

Validation of Antimicrobial Interventions for Reducing *E. coli* Population (Surrogate for Shiga Toxin-Producing *Escherichia coli*; STEC) During Goat Slaughter and Carcass Chilling

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Introduction

- Population growth of ethnic cultures that readily consume goat meat has led to an increase in demand and consumption in the United States.
- Small ruminant animals such as goats are known reservoirs for Shiga toxin-producing *Escherichia coli* (STEC).
- As goat meat demand increases, it is critical to ensure pathogen reduction strategies for STEC are effective during the slaughter and chilling processes.

Objective

- The objectives of this research were to evaluate various antimicrobial interventions for their ability to reduce STEC surrogates and their effects on carcass color from slaughter through chilling.
- These antimicrobials included:
 - 4.5% lactic acid (LA)
 - 400 ppm peroxyacetic acid (PAA; pH 4.6)
 - CitrilowTM (a proprietary blend of hydrochloric and citric acid; CL; pH 1.2)
 - 5% levulinic acid plus 0.5% sodium dodecyl sulfate (LVA+SDS)
 - A non-treated control (CON)

Materials and Methods

- A total of 15 goat carcasses (28±6 kg) across three replications were inoculated with a 5-strain cocktail (ca. 8 log CFU/ml) containing rifampicin-resistant *Escherichia coli* (*E. coli*; BAA-1427, BAA-1428, BAA-1429, BAA-1430, and BAA-1431), surrogates for STEC.



Results

- Mean log reductions ($P < 0.05$) achieved after prerigor treatment with CL, LA, LVA+SDS, and PAA were 2.27, 2.00, 1.9, and 1.87 log CFU/cm², respectively.
- Antimicrobial treatment after the 24 h chilling period resulted in subsequent reductions ($P < 0.05$) of surrogate *E. coli* by 1.89, 1.17, 1.03, and 0.47 log CFU/cm² for CL, LA, PAA, and LVA+SDS, respectively.
- Antimicrobial treatments did not have a large impact on goat carcass objective color.

Conclusions

- The antimicrobials tested in this study were effective at reducing *E. coli* populations on goat carcasses during pre- and post-chill applications without compromising carcass color.

Acknowledgement

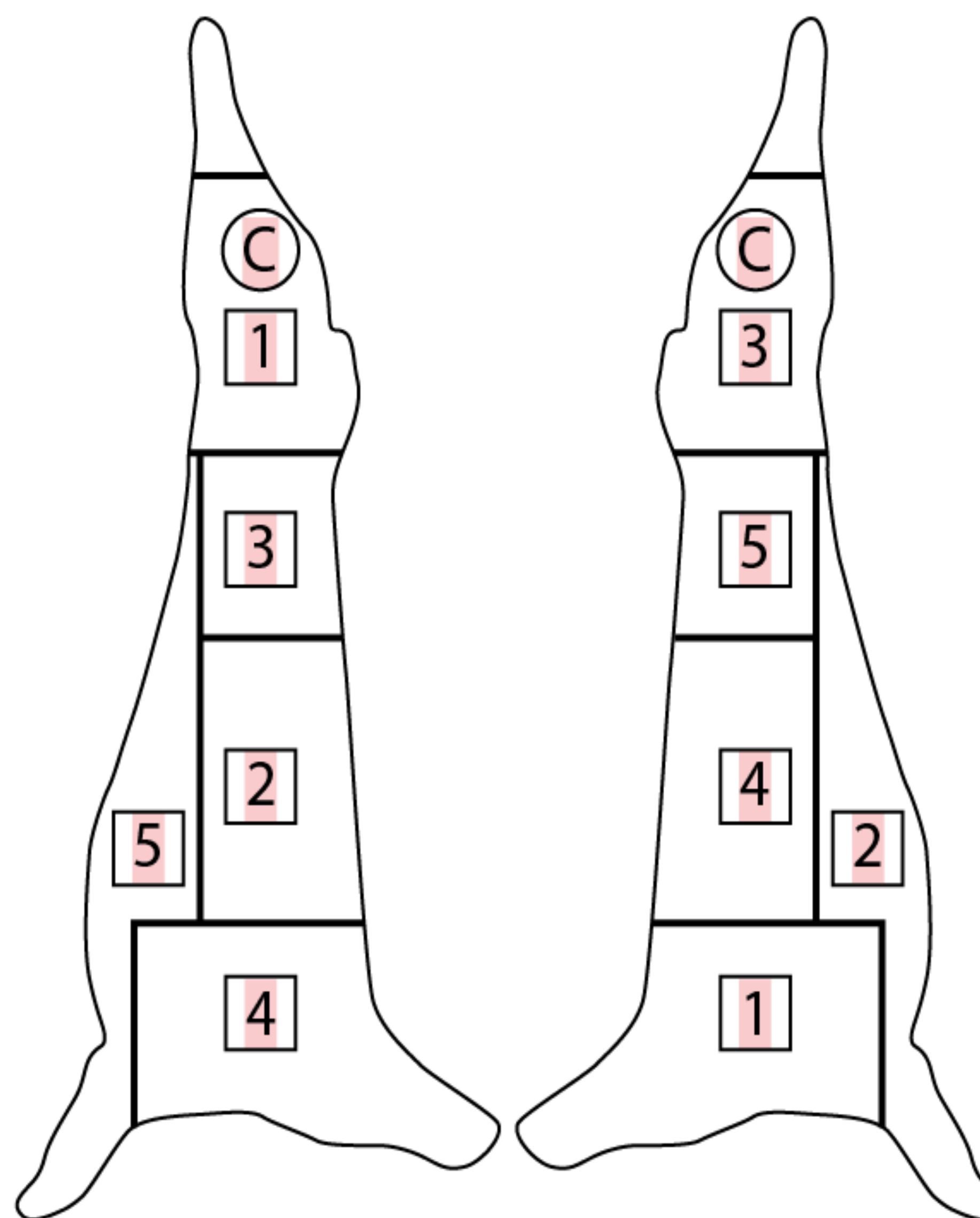
The authors would like to thank the University of Georgia-Meat Science and Technology Center and Dr. Thippareddi's laboratory for technical support. Mention of trade names or commercial products is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the academic institutions.



Materials and Methods

Microbial Sampling

- The exterior of each carcass was evenly inoculated to achieve 6 log CFU/cm².
- After inoculation, the carcasses were held on the slaughter line for 30 min (25° C) for attachment prior to antimicrobial treatment application.
- Antimicrobial treatments were randomly assigned to each carcass and applied pre-rigor and 24 h post chill.
- Each carcass was sampled at five different points during processing
 - After inoculation with a 30-min attachment period
 - After the standard water wash (55° C)
 - 5 min after the pre-chill carcass antimicrobial spray application
 - Post-24 h chilling
 - 5 min after the 24 h post-chill carcass antimicrobial spray application.
- One of five anatomical carcass locations was randomly assigned for sample collection on each sides of the carcass at each time point and then combined for analysis.



Objective Color Measurements

- Objective carcass color was measured below the hipbone on a surface that was not sampled for microbial analysis, at five different processing points:
 - Pre-treatment (immediately prior to application of inoculum)
 - After pre-chill antimicrobial spray treatment
 - Post-1 h chill
 - Post-24 h chill,
 - After the post-24 h chill antimicrobial spray application.

Statistical Analysis

- E. coli* population (log CFU/cm²) and color values were analyzed using PROC GLM (SAS V.9.4).
- E. coli* population and color values were analyzed for the main effects of antimicrobial treatment, sampling time point, and their interaction.
- Least squares means were generated and separated using the PDIF option.
- Means were considered different at $\alpha \leq 0.05$.



Results

Table 1. Least squares means and standard deviation of rifampicin resistant surrogate *E. coli* (log CFU/cm²) found on goat carcasses treated with antimicrobial interventions^a

Treatment ^b	Inoculation	Water wash ^c	Prechill treatment	24-h chill	Post-chill treatment
CON ^d	5.75 ± 0.35 ^{AX}	5.13 ± 0.31 ^{ABX}	5.13 ± 0.31 ^{ABX}	4.55 ± 0.36 ^{BX}	4.55 ± 0.36 ^{BX}
LVA+SDS	5.57 ± 0.27 ^{AX}	5.09 ± 0.31 ^{AX}	3.19 ± 0.72 ^{BY}	2.31 ± 0.52 ^{CY}	1.84 ± 0.42 ^{CY}
LA	5.74 ± 0.32 ^{AX}	5.33 ± 0.36 ^{AX}	3.33 ± 0.36 ^{BY}	1.40 ± 1.45 ^{CY}	0.23 ± 0.40 ^{DZ}
PAA	5.56 ± 0.17 ^{AX}	4.82 ± 0.20 ^{AX}	2.97 ± 0.40 ^{BCY}	3.44 ± 0.76 ^{BZ}	2.41 ± 0.70 ^{CY}
CL	5.74 ± 0.14 ^{AX}	5.25 ± 0.42 ^{AX}	2.98 ± 0.97 ^{BY}	3.73 ± 0.85 ^{BXZ}	1.84 ± 0.63 ^{CY}

^aA, B, and C, indicates means within treatments (within rows) that do not share a common letter are statistically different ($P \leq 0.05$); X, Y and Z, indicates means within sampling point (within column) that do not share a common letter are statistically different ($P \leq 0.05$).

^bTreatment groups: control = no antimicrobial application; 5.0 % levulinic acid plus 0.5% sodium dodecyl sulfate (LVA+SDS; pH 2.6); 4.5% lactic acid (LA; pH 2.0); peragonn (PAA; 400 ppm); and citrilow (CL; pH 1.2).

^cWater wash (55°C for 1 min) was applied using a handheld hose with spray nozzle.

^dThe control carcass did not receive any antimicrobial spray treatment; therefore, least squares means of surrogate recoveries were reported to be the same as the previous sampling point for the prechill and postchill antimicrobial sampling points.



Results

Table 2. Least squares means and standard deviation for objective color main effects by treatment of goat carcasses subjected to antimicrobial interventions^a

Variable ^b	CON	LVA+SDS	LA	PAA	CL
L*	48.59 ± 6.03	51.4 ± 6.47	49.27 ± 6.03	48.94 ± 6.63	49.38 ± 7.43
a*	14.77 ± 2.14	13.68 ± 4.07	13.38 ± 3.05	14.18 ± 3.48	11.96 ± 3.10
b*	8.25 ± 2.55 ^A	6.46 ± 3.54 ^{BC}	7.4 ± 3.12 ^{AB}	7.14 ± 2.31 ^{ABC}	5.57 ± 3.35 ^C
Hue	28.51 ± 4.86	23.88 ± 8.31	27.97 ± 7.14	26.71 ± 5.73	23.04 ± 9.09
Chroma	16.97 ± 3.00	15.26 ± 4.96	15.38 ± 3.98	15.94 ± 3.90	13.33 ± 4.11
Delta E	6.35 ± 3.76	7.18 ± 4.43	6.72 ± 6.44	6.49 ± 6.57	7.6 ± 7.46

^aAll carcasses were subjected to a standard water wash (55°C for 1 min) followed by one of four spray treatments: 5.0 % levulinic acid plus 0.5% sodium dodecyl sulfate (LVA+SDS; pH 2.6); 4.5% lactic acid (LA; pH 2.0); peragonn (PAA; 400 ppm); and citrilow (CL; pH 1.2).
^bL* = 0 = black to 100 = white; a* = measurement of green to red on color spectrum, high values indicate more red; b* = measurement of yellow to blue on color spectrum, higher values indicate more yellow; Hue = lower values indicate redder color; Chroma = higher value indicates more red saturation. Delta= ΔE accounts for the combined changes in L*, a*, and b* values over time.
^{ABC} Least squares means within row with different superscripts are different (P ≤ 0.05).

Table 3. Least squares means and standard deviation for objective color main effects by sample time of goat carcasses subjected to antimicrobial interventions^a

Variable ^b	Pretreatment	Pre-chill treatment	Post 1-h chill	Post 24-h chill	Post-chill treatment
L*	53.33 ± 2.86 ^{AB}	55.47 ± 4.06 ^A	51.47 ± 5.62 ^B	43.53 ± 4.13 ^C	43.77 ± 3.74 ^C
a*	12.42 ± 1.88 ^A	10.30 ± 1.92 ^B	12.45 ± 2.80 ^A	16.11 ± 2.45 ^C	16.67 ± 2.16 ^C
b*	4.91 ± 1.66 ^A	4.04 ± 1.81 ^A	6.46 ± 2.08 ^B	9.61 ± 2.30 ^C	9.8 ± 2.00 ^C
Hue	21.11 ± 6.59 ^A	20.65 ± 7.32 ^A	27.35 ± 6.43 ^B	30.77 ± 5.64 ^B	30.22 ± 3.57 ^B
Chroma	13.42 ± 2.11 ^A	11.14 ± 2.27 ^B	14.10 ± 3.14 ^A	18.84 ± 2.77 ^C	19.37 ± 2.62 ^C
Delta E	0.00 ± 0.00 ^A	4.87 ± 4.92 ^B	5.81 ± 4.47 ^B	11.81 ± 4.31 ^C	12.83 ± 2.39 ^C

^aAll carcasses were subjected to a standard water wash (~55°C for 1 min) followed by one of four spray treatments: 5.0 % levulinic acid plus 0.5% sodium dodecyl sulfate (LVA+SDS; pH 2.6); 4.5% lactic acid (LA; pH 2.0); peragonn (PAA; 400 ppm); and citrilow (CL; pH 1.2).
^bL* = 0 = black to 100 = white; a* = measurement of green to red on color spectrum, high values indicate more red; b* = measurement of yellow to blue on color spectrum, higher values indicate more yellow; Hue = lower values indicate redder color; Chroma = higher value indicates more red saturation. Delta= ΔE accounts for the combined changes in L*, a*, and b* values over time.
^{ABC} Least squares means within row with different superscripts are different (P ≤ 0.05).