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INFLUENCE OF LACTATE, PHOSPHATE, SALT AND ACETATE ON THE PROPERTIES OF INJECTION-ENHANCED BEEF

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Introduction

Tenderness, juiciness, and flavor are the three most important components of meat palatability. Tenderness is regarded as more important than flavor by consumers because consumers feel they may have a greater impact on flavor than tenderness (Patterson, 1998). Beef tenderness may be enhanced or improved in a number of ways, including electrical stimulation, aging carcasses or cuts, mechanical tenderization, marination, or injection enhancement.

Common ingredients in enhanced pork include phosphates, salt, sodium or potassium lactate, sodium diacetate, and flavoring, as well as water (Miller, 1998). These ingredients have positive impacts on the tenderness and juiciness of pork products and may also be applicable to beef cuts. Moeller and Courington (2002) found that consumers had interest in an economical line of marinated beef products that would have improved tenderness and juiciness.

Little research has been published concerning injection-enhanced whole muscle beef products, though it is commonplace in industry. Ingredients included in injection-enhancement solutions may impact various traits of beef, including color and flavor.

Objectives

The objectives of this study were to determine the influence of lactate, phosphate, salt and acetate on the visual and sensory properties of injection-enhanced beef.

Methodology

Seven USDA Select beef ribs and four USDA Select beef strip loins (8 d postmortem) were used to evaluate injection-enhancement treatments. Five treatments were applied to the beef ribs and four treatments were applied to the strip loins. Treatments were as follows: No Lactate or Acetate - 0.3% salt, 0.3% phosphate, 0% lactate and 0% acetate; Lactate Control - 1.5% potassium lactate, 0.3% salt, 0.3% phosphate; Lactate + High Salt - 1.5% potassium lactate, 0.6% salt, 0.3% phosphate; Lactate + Acetate - 1.5% potassium lactate, 0.3% salt, 0.3% phosphate, 0.1% acetate; Lactate + Acetate (No phosphate) - 1.5% potassium lactate, 0.3% salt, 0% phosphate, 0.1% acetate. All treatments were the same for the ribs and strip loins, except the Lactate + Acetate (No phosphate) treatment was not applied to strip loins.

All treatments were applied to a 7.62-cm thick section of seven paired beef ribs. Three 2.54-cm thick steaks were cut from each section and evaluated on d 2, 9, and 14 post-injection after storage at 2°C. Steaks were evaluated on a 1 to 7 scale for visual color, muscle darkening, discoloration (metmyoglobin formation), and shine, where 1 was the best and 7 was the worst for each trait. Also, on d 2, 9, and 14, steaks were evaluated for instrumental CIE color, odor, microbial growth, and oxidation (TBARS). Odor was evaluated on a 1 to 5 scale with 1 being no odor and 5 being extremely objectionable.

Four treatments were applied to each section of each beef strip loin. Three 1.91-cm thick steaks and one 2.54-cm steak were cut from each section. The 1.91-cm steaks were used to evaluate surface shine and a battery of sensory attributes on d 2, 9 and 14 post-injection. The 2.54-cm steaks were used for Warner-Bratzler shear force (WBSF) evaluation.

Results & Discussion

The lactate + high salt treatment steaks had the darkest ($P < 0.05$; Table 1) visual color each day of all treatments throughout the trial. All treatments had higher visual color scores on d 9 than on d 2 ($P < 0.05$), indicating color deterioration. The no lactate or acetate treatment steaks had less muscle darkening ($P < 0.05$) on d 2 than steaks from the lactate control, lactate + high salt, and lactate + acetate treatments. High-salt treatment steaks showed the most darkening ($P < 0.05$) each day of evaluation and for the longissimus thoracis and spinalis dorsi. Treatment did not affect discoloration (percent surface metmyoglobin), but the spinalis muscle discolored faster and to a greater extent than the longissimus. The lactate + high-salt treatment steaks had less ($P < 0.05$) shine on d 2 than the lactate control steaks.

CIE L* values showed the lactate + high salt steaks were the darkest (Table 2). Steaks on d 9 were significantly darker than on d 2 or d 14. Steaks from all treatments were more red ($P < 0.05$) on d 2 than on d 9. The CIE color value b* indicated that no differences ($P > 0.05$) existed among treatments or among days after injection. On d 9, no lactate or acetate treatment steaks had less intense ($P < 0.05$) color (lower chroma value) than lactate + acetate and the lactate + acetate without phosphate treatment steaks. Chroma values decreased for all treatments over time indicating decreasing color intensity. All steaks were the most ($P < 0.05$) red (lower hue angle values) on d 2 ($P < 0.05$), but were not different among treatments. Objectionable off-odor scores were lowest on d 2, and increased significantly on d 9 and d 14. Mean objectionable off odor scores for any day did not exceed 2.5, which is typically considered unacceptable on the given scale. TBARS values on d 2 (0.280 mg malonaldehyde/kg meat) were less ($P < 0.05$) than d 9 (0.540), which were less ($P < 0.05$) than d 14 (0.990). Microbial growth was not affected by treatment or day in MAP, contrary to expectations. Microbial counts were very low throughout the trial, with means for treatment and day never exceeding 1 log.

Lactate + acetate steaks were more tender ($P < 0.05$) than the no lactate or acetate and the lactate control steaks (Table 3). Gloss generally lessened with increasing time (Table 4). Rancid flavor development was greater in the no lactate or acetate steaks and lactate + high salt steaks on d 14 than for the lactate control and lactate + acetate steaks (Table 5).

Brown/roasted and beef flavors were greatest on d 9 (Table 6 and 7). As time increased, oxidized meat and stale flavors increased (Table 7). However, meat protein flavor decreased over time (Table 7). Salty flavor increased in lactate + high salt treatment steaks when compared to other treatments (Table 8).

Conclusions

The lactate control showed the least darkening from d 2 to d 9, indicating lactate's ability to stabilize color. Lactate appeared to reduce shine of the steaks, prevent rancid flavor development, and increase brown/roasted flavor. Lactate also impacted flavor to a greater degree at d 9 post-injection, indicating that lactate may require dwell time to impact flavor development.

Increasing the salt level had detrimental impacts on visual color, darkening, and flavor. The lactate + high salt steaks had the most darkening of all treatments. Generally, the lactate + high salt steaks had the least shine, possibly due to its dark appearance. Steaks with the increased salt level also had greater red color deterioration from d 9 to d 14 than all other treatments as well as increased rancid flavor development and increased salty flavor.

Acetate may have aided the reduction of shine as the no lactate or acetate steaks generally had the greatest shine. Acetate may have increased color intensity because steaks from the two acetate containing treatments had greater chroma values than the no lactate or acetate steaks. Acetate generally had a tenderizing effect. However, the mechanism through which this takes place is unknown.

References

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Tables and Figures

Table 1. Least squares means of trained visual panel values during a 14-day trial of beef rib steaks enhanced with five different solutions

	Days in MAP							
Trait/Trt/Muscle	**2**	**9**	**10**	**11**	**12**	**13**	**14**	**SEM**
Visual Color[i]								
No Lac or Ace	$2.6^{a,z}$	$3.2^{b,z}$	$3.6^{c,z}$	$3.9^{d,z}$	$3.9^{cd,z}$	$4.4^{e,z}$	$4.5^{e,z}$	0.183
Lac Con	$3.0a,y$	$3.4^{b,z}$	$4.2^{cd,y}$	$4.0^{c,zy}$	$4.3^{de,y}$	$4.5^{e,z}$	$4.5^{e,z}$	
Lac + High Salt	$3.7^{a,x}$	$4.6^{b,x}$	$5.3^{c,x}$	$5.5^{cd,w}$	$5.3^{cd,x}$	$5.5^{cd,x}$	$5.6^{d,y}$	
Lac + Ace	$3.1^{a,y}$	$4.1^{b,y}$	$4.5^{c,y}$	$4.7^{c,x}$	$4.6^{c,y}$	$5.0^{d,y}$	$4.7^{cd,z}$	
Lac + Ace(no Phos)	$2.8^{a,zy}$	$3.8^{b,y}$	$4.4^{d,y}$	$4.3^{cd,y}$	$4.5^{d,y}$	$4.5^{d,z}$	$4.8^{e,z}$	
Muscle								
Longissimus	$3.1^{a,z}$	$3.6^{b,z}$	$4.2^{c,z}$	$4.2^{c,z}$	$4.3^{c,z}$	$4.5^{d,z}$	$4.6^{d,z}$	0.148
Spinalis	$3.0^{a,z}$	$4.0^{b,z}$	$4.6^{c,y}$	$4.8^{c,y}$	$4.8^{c,y}$	$5.0^{d,y}$	$5.0^{d,y}$	
Darkening[j]								
No Lac or Ace	$2.4^{a,z}$	$2.8^{b,z}$	$3.1^{bc,z}$	$3.3^{cd,z}$	$3.3^{cd,z}$	$3.7^{de,z}$	$3.9^{e,z}$	0.242
Lac Con	$3.4^{ab,x}$	$3.2^{a,zy}$	$3.8^{cd,y}$	$3.5^{abc,z}$	$3.7^{bcd,zy}$	$3.8^{cd,z}$	$3.9^{d,z}$	
Lac + High Salt	$3.9^{a,w}$	$4.6^{b,w}$	$5.0^{c,x}$	$5.1^{c,x}$	$5.0^{c,w}$	$5.1^{c,x}$	$5.1^{c,y}$	
Lac + Ace	$3.1^{a,yx}$	$3.9^{b,x}$	$4.2^{bc,y}$	$4.4^{c,y}$	$4.2^{bc,x}$	$4.3^{bc,y}$	$4.2^{bc,z}$	
Lac+ Ace(no Phos)	$2.7^{a,zy}$	$3.4^{b,y}$	$4.1^{cd,y}$	$3.8^{bc,z}$	$4.0^{cd,yx}$	$3.8^{cd,zy}$	$4.2^{d,z}$	
Muscle								
Longissimus	$3.1^{a,z}$	$3.3^{a,z}$	$3.8^{b,z}$	$3.8^{b,z}$	$3.9^{b,z}$	$4.0^{bc,z}$	$4.1^{c,z}$	0.192
Spinalis	$3.0^{a,z}$	$3.9^{b,y}$	$4.3^{c,y}$	$4.2^{c,y}$	$4.2^{c,y}$	$4.3^{c,y}$	$4.4^{c,z}$	
Discoloration[k]								
Muscle								
Longissimus	$1.0^{a,z}$	$1.0^{a,z}$	$1.0^{a,z}$	$1.1^{a,z}$	$1.1^{a,z}$	$1.3^{b,z}$	$1.3^{b,z}$	0.079
Spinalis	$1.0^{a,z}$	$1.2^{ab,z}$	$1.2^{b,y}$	$1.6^{c,y}$	$2.0^{d,y}$	$2.2^{e,y}$	$2.4^{f,y}$	
Shine[l]								
No Lac or Ace	$2.7^{a,zy}$	$3.7^{c,x}$	$3.1^{a,x}$	$3.0^{a,y}$	$2.7^{ab,y}$	$2.2^{b,z}$	$2.5^{b,y}$	0.196
Lac Con	$2.7^{bc,y}$	$3.0^{c,y}$	$2.7^{bc,yx}$	$2.5^{ab,zy}$	$2.0^{a,z}$	$2.0^{a,z}$	$2.1^{a,zy}$	
Lac + High Salt	$2.2^{ab,z}$	$2.3^{ab,z}$	$2.6^{b,yx}$	$2.3^{ab,z}$	$2.2^{ab,zy}$	$2.0^{a,z}$	$2.1^{a,zy}$	
Lac + Ace	$2.5^{b,zy}$	$2.3^{ab,z}$	$2.4^{b,zy}$	$2.2^{ab,z}$	$2.0^{ab,z}$	$1.9^{a,z}$	$1.9^{a,z}$	
Lac + Ace(no Phos)	$2.3^{b,zy}$	$1.9^{ab,z}$	$2.0^{ab,z}$	$2.1^{ab,z}$	$1.8^{ab,z}$	$1.8^{ab,z}$	$1.7^{a,z}$	

[abcde] Means in a row with different superscript letters differ (P<.05).

[l]Shine scale: 1 = no shine, 2 = slight amount of shine, 3 = small amount of shine.

[j]Darkening scale: 2 = very slightly dark, 3 = slightly dark, 4 = modestly dark, 5 = moderately dark.

[i]Visual color scale: 2 = bright red, 3 = dull red, 4 = slightly dark red, 5 = moderately dark red or brown, 6 = dark red to brown.

[k]Discoloration scale: 1 = no discoloration (0%), 2 = slight discoloration (1-19%), 3 = small discoloration (20-39%).

[wxyz] Means in a column within a trait or muscle with different superscript letters differ ($P < 0.05$).

Table 2. Least Squares means of instrumental color values[i] of beef rib steaks injection-enhanced with five treatment solutions and evaluated on d 2, 9, and 14 post-injection.

	Days in MAP				
Trait/Trt	**2**	**9**	**14**	**trt mean**	**SEM**
L*					
No Lac or Ace	40.3	37.0	40.6	39.3^{b}	0.440
Lac Con	39.6	37.1	39.9	38.9^{b}	
Lac + High Salt	37.4	37.2	38.0	37.6^{a}	
Lac + Ace	38.6	38.4	39.3	38.8^{b}	
Lac + Ace (no Phos)	39.8	38.7	40.3	39.6^{b}	
Mean	39.1^{b}	37.7^{a}	39.6^{b}		0.368
a*					
No Lac or Ace	$31.9^{b,z}$	$27.8^{a,z}$	$28.6^{a,y}$		0.575
Lac Con	$31.8^{b,z}$	$29.1^{a,yz}$	$29.0^{a,y}$		
Lac + High Salt	$31.5^{c,z}$	$29.4^{b,yz}$	$26.0^{a,z}$		
Lac + Ace	$30.8^{b,z}$	$29.8^{ab,y}$	$28.3^{a,y}$		
Lac + Ace (no Phos)	$31.8^{b,z}$	$29.6^{a,y}$	$28.3^{a,y}$		
b*					
No Lac or Ace	24.7	23.4	24.3		
Lac Con	24.7	24.1	24.6		
Lac + High Salt	24.1	23.9	22.9		
Lac + Ace	23.8	24.6	24.5		
Lac + Ace (no Phos)	24.9	24.5	24.5		
Chroma[j]					
No Lac or Ace	$40.34^{b,z}$	$36.39^{a,z}$	$37.55^{a,y}$		0.747
Lac Con	$40.24^{b,z}$	$37.78^{a,yz}$	$37.99^{a,y}$		
Lac + High Salt	$39.68^{b,z}$	$37.87^{b,yz}$	$34.63^{a,z}$		
Lac + Ace	$38.93^{a,z}$	$38.63^{a,y}$	$37.47^{a,y}$		
Lac + Ace (No PO4)	$40.33^{b,z}$	$38.41^{ab,y}$	$37.45^{a,y}$		
Hue Angle[k]					
No Lac or Ace	$37.66^{b,z}$	$40.02^{a,z}$	$40.33^{a,y}$		0.307
Lac Con	$37.89^{b,z}$	$39.51^{a,yz}$	$40.34^{a,y}$		
Lac + High Salt	$37.42^{c,z}$	$39.14^{b,y}$	$41.49^{a,z}$		
Lac + Ace	$37.65^{c,z}$	$39.54^{b,yz}$	$40.98^{a,yz}$		
Lac + Ace (No PO4)	$38.05^{c,z}$	$39.53^{b,yz}$	$40.85^{a,yz}$		
Muscle					
Longissimus	$37.59^{c,z}$	$39.18^{b,y}$	$40.06^{a,y}$		0.194
Spinalis	$37.88^{c,z}$	$39.91^{b,z}$	$41.54^{a,z}$		

[abc] Means in a row with different superscript letters differ ($P < 0.05$).

[i]L* - greater values are lighter, a*- greater values are more red, b*- greater values are more yellow, chroma- greater values are more intense, hue angle- greater values are less red.

[j]Calculated using the equation: chroma = $[(a^{*2} + b^{*2})^{1/2}]$.

[k]Calculated using the equation: hue angle = $[(b^*/a^*)^{\tan-1}]$.

[yz] Means in a column within a trait or muscle and trait with different superscript letters differ($P<.05$).

Table 3. Warner-Bratzler shear force and sensory panel tenderness and juiciness least squares means for strip loin steaks injection-enhanced with four solutions

	Treatment					
	No Lac or Ace	Lac Con	Lac + High Salt	Lac + Ace	Day Mean	SEM
Warner-Bratzler shear force, kg	2.6[a]	2.6[a]	2.2[ab]	1.9[b]		0.384
Panel tenderness[c]						
d 2	9.6	9.7	10.1	10.0	9.8[y]	0.150
d 9	9.6	8.9	9.1	9.1	9.2[z]	
d 14	9.1	8.7	8.9	9.3	9.0[z]	
Mean	9.5	9.1	9.4	9.4		
Panel juiciness[c]						
d 2	6.1	5.7	6.5	6.0	6.1[y]	0.146
d 9	5.5	5.1	5.9	5.6	5.5[z]	
d 14	5.1	5.0	5.4	5.7	5.3[z]	
Mean	5.6	5.3	6.0	5.8		

[ab]Means with a different superscript letter differ ($P < 0.05$).
[c]Scored on a 15 point scale.
[yz]Means within a column and trait with a different superscript letter are different ($P < 0.05$).

Table 4. Instrumental gloss and trained sensory panel shine least squares means for strip loin steaks injection-enhanced with four solutions

	Days in MAP			
	2	**9**	**14**	**SEM**
gloss at 20°				
No Lac	0.5	0.4	0.7	
Lac Con	0.5	0.5	0.6	
Lac + Hi Salt	0.5	0.5	0.6	
Lac + Ace	0.7	0.5	0.7	
Mean	0.6	0.5	0.6	0.094
gloss at 60°				
No Lac	2.95	1.95	1.53	
Lac Con	3.08	2.85	2.10	
Lac + Hi Salt	3.93	2.63	2.08	
Lac + Ace	4.05	2.40	2.10	
Mean	3.50[a]	2.45[ab]	1.95[b]	0.525
gloss at 85°				
No Lac	0.8	0.4	2.1	
Lac Con	1.2	0.4	5.8	
Lac + Hi Salt	1.8	1.2	6.1	
Lac + Ace	1.8	1.4	13.5	
Mean	1.4	0.8	6.9	2.414
shine score[i]	8.67[a]	8.18[a]	6.52[b]	0.256

[ab] Means within a row within a trait with a different superscript letter differ ($P < 0.05$).
[i]Shine scale: 1 = no shine, 15 = extremely shiny.

Table 5. Least squares means for the day x rancid flavor[c] interaction of beef strip loin steaks injection-enhanced with four treatment solutions evaluated on d 2, 9, and 14 post-enhancement

	Day in MAP			
	D 2	**d 9**	**D 14**	**SEM**
No Lac or Ace	0.40[a,y]	0.59[a,yz]	2.06[b,z]	0.336
Lac Con	0.19[a,y]	1.19[b,z]	0.75[ab,y]	
Lac + High Salt	0.65[a,y]	0.86[a,yz]	2.36[b,z]	
Lac + Ace	0.48[a,y]	0.19[a,y]	0.96[a,y]	

[ab]Means within a row with different superscript letters differ ($P < 0.05$).

[c]Rancid flavor scored on a 0 to 15-pt scale.

[yz]Means within a column with different superscript letters differ ($P < 0.05$).

Table 6. Least squares means for brown/roasted flavor[d] for beef strip loin steaks injection-enhanced with four solutions and evaluated on d 2, 9, and 14 post-enhancement

Day/Treatment	**Brown/Roasted Flavor**	**SEM**
Day		
d 2	6.05[a]	0.156
d 9	6.87[c]	
d 14	6.47[b]	
Treatment		
No Lac or Ace	5.92[a]	0.138
Lac Con	6.72[b]	
Lac + High Salt	6.43[b]	
Lac + Ace	6.81[b]	

[abc]Means with different superscript letters differ ($P < 0.05$).

[d]Brown/roasted flavor scored on a 0 to 15-pt scale.

Table 7. Least squares means for flavor[c] attributes x day interactions for injection-enhanced strip loin steaks evaluated on d 2, 9, and 14 post-enhancement

	Day in MAP			
	d 2	**d 9**	**d 14**	**SEM**
Beef flavor[c]	4.95[a]	6.35[b]	5.35[a]	0.325
Bloody/serumy flavor[c]	0.20[a]	0.42[b]	0.30[ab]	0.064
Meat protein flavor[c]	1.65[c]	1.06[b]	0.90[a]	0.202
Oxidized flavor[c]	0.39[a]	0.28[a]	1.01[b]	0.106
Metallic flavor[c]	2.64[b]	2.31[a]	2.75[b]	0.136
Stale flavor[c]	0.93[a]	0.90[a]	2.63[b]	0.194

[ab]Means with different superscript letters differ ($P < 0.05$).

[c]Flavor scored on a 0 to 15-pt scale.

Table 8. Least squares means for salty flavor[c] for strip loin steaks injection-enhanced with four solutions

Treatment	Mean	SEM
No Lac or Ace	4.79[a]	0.138
Lac Con	4.86[a]	0.138
Lac + High Salt	5.56[b]	0.138
Lac + Ace	4.63[a]	0.138

[ab] Means with different superscript letters differ ($P < 0.05$).

[c] Salty flavor scored on a 0 to 15-pt scale.