Effects of Organic Acid Salts on the Quality Characteristics of Whole Muscle Hams

Karaline A. Poovey
University of Nebraska-Lincoln

Dennis E. Burson
University of Nebraska-Lincoln, dburson1@unl.edu

Roger W. Mandigo
Universit y of Nebraska - Lincoln, rmandigo1@unl.edu

Susan L. Cuppett
University of Nebraska-Lincoln, scuppett1@unl.edu

Harshavardhan Thippareddi
University of Nebraska-Lincoln, harsha15@uga.edu

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Using organic acid salts in hams at increased formulation use levels will reduce product yields, flavor and texture desirability, and overall ham acceptability.

Karaline A. Poovey
Dennis E. Burson
Susan L. Cuppett
Roger W. Mandigo
Harshavardhan Thippareddi[1]

Summary

The use of organic acid salts in the meat industry enhances product shelf life and safety. Minimal research is available evaluating the effects of high levels of organic acid salts on quality and sensory attributes of ready-to-eat products. Whole muscle hams were cured with brine solutions containing one of the following organic acid salt additions: 0% Control; 2.5 or 3.5% L-sodium lactate and sodium diacetate; 1.3, 2.5, or 3.5% buffered sodium citrate; 1.3, 2.5, or 3.5% buffered sodium citrate and sodium diacetate. The increased use of organic acid salts decreased product moisture and cooking yield ($P < 0.05$). Sensory panelists perceived decreased overall acceptability, with increased sourness/acidity and bitterness. Moderate levels of organic acid salts provided more acceptable products while maintaining many sensory attributes. Meat processors choosing to use organic acid salts in ready-to-eat products should be cautious as product yield losses and flavor changes may outweigh benefits at certain levels.

Introduction

Organic acid salts, often used as "antimicrobial agents" in the meat industry, offer processors enhanced product shelf life and improved product safety for consumers without losing quality attributes. These ingredients are commonly used to control the growth of *Listeria monocytogenes*, a pathogen of concern in ready-to-eat meat products. In addition, USDA Food Safety and Inspection Service (FSIS) regulations for *Listeria monocytogenes* control encourage the use of these antimicrobial ingredients. Common organic acid salts include buffered sodium citrate, sodium lactate, potassium lactate, and sodium diacetate.

FSIS currently limits the inclusion of buffered sodium citrate to 1.3% of the formulation, yet higher levels may be needed for effective control of *Listeria monocytogenes*. Research on the effects of higher levels of organic acid salts on sensory and quality traits of ready-to-eat meat products such as ham is lacking. Research in this area is essential for improving product quality and safety as well as providing information to FSIS for evaluating regulatory limits.

The purpose of this experiment was to evaluate the effects of various levels of organic acid salts on sensory and quality characteristics of whole muscle hams.

Procedures

Ham production

Boneless inside hams (IMPS 402F) were purchased from a commercial processor and delivered to the University of Nebraska–Lincoln's (UNL) Loeffel Meat Laboratory. Ham muscles were trimmed of external fat and macerated to increase surface area for tumbling and curing. The hams were cured with one of nine different brine solutions. The base brine included water, salt, sugar, organic acid salt (level and type depended on treatment), sodium nitrite and sodium erythorbate. The treatments included the following organic acid salt additions: 0% Control; 2.5 or 3.5% L-sodium lactate and sodium diacetate (SL+SDA) (Optiform SD4, Purac, Lincolnshire, Ill.); 1.3, 2.5 or 3.5% buffered sodium citrate (SC) (Ional, WTI, Jefferson, Ga.); and 1.3, 2.5 or 3.5% buffered sodium citrate and sodium diacetate (SC+SDA) (Ional LC, WTI, Jefferson, GA). Treatments were replicated on three separate production days.

Each of nine brines were individually mixed and added to 20 lb of ham muscle in a bag for tumbling to achieve a final weight of 112% of green weight. The bags were clipped and treatments were tumbled at 39°F without vacuum for three hours. All treatments were held at 39°F overnight, tumbled for 1.5 hours, stuffed into fibrous casings, and cooked to an internal temperature of 158°F.

After cooking, hams were chilled in a 36°F cooler. Final cooked ham size measured approximately 3.5 in deep, 5.5 in wide, and at least 11.8 in long. Hams were weighed again to achieve a final cooked (chill) weight and smokehouse yield was calculated (Smokehouse Yield (%) = [1- (pre-cook weight – final cook weight)/ pre-cook weight] x 100).

Slicing and packaging

Five hams from each treatment were sliced into one half inch thick slices and the slices were vacuum packaged. Slices from each ham were randomly assigned to the following analyses: color, purge, consumer taste panel, and focus taste panel. The slices were placed in dark storage in a 37°F cooler (day 0 of storage) and held in dark storage until analysis on the designated day of storage.

Qualitative analyses

Proximate analysis (moisture, ash, and fat) and pH were analyzed on day 0. Protein was calculated by difference. The percentage of purge lost from slices in the vacuum-packaged bags was determined from slices held in dark storage at 37°F on day 28. Hunter L* (lightness), a* (redness), b* (yellowness) were determined on the ham slices on day 28.

Sensory analysis was conducted using both a consumer panel and a focus panel. Consumer panels occurred at day 29 and focus panel evaluations were conducted at day 35. The consumer panel survey scale was composed of 6 in horizontal lines for the attributes measured and panelists marked their preference point with a vertical mark on the scale whereas lacking was 0 and intense was 15. Attributes included: appearance, flavor (saltiness, sweetness, sourness/acidity, bitterness, and overall ham flavor), juiciness, texture, ham aftertaste, and overall ham acceptability. The focus panel participants tasted and evaluated ham samples as training for sample analysis. Panelists chose major attributes during trainings to be used in the sample survey. The focus panel survey evaluated the following: odor (smoke, sour, sweet, off-odor), texture (first bite, chew, juiciness), flavor (saltiness, sweetness, sourness/acidity, smoke, metallic, overall ham flavor), and ham aftertaste (metallic, sour).

Statistical analysis

Data were analyzed as a completely randomized design by analysis of variance (ANOVA) using the SAS 9.1 GLIMMIX procedure with a predetermined significance level of $P \leq 0.05$. Proximate composition data, purge, yield, pH, were analyzed as a completely randomized design. Colorspace values were analyzed as a repeated measures design, and sensory

Table 1. Least square (LS) means of proximate composition, purge, cooking yield, and pH of boneless ham slices by treatment.

Treatment	Moisture (%)	Fat (%)	Ash (%)	Protein (%)	Purge (d28)	Yield (%)	pH (d0)
Control	72.94^{a}	1.95	3.73	21.38^{f}	1.73	87.70^{a}	6.15
2.50% SL+SDA[g]	70.50^{b}	2.36	4.02	23.13^{e}	1.81	88.06^{a}	6.21
3.50% SL+SDA	68.79^{bcd}	3.07	4.25	23.90^{de}	1.86	88.15^{a}	6.14
1.30% SC[h]	70.11^{bc}	2.70	3.69	23.50^{e}	1.74	81.66^{b}	6.02
2.50% SC	67.06^{ef}	2.94	3.66	26.33^{ab}	1.57	75.63^{de}	6.03
3.50% SC	66.44^{f}	2.74	3.64	27.18^{a}	1.73	74.09^{e}	5.96
1.30% SC+SDA[i]	70.32^{b}	2.24	3.37	24.07^{cde}	1.92	82.88^{b}	6.11
2.50% SC+SDA	68.49^{cde}	2.31	3.73	25.46^{bc}	1.52	78.99^{c}	6.03
3.50% SC+SDA	67.76^{def}	2.87	4.02	25.36^{bcd}	1.96	77.59^{cd}	6.08
SEM[j]	0.593	0.429	0.22	0.556	0.252	1.453	0.104
P-Value	< 0.0001	0.601	0.204	< 0.0001	0.11	< 0.0001	0.794

[abcdef]Means within the same column and within a main effect without a common superscript differ ($P < 0.05$).
[g]SL+SDA = Sodium lactate + sodium diacetate
[h]SC = Sodium citrate
[i]SC+SDA = Sodium citrate + sodium diacetate
[j]SEM = Standard error of the mean

Table 2. LSMeans for day 28 HunterLab L*, a*, and b* for ham slices from different treatments.

Treatment	L*	a*	b*
Control	66.39	13.58	9.22^{d}
2.50% SL+SDA[e]	65.31	14.05	9.50^{cd}
3.50% SL+SDA	65.23	14.00	9.68^{bcd}
1.30% SC[f]	70.01	12.36	10.25^{ab}
2.50% SC	67.29	13.47	10.39^{a}
3.50% SC	67.07	13.34	10.46^{a}
1.30% SC+SDA[g]	67.27	13.52	10.42^{a}
2.50% SC+SDA	67.20	13.51	10.10^{abc}
3.50% SC+SDA	67.05	13.61	10.31^{a}
SEM[h]	1.414	0.536	0.211
P-Value	0.420	0.532	0.003

[abcd]Means within the same column and within a main effect without a common superscript differ ($P < 0.05$).
[e]SL+SDA = Sodium lactate + sodium diacetate.
[f]SC = Sodium citrate.
[g]SC+SDA = Sodium citrate + sodium diacetate.
[h]SEM = Standard error of the mean.

evaluation data were analyzed as a partial balanced incomplete block design. When significance was indicated by ANOVA, means separations were performed using the LSMEANS and DIFF function of SAS.

Results and Discussion

The addition of organic acid salts had a significant effect on the percentage of moisture and protein in cured hams ($P < 0.0001$); however, no differences were noted among treatments for percent fat or ash ($P > 0.05$; Table 1). Hams that had no organic acid salt added (Control treatments) had the greatest percentage of moisture ($P < 0.0001$) and the percentage of moisture decreased as the percentage of organic acid salt increased ($P < 0.05$). The decrease in moisture was mostly explained by differences in cooking yields for the different treatments. The cooking yield percentage decreased as percentage of buffered sodium citrate increased. However, hams with SL+SDA increased in cooking yield as the percentage of organic acid salt increased ($P < 0.0001$). A reduction in percentage moisture and cooking yield may impact the sensory qualities of the ham.

No differences were found among treatments when measuring percentages of purge lost at day 28 post-packaging ($P = 0.11$). While purge indicates mois-

(Continued on next page)

Table 3. LSMeans for flavor of ham by treatment as evaluated by consumer panels.

	Flavor				
Treatment	Saltiness[i]	Sweetness[i]	Sourness/ acidity[i]	Bitterness[i]	Ham aftertaste[j]
Control	6.67^{bc}	6.26^{b}	6.13^{c}	5.50^{d}	7.76^{a}
2.5% SL+SDA[e]	7.43^{b}	5.51^{b}	6.78^{abc}	6.11^{bcd}	7.92^{a}
3.5% SL+SDA	8.56^{a}	6.35^{b}	7.52^{a}	6.48^{abc}	7.76^{a}
1.3% SC[f]	7.14^{bc}	6.10^{b}	6.51^{bc}	5.65^{cd}	8.28^{a}
2.5% SC	7.06^{bc}	5.51^{b}	7.40^{a}	6.77^{ab}	7.64^{a}
3.5% SC	7.41^{b}	5.72^{b}	7.30^{ab}	6.39^{abcd}	7.80^{a}
1.3% SC+SDA[g]	6.48^{c}	6.45^{b}	6.09^{c}	5.62^{cd}	8.26^{a}
2.5% SC+SDA	6.85^{bc}	6.46^{b}	6.91^{abc}	6.11^{bcd}	8.05^{a}
3.5% SC+SDA	6.84^{bc}	7.64^{a}	7.51^{a}	7.15^{a}	6.56^{b}
SEM[h]	0.32	0.40	0.32	0.32	0.36
P-Value	0.0003	0.027	0.0005	0.001	0.032

[abcd]Means within the same column and within a main effect without a common superscript differ ($P < 0.05$).
[e]SL+SDA = Sodium lactate + sodium diacetate.
[f]SC = Sodium citrate.
[g]SC+SDA = Sodium citrate + sodium diacetate.
[h]SEM = Standard error of the mean.
[i]Flavor attributes were evaluated individually on a 15 point scale where 1 = lacking and 15 = intense.
[j]Ham aftertaste was evaluated on a 15 point scale where 1 = undesirable and 15 = highly desirable.

Table 4. LSMeans of juiciness, texture, appearance, and acceptability of ham by treatment as evaluated by consumer panels.

Treatment	Juiciness[i]	Texture[j]	Appearance[k]	Overall ham acceptability[l]
Control	7.77^{abc}	8.71^{a}	7.68	7.97^{ab}
2.5% SL+SDA[e]	8.69^{a}	8.24^{ab}	8.82	8.28^{ab}
3.5% SL+SDA	7.89^{ab}	7.47^{bc}	8.45	8.19^{ab}
1.3% SC[f]	6.32^{cd}	7.99^{ab}	8.09	8.41^{a}
2.5% SC	5.90^{d}	6.34^{d}	8.06	7.18^{bc}
3.5% SC	5.76^{d}	6.79^{cd}	8.96	7.68^{abc}
1.3% SC+SDA[g]	7.00^{bcd}	8.14^{ab}	7.96	8.33^{a}
2.5% SC+SDA	6.37^{cd}	7.36^{bc}	7.94	7.72^{abc}
3.5% SC+SDA	5.77^{d}	6.59^{cd}	8.21	6.69^{c}
SEM[h]	0.53	0.33	0.36	0.39
P-Value	0.0002	< .0001	0.149	0.016

[abcd]Means within the same column and within a main effect without a common superscript differ ($P < 0.05$).
[e]SL+SDA Sodium lactate + sodium diacetate
[f]SC = Sodium citrate
[g]SC+SDA = Sodium citrate + sodium diacetate
[h]SEM = Standard error of the mean
[i]Juiciness was evaluated on a 15 point scale where 1 = very dry and 15 = very juicy.
[j]Texture was evaluated on a 15 point scale where 1 = tough/hard/coarse and 15 = tender/soft/smooth.
[k]Appearance was evaluated on a 15 point scale where 1 = very undesirable and 15 = very desirable.
[l]Overall ham acceptability was evaluated on a 15 point scale where 1 = extremely dislike and 15 = extremely like.

ture loss over time, smokehouse yields provide insight on potential moisture loss of the product during thermal processing (Table 1). There were no statistical differences found for HunterLab L* or a* ($P > 0.05$); however, treatments with SC tended to have higher, or more yellow, HunterLab b* values ($P = 0.003$) (Table 2).

Sensory analysis

Sensory characteristics were measured using both consumer and focus panels. Consumer panelists identified traits by preferences, while the focus panels more precisely identified descriptive differences in sensory characteristics.

Basing their decisions on a 0.4 in^3 ham sample, consumers were not able to distinguish differences in appearance ($P = 0.149$) or overall ham flavor ($P = 0.158$; Tables 3, 4). Significant differences ($P < 0.03$) were found in traits like saltiness, sweetness, sourness/acidity, and bitterness. In addition to flavor attributes, consumers also determined significant distinctions in levels of juiciness, texture, and overall ham acceptability ($P < 0.02$).

Treatments with 3.5% SL+SDA were rated highly by consumer panels for saltiness, sourness/acidity, bitterness, ham aftertaste, juiciness, and overall ham acceptability (Tables 3, 4). The 2.5% SL+SDA treatments ranked high among attributes such as sourness/acidity, ham aftertaste, juiciness, texture, and overall ham acceptability. It appears that lower levels of SL+SDA have more desirable sensory traits, and that the addition of SL at either level boosts acceptable flavor traits while reducing negative traits like bitterness or sourness.

Although hams including 3.5% SC+SDA provided consumers a sweeter ham, they also increased more undesirable characteristics: sourness/acidity, bitterness, undesirable aftertaste, decreases in juiciness, and lower overall acceptability (Tables 3, 4). If lower levels of SC+SDA are used (1.3%), these traits are significantly reduced and comparable to Control ($P < 0.05$). Without the inclusion of SDA, product overall acceptability was similar to Control; however, sourness and bitterness traits at 2.5% and 3.5% were still less desirable.

While the focus panel also based their sensory decisions on a 0.4 in^3 ham piece, additionally they evaluated whole ham slices for appearance. The focus panelists found no differences among samples when examining for smoke odor, off-odor, smoke flavor, overall ham flavor, sour aftertaste, or iridescent sheen ($P > 0.05$) (Tables 5, 6).

Focus panelists reported a more tender first bite, smoother chewing capabilities, increased juiciness, and increased slice integrity while increasing the saltiness for hams containing

Table 5. **LSMeans of odor, texture, and appearance of ham by treatment as evaluated by focus panels.**

	Odor[i]		Texture			Appearance	
Treatment	Sour	Sweet	First bite[j]	Chew[k]	Juiciness[k]	Cured color intensity[l]	Slice integrity[m]
Control	5.14^{abc}	2.93	8.76^{a}	7.86^{abcd}	7.82^{ab}	6.76^{cd}	6.91^{a}
2.5% SL+SDA[e]	5.84^{ab}	4.32	8.59^{ab}	8.23^{abc}	8.01^{ab}	7.57^{b}	7.14^{a}
3.5% SL+SDA	3.91^{c}	3.32	8.78^{a}	8.72^{a}	7.06^{abc}	8.61^{a}	6.98^{a}
1.3% SC[f]	4.86^{bc}	2.97	7.80^{abc}	8.29^{ab}	6.67^{bc}	6.51^{d}	6.63^{a}
2.5% SC	5.05^{abc}	3.33	5.36^{d}	6.08^{d}	5.05^{d}	7.27^{bc}	5.63^{bc}
3.5% SC	4.68^{bc}	2.83	6.74^{abcd}	6.09^{cd}	4.48^{d}	6.67^{cd}	5.17^{c}
1.3% SC+SDA[g]	6.50^{a}	3.99	8.6^{ab}	8.65^{a}	8.42^{a}	6.6^{cd}	6.65^{a}
2.5% SC+SDA	5.17^{abc}	3.40	6.61^{bcd}	6.47^{bcd}	4.92^{d}	6.71^{cd}	6.57^{ab}
3.5% SC+SDA	6.05^{ab}	3.92	6.34^{cd}	6.59^{abcd}	5.75^{cd}	7.18^{bcd}	6.46^{ab}
SEM[h]	0.55	0.40	0.74	0.78	0.56	0.28	0.35
P-Value	0.049	0.08	0.003	0.036	< .0001	< .0001	0.001

[abcd]Means within the same column and within a main effect without a common superscript differ ($P < 0.05$).
[e]SL+SDA = Sodium lactate + sodium diacetate.
[f]SC = Sodium citrate.
[g]SC+SDA = Sodium citrate + sodium diacetate.
[h]SEM = Standard error of the mean.
[i]Odor attributes were evaluated individually on a 15 point scale where 1 = lacking and 15 = intense.
[j]First Bite was evaluated on a 15 point scale where 1 = tough and 15 = tender.
[k]Chew was evaluated on a 15 point scale where 1 = fibrous and 15 = smooth.
[l]Cured color intensity was evaluated on a 15 point scale where 1 = pale pink and 15 = dark pink.
[m]Slice integrity was evaluated on a 15 point scale where 1 = lacking bind and 15 = bound.

Table 6. **LSMeans for flavors of ham by treatments as evaluated by focus panels.**

	Flavor[j]				
Treatment	Saltiness	Sweetness	Sourness/ acidity	Metallic	Metallic aftertaste
Control	6.35^{c}	4.28^{c}	5.66	1.53^{de}	2.35^{c}
2.5% SL+SDA[f]	8.31^{ab}	4.99^{bc}	6.78	1.39^{e}	2.04^{c}
3.5% SL+SDA	8.99^{a}	4.36^{c}	6.66	1.84^{cde}	2.9^{bc}
1.3% SC[g]	7.19^{bc}	4.89^{bc}	5.38	2.83^{abc}	3.22^{bc}
2.5% SC	8.28^{ab}	4.61^{c}	6.31	3.26^{a}	4.9^{a}
3.5% SC	8.33^{ab}	4.92^{bc}	7.18	2.06^{bcde}	3.91^{ab}
1.3% SC+SDA[h]	6.79^{c}	5.09^{bc}	6.25	2.58^{abcd}	4.18^{ab}
2.5% SC+SDA	7.41^{bc}	5.75^{ab}	5.73	2.53^{abcd}	3.87^{ab}
3.5% SC+SDA	7.56^{bc}	6.28^{a}	10.64	3.10^{ab}	5.13^{a}
SEM[i]	0.43	0.39	1.16	0.39	0.52
P-Value	0.0003	0.086	0.067	0.003	< .0001

[abcde]Means within the same column and within a main effect without a common superscript differ ($P < 0.05$).
[f]SL+SDA = Sodium lactate + sodium diacetate.
[g]SC = Sodium citrate.
[h]SC+SDA = Sodium citrate + sodium diacetate.
[i]SEM = Standard error of the mean.
[j]Flavor attributes were evaluated individually on a 15 point scale where 1 = lacking and 15 = intense.

3.5% SL+SDA ($P < 0.05$). Reducing the concentration of SL+SDA (2.5%) resulted in reduced ham saltiness and metallic flavors ($P < 0.05$) without compromising juiciness and sweetness intensities.

Hams with 3.5% SC+SDA were more sour/acidic, less juicy, and more intense in metallic flavor and metallic aftertaste while also testing more sweet. Hams from 1.3% SC+SDA were more tender during the first bite, and more smooth and juicy during chewing when compared to hams of 3.5% SC+SDA. The lowest level treatment (1.3%) with SC alone provided hams with a more tender first bite, smooth chewing capabilities, moderate juiciness and highly bound slice integrity. In both SC and SC+SDA samples, cured color intensity greatly declined. As well, panelists noticed modest saltiness, metallic flavor, and metallic aftertastes.

Conclusion

Though the utilization of organic acid salts (SL+SDA, SC, and SC+SDA) may increase product shelf life and safety, this research revealed that their incorporation affects quality and sensory attributes of ham. As the concentration of organic acid salt treatments increased product yields while product moisture decreased. Decreases in moisture led to sensory panelists finding decreased levels of juiciness, slice integrity, and overall acceptability. As well, consumers perceived increased levels of saltiness, sourness/acidity, and bitterness with increasing concentration of the organic acid salts, while total ham aftertaste decreased.

Formulations of ham with lower levels of organic acid salts are capable of providing processors a product with minimal impact on processing quality, as well as sensory and quality attributes for consumer acceptance. When using organic acid salts in ready-to-eat meat products, meat processors should carefully evaluate the effects on quality and sensory properties while achieving improved product safety and shelf life.

[1]Karaline A. Poovey is a master's graduate student in the Animal Science Department. Dennis E. Burson and Roger W. Mandigo are professors in the Animal Science Department. Susan L. Cuppett and Harshavardhan Thippareddi are professor and associate professor, respectively, in the Department of Food Science and Technology.