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Research Article
Processing and Sensory Characteristics of Ground Beef Treated with Long Chain Organic Acids

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Abstract

Background and Objective: Organic acids have been evaluated for food safety. More information is needed regarding the impact of organic acids on meat quality and sensory characteristics. Therefore, the objective of this study was to determine the effect of decanoic, fumeric and octanoic acid treatments on sensory characteristic of ground beef. **Materials and Methods:** Beef trimmings (80/20) were electrostatically sprayed with fumaric acid, malic acid, octanoic acid and decanoic acid at 3% (w/v) and were compared to untreated samples (control) after grinding and patty formation for 7 days during simulated retail display. Trained panelists evaluated meat sensory color, odor and product display characteristics on days: 0, 1, 2, 3 and 7 of display. The experiment was arranged in a completely randomized 5×5 factorial design. Data were analyzed using the General Linear Model procedure of SAS for interaction and main effects. **Results:** The decanoic, fumeric and octanoic acid treatments increased subjective redness ($p<0.05$), reduced discoloration ($p<0.05$) and had greater a* values ($p<0.05$) compared to control on 0 and 1 day of display. There was no difference ($p>0.05$) in beef flavor, between control and the rest of the treatments. **Conclusion:** The use of 3% solutions containing fumaric, malic, octanoic and decanoic acid as antimicrobials on beef trimmings prior to grinding may improve or maintain sensory retail display properties such as: meat color and odor without affecting beef flavor of ground beef patties on 0 and 1 days of retail display.

Key words: Electrostatic spraying, antimicrobials, meat safety, organic acids, meat color

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Concern about public health has increased but some consumers still consume undercooked meat products, increasing the risk of foodborne illnesses. Even though food production techniques have been improved, foodborne pathogens such as *Salmonella* (SM) and *E. coli* O157:H7 have the potential to evolve and thrive. About 76 million cases of foodborne illnesses are estimated to occur annually in the United States, resulting in 325,000 hospitalizations and 5,000 deaths[1]. Because ground beef is ground and mixed, it has the potential to intersperse microorganisms into the matrix and is therefore a perfect vehicle for pathogens to colonize. As a result, Multiple Drug Resistant (MDR) *Salmonella* Newport and *Salmonella* Typhimurium infections have been reported[2].

Due to concerns related to food safety, organic acids have been utilized in the industry to improve safety and extend shelf life by retarding food deterioration. They have been applied in both pre-harvest and post-harvest food production and processing systems[3] and have been widely studied in ground beef[4,5], minced beef[6] and cured turkey[7]. Limited research on ground beef has been done with fumaric acid but its antimicrobial properties against *E. coli* have been demonstrated in apple cider[8] and acidified foods[9]. Antimicrobial properties of malic acid have been studied in ground beef with a reported reduction of *E. coli* and *Salmonella* in inoculated ground beef with minimal impact on meat color characteristics[10]. Octanoic or caprylic acid has been effective against *Salmonella entrica* serovar Typhimurium in reconstituted infant formula[11].

Although many antimicrobials have been evaluated as intervention treatments to reduce pathogens and extend shelf life, researchers pay less attention to the effects of antimicrobials on meat color as well as sensory properties[12]. Therefore, this study seeks to develop knowledge of novel organic acids for use within the meat industry, specifically the impact of fumaric, malic, octanoic and decanoic acid on ground beef patty color, odor and sensory characteristics. All the antimicrobials used in this study are approved for use in meat and poultry products by the Food Safety Inspection Services (FSIS) of the US Department of Agriculture and food products by the Food and Drug Administration.

MATERIALS AND METHODS

Antimicrobial treatment application: The antimicrobial treatments used for this study were 3% (w/v) fumaric acid (F) (A.E. Staley Manufacturing Company, Decatur, IL), 3% (w/v) malic acid (M) (Sigma-Aldrich, St. Louis, MO), 3% (w/v) octanoic acid (O) (Sigma-Aldrich, St. Louis, MO), 3% (w/v) decanoic acid (D) (Sigma-Aldrich, St. Louis, MO) and an untreated control (CON). Distilled water was used for the preparation of the antimicrobial solutions. Frozen beef trimmings (80/20) were transported directly to the University of Arkansas from a commercial trimmings producer, then were thawed and electrostatically (ESS; Electrostatic Spraying Systems Inc., Watkinsville, GA) sprayed with organic acid antimicrobial treatment solutions at a rate of (~0.1 mL g^{-1}) until meat surfaces were saturated. Each treatment was repeated twice using 1.8 kg of beef trimmings for each replicate. Next, beef trimmings were ground twice through a 3.0 mm plate (AE-G12N, American Eagle Food Machinery Inc., Chicago, IL). After grinding, the beef was hand portioned and processed into 150 g patties, which were individually placed on plastic foam trays with absorbent diapers and over wrapped with polyvinyl chloride film with an oxygen transmission rate of 14,000 cc mm^{-2} 24 h 1 atm^{-1} (Koch Supplies, Inc., Kansas City, MO). Ten patties were produced for each treatment replicate; five of them were used for display and the remaining five were frozen for further sensory evaluation. A total of 50 packages were displayed under simulated retail conditions (4°C; warm white fluorescent lightning; 1630 1x; Phillips Inc., Somerset, NJ) for 7 days and panelists evaluated 10 samples each day of display (0, 1, 2, 3 and 7). The pH of ground beef was determined on day 0 of display by homogenizing 2.0 g of ground beef in 20 mL of distilled water (1:10 ratio) and evaluating with an Orion 3 Star pH meter (Thermo Fisher Scientific Inc., Waltham, MA).

Display properties, sensory color and odor: A nine trained member sensory panel was used to evaluate product display characteristics: smearing and patty forming ability, sensory color and sensory odor characteristics of ground beef patties on days 0, 1, 2, 3 and 7 of simulated retail display. For each treatment, panelists evaluated smearing (6 = extreme smearing, 5 = moderate smearing, 4 = slight smearing, 3 = slight cut-grind, 2 = moderate cut-grind, 1 = extreme cut-grind) and patty forming ability (6 = extremely fragile, 5 = moderately fragile, 4 = slightly fragile, 3 = slightly cohesive, 2 = moderately cohesive, 1 = extremely cohesive). The ground beef patties were also evaluated for worst point color, overall color and percentage of discoloration under simulated retail display and the panelists evaluated worst point color (1 = brown, 2 = moderately brownish red, 3 = slightly brownish red, 4 = dull red, 5 = bright red), which defines a discolored area of at least 2 cm in diameter, overall color

(1 = brown, 2 = moderately brownish red, 3 = slightly brownish red, 4 = dull red, 5 = bright red) and percentage of discoloration [1 = total discoloration (96-100%), 2 = extensive discoloration (80-95%), 3 = moderate discoloration (60-79%), 4 = modest discoloration (40-59%), 5 = small discoloration (20-39%), 6 = slight discoloration (1-20%), 7 = no discoloration (0%)] on days 0, 1, 2, 3 and 7 of display. Ground beef patty packages were then opened and evaluated for beef odor and off odor characteristics. Beef odor was evaluated using an eight point scale where 8 = extremely beef like, 7 = very beef like, 6 = moderately beef like, 5 = slightly beef like, 4 = slightly non beef like, 3 = moderately non-beef like, 2 = very non-beef like, 1 = extremely non-beef like and off odor attributes using a five point scale (5 = No. off odor, 4 = slight off odor, 3 = small off odor, 2 = moderate off odor, 5 = No. off odor) on the display days previously described.

Instrumental color: Instrumental color of ground beef patties was measured using a Hunter Lab Mini Scan Illuminant A/10° observer (Hunter Associates Laboratory, Inc., Reston, WV) on days: 0, 1, 2, 3 and 7 of display. Samples were evaluated for CIE; L*, a* and b* color values. The proportion of oxymyoglobin to metmyoglobin was estimated in the visible spectrum using 580 and 630 nm reflectance measurements. Saturation index, which describes the brightness of color was calculated $[(a^{*2}+b^{*2})^{0.5}]$ as was the hue angle $[\tan^{-1} (b^*/a^*)]$, which represents the shift from red to yellow of the patties. The colorimeter was standardized each day before sampling using a white tile and a black tile. Three measurements were taken on different areas for each sample and averaged for statistical analysis.

Sensory evaluation: Sensory evaluation of ground beef patties was conducted after thawing ground beef samples under refrigerated conditions. A nine-member panel was trained following the American Meat Science Association Guidelines[13]. Specifically, ground beef patties were thawed, removed from the foam trays and cooked for evaluation in a Blodget/Zephaire forced air convection oven (Blodgett Oven, Burlington, VT) at 163°C until an internal temperature of 71°C was reached. Five patties/treatment replicate were sectioned into squares (2.54×2.54 cm) discarding the exterior in order to keep uniformity, wrapped in foil and maintained at 49°C in an Alto-Shaam commercial food warmer (Alto-Shaam Inc., Menomonee Falls, WI) for approximately 15 min until served to panelists. Ten samples were randomly presented to the panelists using a complete block design. Trained panelists evaluated samples at their own pace, indicating whenever the next sample was required. Panelists evaluated bind (1 = extremely fragile, 2 = very fragile, 3 = moderately fragile, 4 = slightly fragile, 5 = lightly bind, 6 = moderately bind, 7 = very strong bind, 8 = extremely bind), overall tenderness (1 = extremely though, 2 = very tough, 3 = moderately tough, 4 = slightly tough, 5 = slightly tender, 6 = moderately tender, 7 = very tender, 8 = extremely tender), juiciness (1 = extremely dry, 2 = very dry, 3 = moderately dry, 4 = slightly dry, 5 = slightly juicy, 6 = moderately juicy, 7 = very juicy, 8 = extremely juicy), beef flavor (1 = extremely non-beef like, 2 = very non-beef like, 3 = moderately non-beef like, 4 = slightly non-beef like, 5 = slightly beef like, 6 = moderately beef like, 7 = very beef like, 8 = extremely beef like) and off flavor intensity on a five point scale (1 = extremely off flavor 2 = moderate off flavor, 3 = small off flavor, 4 = slight off flavor, 5 = no off flavor).

Statistical analysis: The experiment was arranged in a completely randomized 5×5 factorial design. Data were analyzed using the General Linear Model procedure for interaction and main effects. Least-squares means for significant interactions or main effects were separated using the Probability of Difference procedure (PDIFF), while sensory panel data, means were separated using the Tukey's *post-hoc* analysis test procedure. All statistical values were derived using version 9.4 of SAS[14]. P values of $p<0.05$ were considered significant.

RESULTS

pH: Un-treated ground beef patties (CON) had the greatest ($p<0.05$) pH on day 0 of retail display (Table 1). Past studies have shown a relationship between high pH and redness of color in meat[15,16]. However, that relationship was not found in this study and a possible justification could be the proximity in pH values between treatments.

Processing properties: The impact of antimicrobial treatments on patty forming ability is shown in Table 1. Panelists found treatments D, O and M less ($p<0.05$) fragile than CON for patty forming ability through all seven days of retail display, where M showed more ($p<0.05$) cohesiveness than the rest of the treatments. Patty cohesiveness remained relatively stable through 7 days of display with patties from 1 day of display having similar cohesiveness as patties on 7 day of display ($p>0.05$) (Table 1).

Treatment by day of display interaction effect on smearing (grinding ability) is shown in Table 2. The F and O patties showed greater smearing ($p<0.05$) compared to the

Table 1: Effects of antimicrobial treatments and days of display

	Treatments					
Attributes	CON	D	F	M	O	SE
Product display characteristics						
Patty forming ability	3.25[a]	2.63[bc]	2.92[ab]	2.07[d]	2.49[c]	0.13
pH values on 0 day	5.56[a]	5.14[c]	5.28[bc]	5.37[b]	4.88[d]	0.04
	Days of display					
	0	1	2	3	7	S.E.
Product display characteristics						
Patty forming ability	2.46[b]	2.81[ab]	2.93[a]	2.70[ab]	2.47[b]	0.14

[1]CON: Control, D: 3% decanoic acid, F: 3% fumaric acid, M: 3% malic acid, O: 3% octanoic acid, [2]Patty forming ability score: 6: Extremely fragile, 1: Extremely cohesive. [a-d]Least-squares means within a row bearing different superscripts differ (p<0.05)

Table 2: Antimicrobial treatment interaction effects on beef odor, off-odor and smearing

		Days of display				
Attributes	Treatments	0	1	2	3	7
Beef odor	CON	5.46[ab]	3.97[d-g]	3.50[fg]	2.94[gh]	1.90[hi]
	D	6.08[a]	5.64[ab]	4.12[c-f]	5.44[ab]	1.62[i]
	F	5.55[ab]	5.26[abc]	5.37[ab]	5.72[ab]	3.47[fg]
	M	3.88[efg]	5.12[a-d]	4.87[b-e]	4.11[def]	1.13[i]
	O	5.38[ab]	5.76[ab]	5.00[bcd]	4.83[b-e]	2.90[gh]
	SE	0.43				
Off odor	CON	4.04[ab]	3.44[b-e]	2.50[fgh]	2.16[gh]	1.08[j]
	D	4.00[ab]	3.94[ab]	2.81[efg]	3.61[abc]	1.22[ij]
	F	4.11[ab]	4.22[a]	3.50[bcd]	3.77[ab]	1.94[hi]
	M	3.11[c-f]	3.94[ab]	3.78[ab]	2.94[def]	1.08[j]
	O	4.16[a]	4.01[ab]	3.70[abc]	3.83[ab]	1.36[ij]
	SE	0.27				
Smearing	CON	3.77[b-f]	4.06[abc]	3.00[d-h]	3.38[b-g]	4.28[ab]
	D	3.61[b-f]	3.35[b-g]	3.50[b-g]	3.83[a-e]	3.85[a-e]
	F	2.88[fgh]	2.64[gh]	4.16[ab]	3.88[a-d]	3.42[b-g]
	M	4.00[abc]	4.06[abc]	4.72[a]	3.94[abc]	4.06[abc]
	O	2.11[h]	2.92[e-h]	3.16[c-g]	3.61[b-f]	3.49[b-g]
	SE	0.36				

[1]CON: Control, D: 3% decanoic acid, F: 3% fumaric acid, M: 3% malic acid 3%octanoic acid, [2]Beef odor score: 1: Extremely non beef like and 8: Extremely beef like, [3]Off-odor score: 1: Extreme off odor and 5: No. off odor, [4]Grinding ability score: 6: Extreme smearing, 1: Extreme cut-grind, [a-j]Least-squares means within an attribute bearing different superscripts differ (p<0.05)

rest of the treatments on 0 and 1 days of display. The D and M treatments were similar to CON (p>0.05) on those days of display. On 2 days of display, CON, D and O patties showed the greatest smearing (p<0.05). However, on 3 and 7 days of display, all treatments were similar (p>0.05) in this smearing attribute.

Day by treatment interaction effect on instrumental color: The day of display by treatment interaction effect on CIE L* value, is shown in Table 3. In general, all ground beef patties became darker in color across the 7 days of display. On 0 day of display, the untreated control (CON) and M did not differ (p>0.05) from each other in lightness and at the same time were lighter (p<0.05) than treatments D, F and O. On day 1 of display, all treatments and the untreated control (CON) were darker (p<0.05) than M. However, F and CON were similar (p>0.05) and at the same time lighter (p<0.05) than D and O. On 2 days of display, CON was darker in color (p<0.05) than F and M and was similar (p>0.05) to both D and O patties. On 3 days of display, CON was similar (p>0.05) to D, which was darker (p<0.05) than F and M. On 7 days of retail display, treatments D and O were darker (p<0.05) than CON, F and M, which were not different (p>0.05) from each other.

The day by treatment interaction effect on CIE a* value is summarized in Table 3. On 0 day of display, F, M and O were more red (p<0.05) than CON and D patties, which were similar (p>0.05) to the control. However, on 1 day of display all treatments were more red (p<0.05) than CON. On 2 and 3 days

Table 3: Effect of days of display by antimicrobial treatment

		Days of display				
Attributes	Treatments	0	1	2	3	7
CIE L*	CON	55.99^{ab}	52.36^{ef}	50.18^{ijk}	50.14^{jk}	49.65^{jkl}
	D	51.73^{e-h}	50.01^{jkl}	50.90^{g-j}	49.98^{jkl}	45.85^{n}
	F	52.76^{ef}	51.51^{fi}	54.21^{cd}	53.00^{de}	50.47^{h-k}
	M	56.11^{a}	54.71^{bc}	52.64^{b}	51.92^{efg}	49.18^{klm}
	O	50.95^{g-j}	48.13^{m}	49.79^{jkl}	48.67^{lm}	44.56^{n}
	SE	0.47				
CIE a*	CON	19.22^{cd}	10.91^{j}	17.45^{e}	19.60^{cd}	21.78^{b}
	D	20.09^{c}	12.74^{h}	10.13^{j}	10.40^{j}	18.63^{de}
	F	22.79^{ab}	12.92^{h}	10.80^{j}	10.14^{j}	16.66^{ef}
	M	22.13^{ab}	14.50^{g}	11.29^{ij}	15.73^{fg}	23.37^{a}
	O	21.66^{b}	15.40^{g}	12.30^{hi}	11.16^{ij}	19.80^{cd}
	SE	0.44				
CIE b*	CON	21.72^{bc}	19.00^{g-j}	19.49^{fgh}	18.85^{hij}	18.38^{ijk}
	D	21.03^{cd}	17.42^{k}	18.03^{jk}	19.29^{ghi}	19.23^{ghi}
	F	22.69^{ab}	19.53^{fgh}	18.36^{ijk}	19.31^{ghi}	19.23^{ghi}
	M	23.56^{a}	19.80^{fgh}	20.40^{def}	21.97^{bc}	19.74^{fgh}
	O	21.90^{bc}	19.94^{efg}	19.05^{g-j}	19.20^{ghi}	18.12^{jk}
	SE	0.37				

[1]CON: Control, D: 3% decanoic acid, F: 3% fumaric acid, M: 3% malic acid, O: 3% octanoic acid, [2] *CIE* L*: 0: Black and 100: White, [3]*CIE* a*: -60: Green and +60: Red, [4]*CIE* b*: -60: Blue and +60: Yellow, [a-k]Least-squares means within an attribute bearing different superscripts differ (p<0.05)

of retail display, CON was more red (p<0.05) than the rest of the treatments. By 7 days of display, M was more red (p<0.05) than the rest of the treatments. The *CIE* a* values on 7 days of display are greater (p<0.05) than those on 3 days display for each treatment. This increase in redness on 7 days is probably due to the accumulation of purge (water soluble myoglobin) on the surface of ground beef patties, increasing the redness of all treatments and the untreated control.

The day by treatment interaction effect on CIE b* value is summarized in Table 3. On 0 day of retail display, D, F and O patties were not different (p>0.05) from CON. However, M patties were more (p<0.05) yellow than the rest of the treatments, except F. On 1 day of display, treatments F, M and O were similar (p>0.05) to CON while D treated patties were less yellow (p<0.05) than the rest of the treatments. On 2 days of display, M and O patties were similar (p>0.05) to those left untreated (CON) while D and F were less (p<0.05) yellow than the rest of the treatments. However, on 7 days of display, CON and O were less yellow (p<0.05) than M.

The day of display by treatment interaction effect on hue angle is shown in Table 4. Hue angle represents the shift in color from red to yellow, resulting in more redness at lower hue angle values. On 0 and 1 day of display, the hue angles of all treatments were lower (p<0.05) than CON, except for M on 0 day, which was similar (p>0.05) to CON. On 2 and 3 days of display, CON was more red (a*; p<0.05) than the rest of the treatments and at the same time its hue angle value was lower (p<0.05). However, on 7 days of display the hue angle value of M was similar (p>0.05) to CON and at the same time lower (p<0.05) than treatments D, F and O. Saturation index refers to the intensity of the a* and b* values and is expressed as vividness or brightness.

The day by treatment interaction effect on saturation index is summarized in Table 4. On 0 and 1 days of display, the F, M and O treatments were more (p<0.05) vivid in color compared to CON and D, which showed no difference (p>0.05) between each other. However, on 2 and 3 days of display, the untreated control presented more (p<0.05) vividness than the rest of the treatments, except for M, which was similar (p>0.05) to CON on 3 days of display. This relates again with the more red (p<0.05) color showed by CON on these days of display compared to the rest of the treatments. On 7 days of display, the M patties were more (p<0.05) vivid than CON and the rest of the treatments.

The estimation of red pigment color (630/580 nm), summarized in Table 4, was higher (p<0.05) for all the treatments on 0 and 1 days of display when compared to the untreated control (CON). However, on 2 and 3 days of display, CON had higher (p<0.05) estimations of red pigment color than the rest of the treatments. On 7 days of display, M treated patties showed no difference (p>0.05) in red pigment color when compared to untreated patties (CON). Similarly to CIE a* value, oxymyoglobin ratio tended to increase from 3-7 days of display. Our results are similar to others who also observed an increase in oxymyoglobin proportions on 7 days of display,

Table 4: Effect of days of display by antimicrobial treatment and interaction effects

		Days of display				
Attributes	Treatments	0	1	2	3	7
Hue angle	CON	48.47^{gh}	60.06^{bc}	48.24^{ghi}	43.96^{kl}	40.16^{m}
	D	46.30^{ij}	53.79^{ef}	60.67^{abc}	61.67^{ab}	45.91^{jk}
	F	44.87^{jk}	56.54^{d}	59.53^{c}	62.29^{a}	49.26^{g}
	M	46.70^{hij}	53.81^{ef}	61.04^{abc}	54.43^{e}	40.19^{m}
	O	45.29^{jk}	52.33^{f}	57.15^{d}	59.84^{bc}	42.66^{l}
	SE	0.73				
Saturation index	CON	29.01^{c}	21.92^{klm}	26.22^{efg}	27.22^{de}	28.50^{cd}
	D	29.09^{c}	21.59^{klm}	20.68^{m}	21.91^{klm}	26.77^{ef}
	F	32.16^{a}	23.42^{ij}	21.31^{lm}	21.81^{klm}	25.48^{fgh}
	M	32.34^{a}	24.55^{hi}	23.31^{ij}	27.05^{e}	30.60^{b}
	O	30.81^{b}	25.20^{gh}	22.68^{jk}	22.20^{jkl}	26.90^{e}
	SE	0.47				
630-580 nm	CON	2.18^{e}	1.04^{l}	1.91^{f}	2.33^{de}	2.76^{ab}
	D	2.43^{cd}	1.42^{hij}	1.03^{l}	1.00^{l}	2.14^{e}
	F	2.91^{a}	1.34^{ijk}	1.14^{kl}	1.01^{l}	1.81^{fg}
	M	2.52^{cd}	1.51^{hi}	1.01^{l}	1.44^{hi}	2.98^{a}
	O	2.63^{bc}	1.63^{gh}	1.20^{jkl}	1.02^{l}	2.47^{cd}
	SE	0.08				

[1]CON: Control, D: 3% decanoic acid, F: 3% fumaric acid, M: 3% malic acid, O: 3% octanoic acid, [2]Calculated as $\tan^{-1}(b^*/a^*)$, [3]Calculated as $(a^{*2}+b^{*2})^{0.5}$, [4]Calculated as the ratio 630-580 nm reflectance, [a-l]Least-squares means within an attribute bearing different superscripts differ ($p<0.05$)

Table 5: Antimicrobial treatment interactions for color and discoloration

		Days of display				
Attributes	Treatments	0	1	2	3	7
Overall color	CON	3.33^{d-g}	1.45^{klm}	3.44^{c-g}	3.33^{d-g}	3.81^{b-e}
	D	3.83^{bcd}	2.45^{hi}	1.38^{klm}	1.88^{ijk}	2.45^{hi}
	F	4.05^{ab}	3.02^{fgh}	1.00^{m}	1.38^{klm}	2.16^{ij}
	M	3.61^{b-f}	3.31^{d-g}	1.22^{lm}	3.00^{gh}	3.95^{abc}
	O	4.44^{a}	3.23^{efg}	1.66^{jkl}	1.61^{jkl}	2.95^{gh}
	SE	0.22				
Discoloration (%)	CON	5.76^{bcd}	1.91^{kl}	3.72^{hi}	4.66^{efg}	5.45^{cde}
	D	6.50^{ab}	3.17^{ij}	1.61^{kl}	2.38^{jk}	5.10^{def}
	F	6.50^{ab}	4.03^{ghi}	1.33^{l}	1.66^{kl}	4.67^{efg}
	M	6.05^{bc}	4.03^{ghi}	1.29^{l}	4.38^{fgh}	5.81^{bcd}
	O	6.88^{a}	4.03^{ghi}	1.94^{kl}	2.16^{k}	5.24^{cde}
	SE	0.32				
Worst point color	CON	3.05^{d}	1.30^{ijk}	1.44^{h-k}	2.44^{ef}	3.59^{bcd}
	D	3.61^{bcd}	2.37^{efg}	1.22^{jk}	1.82^{g-j}	1.94^{f-i}
	F	3.77^{bc}	3.02^{de}	1.11^{k}	1.08^{k}	1.87^{f-i}
	M	3.83^{b}	3.23^{bcd}	1.09^{k}	1.44^{h-k}	3.37^{bcd}
	O	4.61^{a}	3.16^{cd}	1.55^{h-k}	2.05^{fgh}	2.09^{fgh}
	SE	0.24				

[1]CON: Control, D: 3% decanoic acid, F: 3% fumaric acid, M: 3% malic acid, O: 3% octanoic acid, [2]Color score: 1 = Brown, 5 = Bright red, [3]Percentage discoloration, 1: Total discoloration (96-100%) and 7: No. discoloration (0%), [4]Color score: 1 = brown, 5 = bright red, [a-l]Least-squares means within an attribute bearing different superscripts differ ($p<0.05$)

being similar ($p>0.05$) to the first 2 days of display[17,18]. Again, a possible justification for this is the accumulation of high levels of water-soluble myoglobin on the surface of the package, resulting in a more red color and higher oxymyoglobin proportions.

Day by treatment interaction effects on worst point color, overall color, percentage discoloration, beef odor, off odor and smearing: The day by treatment interaction effect on worst point color is displayed in Table 5. Panelist detected that all treatments were more red ($p<0.05$) than CON on 0 and

Table 6: Antimicrobial treatment effects on characteristics of ground beef patties

	Treatments					
Attributes	CON	D	F	M	O	E.M.S.
Bind	5.64[a]	5.64[a]	5.78[a]	5.85[a]	5.71[a]	2.45
Tenderness	6.42[ab]	6.85[a]	6.35[ab]	5.78[ab]	5.21[b]	1.52
Juiciness	5.92[a]	5.71[a]	5.07[ab]	3.37[c]	4.28[bc]	1.45
Beef flavor	6.35[a]	5.57[a]	5.35[a]	6.36[a]	6.35[a]	1.14
Off flavor	3.92[ab]	3.35[ab]	2.78[b]	4.43[a]	4.14[a]	1.37

[1]CON: Control, D: 3% decanoic acid, F: 3% fumaric acid, M: 3% malic acid, O: 3% octanoic acid. [2]Bind score: 1: Extremely fragile and 8: Extreme bind. [3]Tenderness score: 1: Extremely though and 8: Extremely tender. [4]Juiciness score: 1: Extremely dry and 8: Extremely juicy. [5]Beef flavor score: 1: Extremely non-beef like and 8: Extremely beef like. [6]Off flavor score: 1: Extreme off flavor and 5: No. off flavor. [a-c]Least-squares means within an attribute bearing different superscripts differ (p<0.05)

1 days of display, except for D on 0 day, which remained similar (p>0.05) to CON. On 2 days of display, all treatments were similar (p>0.05) in worst point color. However, on 3 days of display, CON was more red (p<0.05) than D, F and M but at the same time similar (p>0.05) to treatment O. Likewise, on 7 days of display, CON was more red (p<0.05) than treatments D, F and O but at the same time was not different (p>0.05) from M treated patties. Interestingly, treatment M increased in redness of worst point color through the latter stages of display.

The discoloration behavior of the patties (Table 5) exhibited a similar trend to the overall color. On 0 day of display, all treatments had similar (p>0.05) discoloration to CON patties, except for O, which had less (p<0.05) discoloration than CON. On 1 day of display, all treatments showed less (p<0.05) discoloration than CON. On 2 days and 3 of display, all treatments had a greater (p<0.05) discoloration compared to CON, except for M on 3 days, which was not different (p>0.05) from CON. On 7 days of display, all treatments were similar (p>0.05) in discoloration.

The overall color attribute is summarized in Table 5. On 0 day of display, panelists found a more red (p<0.05) color for treatments F and O compared to CON, which was similar (p>0.05) to M and D. Similarly, on 1 day of retail display, all treatments had a more red (p<0.05) color than CON. Conversely, on 2 and 3 days of display, panelist found CON patties more red (p<0.05) than the rest of the treatments, except for M on day 3, which was similar to CON. Similarly to instrumental *CIE a** value, on 7 days of display panelists found both untreated control (CON) and M treated patties more red (p<0.05) than the rest of the treatments and again, M was shown to improve its values through the last days of display. There were no significant differences in beef odor between CON and the rest of the treatments on 0 day of display except for M, showing a less intense (p<0.05) beef odor (Table 2). On 1, 2 and 3 days of display, all treatments had a more intense (p<0.05) beef odor than CON, except for treatment D on 2 days of display, which was similar (p>0.05) in beef odor to CON. By 7 days of retail display, CON was similar (p>0.05) in beef odor to all treatments, except for F, which had a more intense (p<0.05) beef odor than CON but was not different (p>0.05) from treatment O.

The day by treatment interaction effect for off odor is summarized in Table 2. The D, F and O treated patties were similar (p>0.05) to the untreated control (CON) on 0 days of display and at the same time had less (p<0.05) off odor than M. However, on 1 day of display, panelists found all treatments to be similar (p>0.05) in off odor to CON, except for F, which had less (p<0.05) off odor than CON. Treatments F, M and O had similar (p>0.05) off odor on 2 days of display and at the same time showed less (p<0.05) off odor than CON and D. On 3 days of display, all treatments had less (p<0.05) off odor than CON. All treatments were similar (p>0.05) in off odor when compared to the untreated control on 7 days of display, except for F, which had less (p<0.05) off odor than CON.

Effects of antimicrobial treatments on sensory taste characteristics: The effects of antimicrobial treatments on sensory taste characteristics are shown in Table 6. Trained panelists were unable to detect any differences (p>0.05) in beef flavor, off flavor, bind and tenderness between CON and the rest of the treatments. The D and F treatments were similar (p>0.05) in juiciness to CON and juicier (p<0.05) than O and M. Therefore, the use of antimicrobials had little impact on sensory attributes of the resulting patties.

DISCUSSION

Octanoic, decanoic and fumeric acid treatments showed increased subjective redness, reduced discoloration and greater a* values compared to control on 0 and 1 days of display without altering beef flavor. Maintaining a safe and

wholesome product during storage and display of meat products is a concern for both consumers and retail distributors. Meat spoilage during display not only impacts safety but can influence economic losses as well[19]. Consumer surveys show a preference for the use of natural alternatives to synthetic antimicrobial products[20]. Natural products have been safely used as additives in food products for many years[21]. The antioxidant potential of certain organic acids can help retain color and have a positive impact on shelf life[22]. Previous studies have also shown that certain acids can be used without negative impacts on sensory characteristics[23]. Organic acids have shown effectiveness in reducing bacterial counts on meat surfaces[24]. The use of organic acids in the meat industry has shown to be a simple, fast, cheap and effective method of reducing bacterial counts in meat products[25]. The results presented in this study suggests that the use of solutions containing fumaric, malic, octanoic and decanoic acid as antimicrobials on beef trimmings prior to grinding may improve or maintain the same instrumental color and sensory retail display properties such as meat color and odor without affecting sensory taste of ground beef patties. Similar results using other organic acids were observed in a previous study[26]. The use of octanoic acid tended to have some advantages over the rest of the treatments in a number of its quality effects when compared to CON. Treatment M was effective for some attributes such as redness (a*), overall color, estimation of red pigment color and percentage discoloration, which were better demonstrated at the late stages of display (3 and 7 days). Therefore, the application of these antimicrobial treatments can be used to improve ground beef safety without affecting ground beef patty quality or sensory attributes.

CONCLUSION

The results from this project suggest that the use of electrostatic spray application of long chain organic acids on beef trimmings prior to grinding might have potential application in the industry for increasing shelf life and display characteristics in the resulting ground beef product.

Furthermore, the use of electrostatic spray application of long chain organic acids on beef trimmings might have the potential to maintain color and sensory visual characteristics of the resulting ground beef product with both economic as well as safety benefits through possible shelf life extension.

SIGNIFICANCE STATEMENTS

This study seeks to provide additional insight into the use of natural antimicrobials in ground beef and their impact on sensory perception by the consumer. An array of antimicrobials were studied to explore product options for ground beef producers that may limit the number of illnesses related to the consumption of contaminated beef while maintaining sensory and color characteristics.

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