ba}	3.4 ± 0.1^{Ca}
	200	3.7 ± 0.1^{Ab}	3.3 ± 0.1^{Bb}	3.1 ± 0.1^{Cb}
	400	3.4 ± 0.0^{Ac}	3.2 ± 0.0^{Bb}	2.6 ± 0.1^{Cc}
Lactic Acid	5	4.0 ± 0.1^{Aa}	3.7 ± 0.0^{Ba}	3.4 ± 0.0^{Ca}
	200	3.7 ± 0.2^{Ab}	3.3 ± 0.1^{Bb}	3.1 ± 0.1^{Cb}
	400	3.4 ± 0.1^{Ac}	3.2 ± 0.0^{Bb}	2.6 ± 0.1^{Cc}
Citric Acid	5	4.0 ± 0.1^{Aa}	3.7 ± 0.0^{Ba}	3.4 ± 0.1^{Ca}
	200	3.7 ± 0.1^{Ab}	3.3 ± 0.0^{Bb}	3.1 ± 0.1^{Cb}
	400	3.4 ± 0.1^{Ac}	3.2 ± 0.0^{Bb}	2.6 ± 0.1^{Cc}

Excessive use of preservative culture affects the sensory, chemical, and physical properties of the product as lactic acid

bacteria are involved in the spoilage of several nutrients. It is crucial to determine the effect of preservative culture on nutrients (Hutkins, 2006; Rossi *et al*., 2023). Lactic acid bacteria play a significant role in the spoilage of vacuum-packaged meats, the most effective of which are *Lactobacillus*, *leuconostoc*, *Weissella,* and *Corynebacterium.* These bacteria cause changes in taste, gas production, and film formation. Therefore, the culture used as a biological preservative, in addition to having the desired characteristics (easy cultivation, reliable culture, ability to survive throughout the process, etc.) should not have adverse effects on sensory properties. Therefore, to improve the process of using organic acids of bacteriocin-producing bacteria as preservative cultures, it is better to use other technologies (temperature control, a_w, and vacuum-based packaging) (Ammor *et al*., 2006; Darvish *et al*., 2015; de Rezende *et al*., 2023; Zapaśnik *et al*., 2022).

4. Conclusion

Meat quality and shelf-life can be affected by microbial growth during storage. The results of the present study demonstrated that the peracetic acid was able to inhibit the target microorganism on the meat surface at different dilutions, especially at a dilution of 400 mgL^{-1}, which is lower than the limit of food consumption compared to the other organic acids (citric acid, lactic acid) dilutions. Based on the peroxide value measurements, the application of peracetic acid did not result in a rise in fat oxidation on the meat carcass surface, therefore it did not hurt the meat quality. In addition, none of the organic acids and peracetic acid solutions had negative effects on meat and consumer acceptability after application and consecutive days and evaluators review, and all these solutions can be used to reduce microbial load. The results of this study prove application of this substance immediately after slaughter can increase meat storage time.

Conflict of interest

The authors declare that there is no conflict of interest.

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