# The Impact of Acidic Marination Concentration and Sodium Chloride on Sensory and Instrumental Color Characteristics of Dark-cutting Beef

*J.T. Sawyer, J.K. Apple, and Z.B. Johnson*[1]


## Story in Brief

The objectives of this study were to evaluate varying levels of lactic acid (LA) enhancement on cooked color (instrumental and sensory) of dark-cutting beef. Dark-cutting (DC; mean pH = 6.64) and normal pH (NDC; mean pH = 5.43) strip loins (n = 52) were sectioned into thirds, and DC sections were injected to 110% of raw product weight with LA at 0.5, 1.0, 1.5, or 2.0% of product weight, with or without 0.5% of NaCl. Steaks were cooked to an internal temperature of 160°F and evaluated for degree of doneness, internal cooked color, instrumental cooked color (lightness (L*), redness (a*), and yellowness (b*)), and the reflectance ratio of 630nm/580nm (measure of cooked color change from red to brown). Post-enhancement pH values were reduced ($P < 0.05$) with the addition of LA. Sensory panelists recorded an improvement in the degree of doneness of treated DC steaks ($P < 0.05$). Most notably, internal cooked color was improved ($P < 0.05$) when DC sections were enhanced with LA. Redness (a*) of DC steaks enhanced with the lower levels of LA resulted in values similar ($P > 0.05$) to NDC steaks. The 630nm/580nm reflectance ratio indicated that LA was able to impact ($P < 0.05$) cooked beef color, as DC steaks enhanced with the lower levels of LA were similar in internal cooked color to NDC steaks. Results suggest that LA enhancement can reduce muscle pH and improve the cooked beef color/degree of doneness of DC beef.


## Introduction

Dark-cutting meat is a quality defect that results from a depletion of glycogen reserves prior to slaughter, and is often described as a meat that fails to brighten after the cut surface has been exposed to oxygen. More specifically, dark-cutters are often characterized by a high postmortem muscle pH, increased water-binding capacity, sticky surface texture, and a dark red to almost black lean color.

Extensive documentation of muscle pH has indicated that myoglobin is protected from heat denaturation by a high meat pH, allowing a persistent red or pink internal muscle color during and after cooking (Trout, 1989; Hunt et al., 1999). This pink color has been attributed to undenatured myoglobin (Trout, 1989) and/or an interaction between pH and myoglobin (Hunt et al., 1999; Lien et al., 2002).

Previously, organic acids have been used as a method for improving the shelf-life of meat products for exportation. Likewise, lactic acid has been shown to prevent the undesirable raw or persistent pink appearance in cooked patties from dark-cutting beef, but a notable tangy off-flavor was reported (Moiseev and Cornforth, 1999). Therefore, the objectives of this study were to compare the effects of acid marination on muscle pH, cooked color and thermal denaturation of myoglobin in dark-cutting beef.

## Experimental Procedures

Normal (NDC; n = 12) and dark-cutting (DC; n = 40) beef strip loins were purchased from a large commercial slaughter facility. Dark-cutting beef strip loins were selected based upon postmortem pH values (mean pH = 6.64) and all muscles were transported to the University of Arkansas Red Meat Abattoir. Muscles were then removed from vacuum-sealed bags and all external fat and adjacent muscles were removed from the *longissimus* muscle. Each muscle was transversely sectioned into thirds, and DC sections were allotted to 1 of 9 enhancement treatments of lactic acid (LA) at 0.5, 1.0, 1.5, or 2.0% with or without NaCl and a non-injected negative control. Muscle sections originating from NDC beef were not injected and served as a positive control.

Enhancement solutions were prepared in 53.6°F tap water and agitated continuously with a Rotosolver high-shear mixer (Admix Inc., Manchester, N.H.) until injection. Enhanced strip loins were injected at a targeted 110% of final product weight with their respective treatment solutions via a 5-needle injector (Dayton, Dayton Electric Mfg., Co., Niles, Ill.) and tumbled at 42 rpm (Lyco, Columbus, Wis.) under 18 psi of vacuum (Thomas Compressors and Vacuums, Sheboygan, Wis.) for 3 min. After injection and tumbling, muscle sections from all treatments were re-weighed, vacuum-packaged and stored at 35.6°F for 48 h. Subsequently, muscles sections were removed from their packages, and cut into 1.0-in-thick steaks, individually vacuum-packaged, and stored at -4°F until analyzed for color (sensory and instrumental), myoglobin quantification, post-enhancement pH, and expressible moisture.

Post-enhancement pH was determined using duplicate meat samples (1.8 g) blended with 18 ml of distilled water for 1 min with a polytron homogenizer (Pro250, ProScientific, Monroe, Conn.). The pH filtrate was measured with a pH meter model (UP-10, Denver Instruments, Denver, Colo.) equipped with a combination pH electrode calibrated to pH 4.0 and 7.0.

Steaks were cooked on an open-hearth grill (Star Manufacturing, Int., Inc., Smithville, Tenn.) and turned every 2.5 min until the desired internal temperature of the steak reached 160°F. Steaks were cut in half through the vertical center, and cooked color differences were evaluated on the cut surface using a selected panel of 5 members trained according to AMSA (1991) guidelines. Sensory panelists evaluated each cut surface to the nearest 0.5, for surface color differences (3 = moderately lighter, 2 = slightly lighter, 1 = very slightly lighter, 0 = not different from con-

[1] All authors are associated with the Department of Animal Science, Fayetteville

trol, -1 = very slightly darker, -2 = slightly darker, -3 = moderately darker), internal cooked color (7 = brown, 6 = gray brown, 5 = pinkish gray, 4 = slightly pink, 3 = pink, 2 = medium red, 1 = very red), and internal doneness (6 = very well, 5 = well done, 4 = medium, 3 = medium rare, 2 = rare, 1 = very rare). Instrumental cooked color readings of steaks were measured immediately after cutting each steak in half and wrapping the cut surface with polyvinyl chloride film to minimize fading. The L*, a*, and b* values were measured using a Hunter MiniScan XE (Model 45/0-L, Hunter Associates Laboratory Inc., Reston, Va.) with a 10º standard observer, and a 0.5 in aperture, and illuminant A. Also, the reflectance ratio 630:580 was used as an estimate of cooked color change from red to brown (AMSA, 1991).

Water-holding capacity of muscle samples was performed using the method set forth by Wierbicki and Deatherage (1958). An additional piece of muscle tissue (5 g) from each sample was utilized for percent moisture determination, and subsequent total moisture (sample weight x percent moisture). Moreover, myoglobin was quantified using a modified procedure described by Warriss (1979) and Hunt et al. (1999).

All data were analyzed as a modified randomized design, with muscle section serving as the experimental unit. The analysis of variance was generated using the mixed models procedure of SAS (SAS Inst., Inc., Cary, N.C.). Enhancement treatment was the lone fixed effect, whereas replication was the lone random effect, in the model for post-enhancement pH, instrumental color, expressible moisture, and myoglobin data. Session was included in the model and fit with all main effects and main effect interactions for sensory cooked color variables, and panelist was also included in the model as a random effect for all visually evaluated variables to account for panelist variation. Least squares means were generated, and when significant ($P < 0.05$) F-values were observed, least squares means were separated using pair-wise t-test (PDIFF option).

## Results and Discussion

Results pertaining to post-enhancement characteristics pH, pump yield, and solution retention are presented in Table 1. Increasing concentrations of LA with or without salt in DC beef resulted in lower pH values not typically seen in NDC beef ($P < 0.05$). The pH values of muscles treated with 0.5% or 1.0% LA and 0.5% NaCl were not different ($P > 0.05$) from NDC muscles.

Steaks treated with lower concentrations of LA (0.5 to 1.0%) were considerably ($P < 0.05$) lighter (L*) and more yellow (b*) than steaks receiving higher concentrations of LA (Table 2). With increasing concentrations of LA, internal cooked color of treated steaks appeared darker which tended to result in an over-cooked internal cooked color. More specifically, lower concentrations (0.5 to 1.0%) of LA reduced ($P < 0.05$) redness (a*) values, indicating that internal cooked color of treated steaks contained less redness than DC controls. The ratio of instrumental spectral values (630:580) was used as an indicator of internal cooked meat color changing from red to brown. Treated steaks receiving lower concentrations (0.5 to 1.0%; with or without NaCl) of LA were similar ($P > 0.05$) to untreated NDC. This change in internal cooked color indicated that LA improved the degree of doneness as captured by instrumental measurements.

Sensory panelists rated DC controls the lowest, indicating that internal cooked color was redder and more rare appearing ($P < 0.05$; Table 3); whereas, NDC and steaks treated with 0.5 to 1.0% LA, with or without NaCl, received the most ideal cooked color ratings, in as much that steaks appeared to have a pink to slightly pink center indicating steaks were cooked to a medium degree of doneness. Cooked color ratings by sensory panelists indicated that DC treated steaks with 0.5 to 1.0% LA, with or without NaCl, tended to be closer ($P < 0.05$) to ratings for NDC controls in which steaks appeared to have a slight pink to pinkish gray internal cooked color. Surface discoloration was assessed to determine if LA enhancement would impact the cooked steak surface. Panelists' ratings indicated that as LA concentration increased, cooked steak surface color became darker ($P < 0.05$).

Minimal differences in raw myoglobin (RMb) levels were seen when using LA as an enhancement ingredient (Table 3), although RMb concentration decreased ($P < 0.05$) as the concentration of LA increased. There were no differences ($P > 0.05$) in total cooked myoglobin values (CMb) between NDC and 0.5% LA with or without NaCl. However, as seen with RMb, when LA concentration increased, CMb values subsequently decreased. Enhancement of DC steaks with LA increased ($P < 0.05$) the percentage of denatured myoglobin (PDMb) values and the percentage of denaturing was higher as LA concentration increased.

Limited results are available outlining the impact of acidic marination on DC whole muscle samples. However, Oreskovich et al. (1992) indicated that as pH is lowered through acidic marination towards the isoelectric point of meat, cooking yield and moisture levels will decrease, which supports findings in the current study. Cooked steak color (instrumental and sensory) and myoglobin concentrations tend to concur with previous studies using DC trim to manufacture ground beef patties. The addition of LA eliminated the persistent pinking as viewed by sensory panelists and instrumentally, approaching color values seen in NDC beef (Moiseev et al., 1999). More importantly, myoglobin denaturation increased with the addition of LA further supporting the acceptable cooked color scores of DC beef treated with LA (Moiseev et al., 1999).

## Implications

Results from this study indicate that the addition of lactic acid to dark-cutting beef strip loins will lower postmortem muscle pH, resulting in an improved cooked steak color of dark-cutting muscles which typically maintain a consistent pinking, regardless of endpoint temperature. More importantly, lactic acid could been used as an ingredient in value-added enhancement methodologies, but further research is warranted to define the ultimate impact of acidic marination on taste and fresh color properties of dark-cutting beef.

## Acknowledgments

Appreciation is expressed to the Arkansas Beef Council for funding this research. Moreover, the authors wish to acknowledge T. Choat and K. Charmasson, of Smithfield Beef Group (Green Bay, Wis.), for assistance with product procurement, and to M. Bittle, and J. Stephenson for their assistance with muscle fabrication and data collection.

## Literature Cited

AMSA. 1991. Guidelines for meat color evaluation. National Cattlemen's Beef Association, Centennial, Colo.
Hunt, M. C., et al. 1999. J. Food Sci. 64:847-851.
Lien, R., et al. 2002. J. Food Sci. 67:1007-1010.
Moiseev, I. V., and D. P. Cornforth. 1999. J. Food Sci. 64:738-743.
Oreskovich, D. C., et al. 1992. J. Food Sci. 57:305–311.
Trout, G. R., 1989. J. Food Sci. 54:536-540.
Wariss, P. D. 1979. J. Food Technol. 14:75-80.
Wierbick, E. and F. E. Deatherage. 1958. J. Ag. Food Chem. 6:387-392.

**Table 1. Effects of lactic acid (LA) enhancement, with or without salt (NaCl), on injection characteristics of dark-cutting beef steaks.**

| Treatment | Injection characteristic | | | | | |
|---|---|---|---|---|---|---|
| | pH[1] | Pump yield[2] | Cook yield[3] | Total Moisture[4] | Free water[5] | Bound water[6] |
| NDC untreated | 5.39[cd] | 98.82[d] | 70.79[b] | 72.54[a] | 32.58[ab] | 67.42[de] |
| DC untreated | 6.37[a] | 99.28[d] | 75.04[a] | 75.86[ab] | 23.31[e] | 76.69[a] |
| 0.5% LA | 5.81[b] | 100.69[c] | 67.51[c] | 70.91[ab] | 30.05[bcd] | 69.95[bcd] |
| 1.0% LA | 4.99[ef] | 102.68[b] | 67.49[c] | 70.29[b] | 35.07[a] | 64.93[e] |
| 1.5% LA | 4.69[efg] | 103.20[b] | 66.59[cd] | 73.26[ab] | 35.16[a] | 64.84[e] |
| 2.0% LA | 4.10[h] | 104.87[a] | 66.69[cd] | 73.31[ab] | 25.49[de] | 74.52[ab] |
| 0.5% LA / 0.5% NaCl | 5.66[bc] | 101.14[c] | 70.68[b] | 69.80[b] | 28.49[bcd] | 71.51[bcd] |
| 1.0% LA / 0.5% NaCl | 5.07[de] | 101.11[c] | 68.19[bc] | 68.64[b] | 27.33[cde] | 72.66[abc] |
| 1.5% LA / 0.5% NaCl | 4.67[fg] | 100.96[c] | 68.27[bc] | 73.95[ab] | 30.58[abc] | 69.43[cde] |
| 2.0% LA / 0.5% NaCl | 4.55[g] | 100.98[c] | 64.18[d] | 71.00[ab] | 28.95[bcd] | 71.05[bcd] |
| SEM | 0.14 | 0.51 | 1.12 | 1.99 | 2.05 | 2.55 |

[1]pH measurement 48 h post-enhancement.
[2]Pumped yield at 48 h post-enhancement = (post-packaged wt./green wt.) x 100.
[3]Cooked yield = [(Fresh wt. – Cooked wt.)/ Fresh wt.] x 100.
[4]Total moisture = [(Fresh wt. – Dried wt.)/ Fresh wt.] x 100.
[5]Free water = (((moisture surface area – meat surface area) x 61.1)/total moisture) x 100.
[6]Bound water = (%Free water – 100).
[a, b, c, d, e, f, g, h] Within a column, least squares means lacking a common superscript are different ($P < 0.05$).

**Table 2. Effects of lactic acid (LA) enhancement, with or without salt (NaCl), on instrumental cooked color characteristics of dark-cutting beef steaks.**

| Treatment | Color characteristic | | | | | |
|---|---|---|---|---|---|---|
| | L*[1] | a*[1] | b*[1] | Hue angle[2] | Chroma[3] | 630:580[4] |
| NDC untreated | 52.56[a] | 19.80[b] | 19.71[ab] | 45.19[b] | 24.14[b] | 2.63[b] |
| DC untreated | 51.57[ab] | 24.63[a] | 21.57[a] | 41.35[c] | 32.70[a] | 3.76[a] |
| 0.5% LA | 50.89[abc] | 16.20[c] | 17.79[bcd] | 48.68[a] | 24.50[bcd] | 2.26[bc] |
| 1.0% LA | 49.21[abcd] | 15.44[cd] | 16.67[cd] | 48.83[a] | 22.84[cde] | 2.34[bcd] |
| 1.5% LA | 39.92[e] | 10.47[e] | 11.98[fg] | 49.49[a] | 15.90[fg] | 1.52[d] |
| 2.0% LA | 40.14[e] | 8.85[e] | 10.54[g] | 49.98[a] | 13.99[g] | 1.40[d] |
| 0.5% LA / 0.5% NaCl | 50.61[abc] | 19.09[bc] | 18.56[bc] | 44.96[b] | 26.79[bc] | 2.77[b] |
| 1.0% LA / 0.5% NaCl | 47.47[cd] | 16.51[bc] | 17.25[cd] | 47.22[ab] | 24.20[bcd] | 2.41[b] |
| 1.5% LA / 0.5% NaCl | 48.52[bcd] | 14.06[cd] | 15.55[de] | 49.40[a] | 20.94[de] | 1.91[cd] |
| 2.0% LA / 0.5% NaCl | 46.46[d] | 12.15[de] | 13.97[ef] | 49.97[a] | 18.88[ef] | 1.74[cd] |
| SEM | 1.58 | 1.38 | 0.88 | 1.21 | 1.59 | 0.26 |

[1] L* values are a measure of darkness to lightness (larger value indicates a lighter color); a* values are a measure of redness (larger value indicates a redder color); and b* values are a measure of yellowness (larger value indicates a more yellow color).
[2] Hue angle represents the change from the true red axis (larger number indicates a greater shift from red to yellow).
[3] Chroma is a measure of total color (larger number indicates a more vivid color).
[4] 630:580nm represents a change in color from red to brown of cooked meat samples.
[a, b, c, d, e, f] Within a column, least squares means lacking a common superscript are different ($P < 0.05$).

**Table 3. Effects of lactic acid (LA) enhancement, with or without salt (NaCl), on cooked color sensory characteristics and myoglobin (Mb) quantification of dark-cutting beef steaks.**

| | Trait | | | | | |
|---|---|---|---|---|---|---|
| Treatment | Internal doneness[1] | Cooked color[2] | Surface discoloration[3] | RMb[4] | CMb[5] | PDMb[6] |
| NDC untreated | 3.93[d] | 4.05[d] | -0.07[abc] | 3.91[a] | 1.71[b] | 60.14[abcd] |
| DC untreated | 2.95[e] | 2.86[e] | -0.03[abc] | 4.09[a] | 2.36[a] | 37.15[e] |
| 0.5% LA | 4.28[c] | 4.56[c] | 0.25[a] | 3.64[ab] | 1.77[b] | 54.57[d] |
| 1.0% LA | 4.36[c] | 4.54[c] | 0.09[abc] | 3.24[cd] | 1.09[cd] | 63.08[abcd] |
| 1.5% LA | 5.12[ab] | 5.75[ab] | -1.51[e] | 2.89[cd] | 1.08[cd] | 58.36[bcd] |
| 2.0% LA | 5.43[a] | 6.09[a] | -0.95[d] | 2.24[f] | 0.68[d] | 71.45[ab] |
| 0.5% LA / 0.5% NaCl | 3.91[d] | 3.89[d] | 0.12[abc] | 3.71[ab] | 1.54[bc] | 57.26[cd] |
| 1.0% LA / 0.5% NaCl | 4.51[c] | 4.67[c] | -0.12[abc] | 3.26[bc] | 1.00[d] | 70.00[abc] |
| 1.5% LA / 0.5% NaCl | 4.41[c] | 4.65[c] | -0.28[bc] | 2.78[de] | 0.94[d] | 62.49[abcd] |
| 2.0% LA / 0.5% NaCl | 5.07[b] | 5.68[b] | -0.31[c] | 2.71[e] | 0.71[d] | 72.79[a] |
| SEM | 0.22 | 0.24 | 0.29 | 0.19 | 0.17 | 5.41 |

[1] 1 = dark red (very rare appearance); 2 = red (rare appearance); 3 = pink center (medium rare appearance); 4 = slightly pink center (medium appearance); 5 = tan/brown center (well done appearance); 6 = dry, brown center (very well done appearance).
[2] 1 = very red; 2 = medium red; 3 = pink; 4 = slightly pink; 5 = pinkish-gray; 6 = gray brown; 7 = brown.
[3] 1 = very slightly lighter; 0 = not different from control; -1= very slightly darker; -2 = slightly darker; -3 = moderately darker.
[4] RMb = total extractable myoglobin of fresh/raw steaks.
[5] CMb = total extractable myoglobin of cooked steaks.
[6] PDMb = percentage of myoglobin denatured during cooking.
[a, b, c, d, e, f] Within a column, least squares means lacking a common superscript are different ($P < 0.05$).