Effect of Potassium Lactate, Sodium Metasilicate, Peroxyacetic Acid or Acidified Sodium Chlorite as Single Antimicrobial Interventions on Un-inoculated Beef Trimmings Prior to Grinding on Ground Beef Instrumental Color and Lipid Characteristics

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Story in Brief

Antimicrobial treatments on beef trimmings prior to grinding on ground beef instrumental color and lipid characteristics through display were evaluated and compared to an untreated control (CON). Beef trimmings were treated with 3% potassium lactate (KL), 4% sodium metasilicate (NMS), 0.1% acidified sodium chlorite (ASC), or 0.02% peroxyacetic acid (PAA) prior to grinding. Ground beef was packaged and sampled at 0, 1, 2, 3, and 7 d of simulated retail display. Instrumental color results indicated that PAA produced lighter ($P < 0.05$) color ground beef compared with all the other treatments. The NMS-treated samples had higher ($P < 0.05$) oxymyoglobin content compared with other treatments. Ground beef made from KL, NMS and ASC treated trimmings maintained a similar ($P > 0.05$) redness to CON on day 0; however, ground beef from CON exhibited less ($P < 0.05$) redness and vividness compared to other treatments from 1 to 3 d of display. Additionally, all antimicrobial-treated ground beef had lower ($P < 0.05$) thiobarbituric acid reactive substances (TBARS) values compared with CON throughout display. These findings indicated that the use of tested antimicrobial agents on beef trimmings does not adversely affect instrumental color characteristics of ground beef, and may improve the oxidative stability of ground beef during retail display.

Introduction

Many studies have shown that decontamination of beef trimmings prior to grinding with antimicrobial agents could improve the microbiological quality of ground beef. Researchers found that treating beef trimmings with 1% ozonated water for 15 min or with 10% chlorine dioxide (Stivarius et al., 2002a), 5% acetic acid or 5% gluconic acid (Stivarius et al., 2002b), or 0.5% cetylpyridinium chloride and/or 10% trisodium phosphate (Pohlman et al., 2002) could reduce microbial pathogens in ground beef.

Meat color is an important factor that primarily determines the purchasing decision of the consumer. Previous studies shave discovered that application of antimicrobials on beef trimmings prior to grinding could adversely affect the ground beef color (Stivarius et al., 2002a, 2002b, 2002c). Red color stability and reduced rancidity values after the treatment of beef trimmings with antimicrobials are considered to be beneficial (Jimenez-Villarreal et al., 2003). In addition, the application of 5% lactic acid and 200 ppm chlorine dioxide produced similar color and lipid oxidation measures to untreated ground beef. Therefore, the objective of this study was to evaluate and compare the effects of antimicrobial agents such as potassium lactate, sodium metasilicate, acidified sodium chlorite, or peroxyacetic acid on un-inoculated beef trimmings prior to grinding on instrumental color and lipid characteristics of ground beef.

Experimental Procedures

Antimicrobial Treatment and Processing. The antimicrobial treatments included 3% (v/v) potassium lactate (KL; Purasal®, Purac America Inc., Lincolnshire, Ill.), 4% (w/v) sodium metasilicate (NMS; Avgard®, Rhodia Inc., Cranbury, N.J.), 0.1% (v/v) acidified sodium chlorite, (ASC; sodium chlorite supplemented with food grade citric acid in 1:1 ratio to obtain a solution of pH = 2.5; SANOVA®, Alcide Cooperation, Redmond, Va.), 0.2% (v/v) peroxyacetic acid (PAA; Inspexx-200®, Ecolab, St Paul, Minn.), and an untreated control (CON).

Antimicrobial application was carried out on 12 lb batches of beef trimming that were placed into a meat tumbler (Model 4Q; Lyco Inc. Janesville, Wis.). The selected volume of antimicrobial agents were added and tumbled at 60 rpm for 3 min. The volume of antimicrobial solution used in tumbling was 500 ml, except for PAA (1,500 ml). As per manufacturer's instructions, ASC treatment was tumbled for only 30 sec. Following the completion of antimicrobial application, beef trimmings were ground twice using a Hobart grinder (Model 310; Hobart Inc. Troy, Ohio) with a 3.2-mm plate. Then, 1 lb ground beef samples were placed on styrofoam trays with absorbent pads and over wrapped with polyvinyl chloride film with an oxygen transmission rate of 14,000 cc/mm^2/24 h/1 atm (Koch Supplies, Inc., Kansas City, Mo.) and stored under simulated retail conditions (39°F; deluxe warm white fluorescent lighting, 1630 lux, Phillips Inc., Somerset, N.J.). The pH of treated ground beef was determined by homogenizing ground beef with distilled water in 1:10 ratio. An ultra basic portable pH-mv meter (UP-10; Denver Inc. Denver, Colo.) was used to measure the pH of the homogenate.

Instrumental Color. For instrument color evaluations, ground beef was sampled on days 0, 1, 2, 3, and 7 of simulated display using a Hunter-Lab MiniScan XE Spectrocolorimeter, (Model 4500L; Hunter Associates Laboratory, Reston, W.Va.). Samples were evaluated for Commission Internationale de l'Eclairage (CIE L^*, a^*, and b^*) color values, hue angle ($\tan^{-1}(b^*/a^*)$, which describes the hue or color of ground beef, and saturation index $(a^{*2}+ b^{*2})^{0.5}$, which describes the brightness or vividness of the color (Hunt et al.,

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1991). In addition, reflectance measurements were taken in the visible spectrum from 580 to 630 nm, and the reflectance ratio (630/580 nm) was used to estimate the oxymyoglobin proportion of the myoglobin pigment (Hunt et al., 1991). All the values were determined from the mean of 5 measurements on each ground beef sample using Illuminant A and a 10° observer. The spectrocolorimeter was standardized using white tile, black tile, and working standards before used in measurements.

TBARS characteristics. Thiobarbituric acid reactive substances (TBARS) analysis was performed following a modified method of Tarladgris et al. (1960) and Rhee (1978). On days 0, 3, and 7 of simulated retail display, ground beef was sampled for TBARS analysis. Two grams of ground beef from each treated-ground beef and untreated-control was homogenized for 20 s using a SciMetric homogenizer (Model PRO250; Pro Scientific Inc., Monroe, Conn.) with 8 ml cold (39°F) phosphate buffer mix, containing 0.1% EDTA and 0.1% n-propyl gallate (Sigma Chemical Co., St Louis, Mo.) and standardized to pH 7. Then 2 ml of trichloroacetic acid was added to the mixture, centrifuged for 5 min, and filtered through a Whatman No. 4 filter paper (Whatman, England). Next, 2 ml of 0.02 M 2-thiobarbituric acid reagent (Sigma Chemical Co., St Louis, Mo.) was added to 2 ml aliquots of clear supernatant in 10-ml screw cap tubes, and boiled for 20 min. Immediately after boiling, tubes were placed into an ice bath for 5 min, and absorbance of the samples was read using a spectrophotometer (Model UV 12015; Shimadzu Scientific instruments, Inc., Japan) at 533 nm. Lipid oxidation (TBARS) values (mg malonaldehyde per kg of meat) were calculated by multiplying the absorbency by a factor of 12.21

Analysis of Data. The data were analyzed as a completely randomized 5 x 5 factorial design. The experiment was replicated 3 times. Main effects of antimicrobial treatment, day of display, and treatment by day interactions were examined using the GLM procedure of SAS (SAS Inst. Inc., Cary, N.C.). Means were generated using LSMEANS and separated with the PDIFF option of GLM.

Results and Discussion

Lightness (CIE L).* The effect of antimicrobial treatments on CIE L^* and estimated oxymyoglobin proportions is summarized in Table 1. The KL and NMS treatments had similar ($P > 0.05$) CIE L^* values compared to CON. The highest ($P < 0.05$) L^* values were found in PAA-treated ground beef. The ASC treatment maintained a CIE L^* value similar ($P > 0.05$) to the NMS and KL treatments, but had a lower ($P < 0.05$) L^* than the CON. Additionally, L^* values from day 1 through day 7 of display were higher ($P < 0.05$) than day 0 of display (Table 2).

630 nm/580 nm Reflectance Ratio. The NMS treatment had the highest ($P < 0.05$) estimated oxymyoglobin proportions and was different ($P < 0.05$) from all the other treatments (Table 1). The KL-, PAA-, and ASC-treated ground beef had similar ($P > 0.05$) estimated oxymyoglobin proportions, but higher ($P < 0.05$) values than CON. Estimated oxymyoglobin proportions in ground beef decreased ($P < 0.05$) from day 0 to 7 of display (Table 2). Jimenez-Villarreal et al. (2003) experienced an increase in estimated oxymyoglobin content in cetylpyridinium chloride, trisodium phosphate, chlorine dioxide, or lactic acid treated ground beef by day 7 of display similar to the level of day 1. The reason for this, as they explained, was the accumulation of high levels of water soluble myoglobin (purge) on the surface of ground beef package.

Redness (CIE a).* The day of display by treatment interaction effect on ground beef redness (a^*), yellowness (b^*), hue angle, and saturation index are shown in Table 3. Ground beef from KL, NMS, and ASC maintained a similar ($P > 0.05$) redness (a^*) compared to CON on day 0 of display (Table 3). The PAA treatment was similar ($P > 0.05$) in red color to the ASC, NMS, and KL treatments but had more red color ($P < 0.05$) compared with CON on day 0 of display. The CON was the least ($P < 0.05$) red from day 1 through 7 of display. The red color in KL-, PAA-, and ASC- treated ground beef did not ($P > 0.05$) differ on day 1 of display, but NMS and PAA treatments maintained equal or greater ($P < 0.05$) a^* values compared with the CON from day 1 to 7 of display. Furthermore, the ASC and KL treatments had similar ($P > 0.05$) redness values throughout retail display. Ground beef became less red across the 7–day retail display, regardless of antimicrobial treatment.

Yellowness (CIE b).* The PAA-treated ground beef was more ($P < 0.05$) yellow compared with CON on day 0 of display; however, other treatments received similar ($P > 0.05$) b^* values to CON. Ground beef from CON was the least yellow on days 1 to 3 of display, and was differed ($P < 0.05$) from other treatments, except from ASC ($P > 0.05$), on day 2 of display. Conversely, antimicrobial treatments produced ground beef of similar ($P > 0.05$) yellowness to CON on day 7 of display.

Hue Angle. On day 0 of display, ground beef from the KL, PAA, and the ASC treatments had similar ($P > 0.05$) hue angles to CON. On day 1, the lowest ($P < 0.05$) and highest ($P < 0.05$) hue angles were observed in NMS and CON, respectively, and were different ($P < 0.05$) from other treatments. After day 3 of display, CON had higher ($P < 0.05$) hue angles than the other treatments; however, no differences ($P > 0.05$) in hue angles were found between the KL, PAA, ASC, and CON on day 7 of display.

Vividness. For saturation index, KL, NMS, and ASC were similar ($P > 0.05$) in vividness of color to CON on day 0 of display; however, the vividness of CON was lower ($P > 0.05$) than other treatments on day 1 through 7 of display, except for ASC on day 7 of display.

TBARS and pH. The effect of antimicrobial treatment on pH and lipid oxidation is shown in Table 4. The CON had the highest ($P < 0.05$) lipid oxidation compared to all other treatments on all days of display. Furthermore, the NMS and PAA treatments had similar ($P > 0.05$) lipid oxidation on day 7.

The results indicate that the use of NMS on beef trimmings prior to grinding raised the ground beef pH (Table 4). According to Jimenez-Villarreal et al. (2003), higher pH resulted in redder ground beef with less lipid oxidation. Our findings were consistent with this hypothesis and NMS-treated ground beef had the most estimated oxymyoglobin proportions, was redder-colored, and incurred in less lipid oxidation compared to the ground beef with lower pH values.

Implications

Results of this study indicate that sodium metasillicate and potassium lactate added to ground beef maintained a similar lightness to untreated controls, and outperformed peroxyacetic acid and acidified sodium chlorite treatments. All the antimicrobial-treated ground beef was similar in redness to the untreated control at the beginning of display. However, the sodium metasilicate and peroxyaetic acid treated ground beef remained red even on day 3 of display. Thus, treating beef trimmings with 3% potassium lactate, 4%

sodium metasilicate, 0.1% acidified sodium chlorite, or 0.02% peroxyacetic acid improved instrumental color and lipid characteristics of ground beef.

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Table 1. Effect of antimicrobial treatments applied to beef trimmings on the least-squares means for CIE *L values, oxymyoglobin, beef odor and off odor intensities of bulk ground beef through simulated retail display.**

	Treatment[a]					
Attribute	CON	KL	NMS	PAA	ASC	SE
CIE *L**[b]	50.03y	49.81yz	49.07yz	52.53x	48.90z	0.39
Oxymyoglobin[c]	2.12z	2.63y	3.07x	2.79y	2.64y	0.06

[a] CON = Control, KL = 3% potassium lactate, NMS = 4% sodium metasilicate, PAA = 200 ppm peroxyacetic acid, ASC = 1000 ppm acidified sodium chlorite.
[b] *L** (Lightness; 0 = black and 100 = white). CIE = Commission Internationale de l'Eclairage.
[c] Calculated as the ratio 630 nm/580 nm reflectance.
[x,y,z] Least-squares means within a row bearing different letters are different (P < 0.05).

Table 2. Effect of duration of display on the least-squares means for CIE *L values and oxymyoglobin content of ground beef.**

	Days of display					
Attribute	0	1	2	3	7	SE
CIE *L**[a]	48.41w	50.64v	50.37v	50.15v	50.77v	0.39
Oxymyoglobin[b]	4.27v	3.09w	2.47x	2.23y	1.21z	0.06

[a] *L** (lightness, 0 = black and 100 = white). CIE = Commission Internationale de l'Eclairage.
[b] Calculated as the ratio 630 nm/580 nm reflectance.
[v,w,x,y,z] Least-squares means within a row bearing different letters are different (P < 0.05).

Table 3. Days of display by antimicrobial treatment[a] interaction effect on the least squares-means of CIE a*[b], CIE b*[c], hue angle[d] and saturation index[e] of ground beef.

Attribute	Days of display				
	0	1	2	3	7
*CIE a**					
CON	25.14x	19.89y	16.90y	13.74z	9.05y
KL	27.49wx	23.34x	19.67x	17.64y	10.97wx
NMS	26.16wx	25.64w	22.94w	22.20w	13.64w
PAA	28.03w	24.21wx	22.07w	20.02x	12.37wx
ASC	26.79wx	23.18x	19.34x	19.22xy	9.62xy
SE	0.77	0.46	0.52	0.63	1.01
*CIE b**					
CON	20.99xy	18.16y	17.20y	16.61y	16.61wx
KL	22.82wx	20.31x	18.94x	17.68x	17.55w
NMS	20.65y	21.41w	19.63wx	19.43w	16.03x
PAA	23.18w	20.82wx	19.84w	19.01w	16.95wx
ASC	22.01wxy	19.95x	17.96y	17.72x	16.27x
SE	0.61	0.32	0.27	0.26	0.31
Hue Angle					
CON	39.87w	42.43w	45.57w	50.42w	61.39w
KL	39.73wx	41.10x	44.12wx	45.14x	58.16w
NMS	38.26x	39.88y	40.56y	41.26y	49.87x
PAA	39.60wx	40.73x	41.97xy	43.59xy	54.19wx
ASC	39.40wx	40.75x	42.89wxy	42.67xy	59.04w
SE	0.49	0.26	0.86	0.84	2.40
Saturation Index					
CON	32.75x	26.94y	24.15y	21.57z	18.91x
KL	35.73wx	30.95x	27.36x	24.99y	20.80w
NMS	33.34x	33.41w	30.20w	29.52w	21.09w
PAA	36.38w	31.94wx	29.69w	27.62x	21.07w
ASC	34.67wx	30.59x	26.39x	26.15xy	18.90x
SE	0.95	0.55	0.43	0.57	0.57

[a] CON = Control, KL = 3% potassium lactate, NMS = 4% sodium metasilicate, PAA = 200 ppm peroxyacetic acid, ASC =1000ppm acidified sodium chlorite.
[b] *a** (redness; -60 = green and +60 = red). CIE = Commission Interantionale de l'Eclairage.
[c] *b** (yellowness; -60 = blue and +60 = yellow).
[d] Calculated as $\tan^{-1}(b^*/a^*)$.
[e] Calculated as $(a^{*2}+b^{*2})^{0.5}$.
[w, x,y,,z] Least–squares means within a column for an attribute bearing different letters are different (P< 0.05).

Table 4. Days of display by antimicrobial treatment interaction effect on the least-squares means of pH and TBARS values of ground beef.

Attribute	Treatment[a]	Days of display				
		0	1	2	3	7
pH						
	CON	5.60w	5.59w	5.58w	5.65w	5.61vw
	KL	5.55w	5.58w	5.54wx	5.62w	5.39w
	NMS	6.49v	6.36v	6.32v	6.19v	5.75v
	PAA	5.47w	5.48y	5.48x	5.52w	5.50wx
	ASC	5.52w	5.54x	5.52wx	5.57w	5.56wx
	SE	0.05	0.01	0.02	0.11	0.05
TBARS[b]						
	CON	2.56v	-	-	4.33v	5.16v
	KL	1.31w	-	-	2.90w	3.42w
	NMS	0.82w	-	-	0.82z	1.90x
	PAA	0.88w	-	-	1.38y	2.22x
	ASC	1.19w	-	-	2.35x	3.73w
	SE	0.25			0.13	0.36

[a] CON = Control, KL = 3% potassium lactate, NMS = 4% sodium metasilicate, PAA = 200 ppm peroxyacetic acid, ASC = 1000 ppm acidified sodium chlorite
[b] Thiobarbituric acid reactive substances
[v,w,x,y,z] Least–squares means within a column for an attribute bearing different letters are different ($P < 0.05$).