Meat and Muscle Biology™

Abstracts from the 2022 AMSA Reciprocal Meat Conference

Meat and Muscle Biology 8(2): 1–118 (2023) **doi:10.22175/mmb.16912**
Submitted 16 August 2023 Accepted 18 August 2023

Animal Welfare

1 ANIMAL WELFARE AS A QUALITY CRITERION IN SOUTH KOREA

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Objectives: Calls for more animal welfare in meat production are becoming louder. However, a transformation of animal husbandry systems results in higher production costs and meat prices. The objective of this explorative study is to assess the meat quality perception of South Korean pork supply chain stakeholders with a special focus on animal welfare as an important export market for German, European, and United States producers.

Materials and Methods: Guideline-based expert interviews are widely used in explorative qualitative research. Fifteen face-to-face interviews were conducted between August and September 2022 in order to assess the perception of South Korean pork supply chain stakeholders regarding meat quality and animal welfare. The interviews were held in English. Fellow Korean researchers assisted as translators; they also reviewed the comprehensibility of each question in terms of content and language prior to the survey. A nonprobability quota sampling was used. A minimum of 3 interview partners was ensured for each market segment: industry, associations, and research institutions. All interviews were conducted by 2 interviewers, who prepared memory protocols. A qualitative content analysis was applied to evaluate the text material. Considering the questionnaires' focus and the text material obtained, a mixed inductive-deductive category system was developed using MaxQDA to analyze the data.

Results: Based on the text material, 4 main categories (i.e., "meat market trends, animal welfare, marketing and quality aspects, further market developments") and 22 subcategories were identified. According to the interviewed experts, visual and nonvisual criteria are relevant to evaluate meat quality in South Korea, whereby different benchmarks apply to fresh and frozen meat. Smell is generally perceived as a meat quality criterion in addition to taste and color. With regard to imported frozen meat, import companies look for marbling and fat layer structure, especially with regard to pork bellies. In this context, slaughter weight is perceived as a selection criterion. Bellies from pigs with 110 to 130 kg life weight are favored. The interviewed experts indicated that meat prices still determine purchasing decisions of import companies operating within the scope of global competition. Animal welfare was not mentioned in connection with meat quality. The overall knowledge on and importance of increased animal welfare standards was considered to be low. The experts emphasized that animal welfare is often not looked at from an ethical perspective. Instead, consumers associate benefits for their own health with meat produced under higher animal welfare standards.

Conclusion: South Korean pork supply chain stakeholders do not perceive animal welfare as a meat quality indicator or unique selling point. Therefore, target-oriented marketing strategies need to promote additional product benefits. Future marketing campaigns should focus on self-oriented purchasing motives such as taste or health benefits in order to address South Korean consumers.

Funding Source: Funding was provided by LSTME Busan, afz, and FLEISCHWIRTSCHAFT, as well as the H. Wilhelm Schaumann Stiftung.

Keywords: animal welfare, meat quality, South Korea

2 BENCHMARKING CURRENT PRESLAUGHTER PRACTICES, WELFARE INDICATORS, AND MEAT QUALITY OUTCOMES AT COMMERCIAL-FED CATTLE PROCESSING FACILITIES IN THE UNITED STATES

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Objectives: A considerable body of research exists on the impacts of preslaughter management practices on cattle welfare and meat quality. However, certain critical factors such as distances traveled to the plant, truck wait times at the plant, lairage pen densities, and time spent in lairage on a large scale are underrepresented in current literature. Obtaining a baseline of key factors that are known to impact welfare and meat quality outcomes at a national scale will allow tracking of industry performance and identify areas for improvement. Therefore, the objective of the current study was to benchmark preslaughter management practices for a nationwide sample of commercial-fed cattle processing facilities.

Materials and Methods: Five commercial processing facilities in the West and Southwest regions of the United States were sampled multiple times over all 4 seasons from March 2021 to July 2022. Data were collected on a total of $n = 637$ slaughter lots representing 82,469 head of cattle. Variables of interest included general cattle characteristics, distance traveled to the plant, truck wait times to unload at the plant, environmental conditions, lairage pen density, and time in lairage. Cattle mobility and carcass bruising were scored by trained individuals for all slaughter lots. Lairage pens, depending on the plant, typically fit anywhere from 1 to 6 trucks per pen, and the average number of truckloads per lot was 4.0 ± 2.6 (mean ± SD). Mobility was scored using a 4-point locomotion scale (1 being normal with no apparent lameness to 4 being extremely reluctant to move). Carcasses were scored as either having no bruises, having a bruise less than or equal to the size of a deck of cards, having a bruise larger than a deck of cards, and having multiple bruises. Descriptive statistics were performed on the data at the lot level.

Results: Approximately 89% of cattle slaughter lots were of *Bos taurus* influence, and the remaining 11% were either cattle with Brahman influence or fed Holsteins. Approximately two thirds (65.8%) of the lots consisted of 50% or greater black-hided cattle. A majority of the population consisted of steer lots (56.4%); however, heifer lots were also common (31.9%), followed by lots of mixed sex (11.7%). On average, cattle traveled 155.8 ± 209.6 km from the feedlot to the processing facility and waited 30.3 ± 39.7 min to unload after arrival at the facility. Once in lairage pens, cattle were held 200.7 ± 195.0 min before being moved for slaughter. The mean lairage stocking density was 3.1 ± 2.0 m^2 per head. A large portion of the cattle scored a mobility score of 1 (91.8%), 7.9% were scored as a 2, and 0.3% and 0.002% of cattle were scored as either a 3 or 4, respectively. Carcass bruising was frequent and varied in severity. Carcasses with bruises less than or equal to the size of a deck of cards (27.1%) were less frequent than bruises measuring greater than the size of a deck of cards (42.6%). Of carcasses that were bruised, 65.2% had multiple bruises of varying severity.

Conclusion: This baseline data on preslaughter management practices identifies opportunities for improvement in wait times and factors that cause bruising and stimulates sharing of best practices. Future studies from this data set will explore the relationships between these factors and their impacts on cattle welfare and meat quality, report the economic value of these welfare outcomes, and explore industry acceptability and adoptability of optimal welfare practices.

Funding Source: This project was supported by Agriculture & Food Research Initiative Competitive Grant no. 2019-67015-29578 from the USDA National Institute of Food and Agriculture.

Keywords: bruising, cattle, mobility, preslaughter, welfare

3 BENCHMARKING LIVE ANIMAL AND CARCASS QUALITY OUTCOMES AT SLAUGHTER TO IDENTIFY FACTORS IMPACTING BISON CARCASS VALUE

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Objectives: There are currently limited quantitative data on live animal and carcass attributes that are important to ultimate bison product quality and value. Thus, the objective of this study was to benchmark live animal and carcass quality outcomes related to animal well-being and carcass value of bison at slaughter and to identify factors that impact carcass value.

Materials and Methods: This study included 2,280 bison (72 lots) from 3 different plants in the United States. Distance traveled, season, visual mobility score, live weight, electric prod use by lot, mud coverage score, grunting, and number of head bumps in the shoot were recorded prior to slaughter. Post-slaughter measurements included visual bruise scoring, ribeye area, loin fat depth, blood splash, and instrumental color. Descriptive statistics and linear regression were done using JMP software.

Results: Average distance traveled to the slaughter plant was 822 ± 556 km (mean ± SD). Bison were categorized by sex class, bull (1,098), cow (198), and heifer (984), and average live weights differed ($P < 0.0001$) between sex class. Ninety-one percent of animals had less than 33% of mud on their hide. An observer recorded bruise size using a 5-point scale (0 being no bruising to 4 having a bruise longer than 30.48 cm). Forty-seven (2%) animals had no bruising and 2,233 (98%) animals had at least one bruise with a size between 0 and 7.62 cm. The average bison dressing percentage was 60.51% ± 0.07%. Instrumental color, ribeye area, and loin fat thickness were measured on all carcasses between the 12th and 13th rib after 1 h of bloom time.

Lightness (L^*) and redness (a^*) values were higher ($P < 0.0001$) on heifers compared with bulls and cows. Ribeye area (cm^2) was greater ($P < 0.0001$) for bulls (66.1 ± 0.04) followed by cows (60.56 ± 0.65) and heifers (59.0 ± 0.29). Loin fat thickness (cm) was greater ($P < 0.0001$) for heifers and cows (1.97 ± 0.02, 1.84 ± 0.05) compared with bulls (0.88 ± 0.02). Blood splash percentages were 5.27% for bulls and 4.17% for heifers but were not observed in cows. Linear regression models indicated that sex class, live weight, distance traveled, number of head bumps in chute, and loin fat thickness have varying effects on a^* (redness; $P < 0.05$). Additionally, dressing percentage was influenced ($P < 0.05$) by ribeye area, fat thickness, sex class, and bruising score. Electric prod use rate at the slaughter plant was higher ($P < 0.05$) during the fall and lower ($P < 0.05$) during the summer and the winter season(s).

Conclusion: Overall, these results indicated that multiple live animal factors can affect the quality and value of bison carcasses. Furthermore, these results can serve as a useful tool for the bison meat industry to evaluate its condition, based on quality parameters and monitor their production allowing for continuous improvement.

Funding Source: This project was made possible through the Center of Excellence for Bison Studies, a partnership among South Dakota State University, the National Bison Association, and the National Buffalo Foundation. Financial support was provided by the National Buffalo Foundation.

Keywords: benchmark, bison, meat quality, welfare

Consumer Topics

4 THE EFFECTS OF THAWING METHOD ON CONSUMER PALATABILITY RATINGS OF BEEF STRIP LOIN STEAKS

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Objectives: Freezing is widely used as a beef preservation method for consumers to extend shelf life. Thus, thawing is necessary in many cases before final product use; however, the impact of different thawing methods on beef palatability is unknown. Therefore, the objective of this study was to determine the palatability differences of steaks utilizing varying thaw methods as determined by consumers.

Materials and Methods: This study utilized paired Low Choice strip loins ($n = 15$ pairs) collected from a Midwest processing facility and transported to the Kansas State University meat lab. Each pair of loins was blocked into 6 sections, from which four 2.5-cm steaks were cut. The steaks were all aged for 21 d and then frozen at −20°C. Each of the 6 sections was assigned a thawing treatment. Of the 6 thaw methods, 4 were the USDA-approved thawing methods: thaw in refrigerator (REF), thaw in cold water (CW), thawing during cooking (COOK), and thaw in microwave (MIC). The 2 additional thaw methods are methods commonly used by consumers: thaw on counter (CT) and thaw in hot water (HW). Steaks assigned REF were thawed in 2°C to 3°C for 24 h. Steaks assigned CW were placed in 2°C to 3°C water for 24 h. Steaks assigned COOK were cooked directly from the frozen state. Steaks assigned MIC were microwaved for 3.5 min at 50% power, rotated, and microwaved again using the same settings. Steaks assigned CT were placed on trays at 17°C to 20°C for 5 h or until the internal temperature reached 0°C. Steaks assigned HW were placed in 40°C water for 20 min (±2 min). Steaks were thawed according to their designated thaw methods and cooked to an internal peak temperature of 71°C monitored throughout the cooking process. Steaks were then cut into 1-cm × 1-cm cubes and served to consumers. Consumers ($n = 120$) evaluated each sample for juiciness, tenderness, flavor liking, and overall liking on 100-point line scales. Each scale had anchors at 0 and 100, indicating extremely dry/tough/dislike extremely OR extremely juicy/tender/like extremely, respectively. Consumers also determined the acceptability (yes/no) of each trait. Consumers also rated each sample as premium quality, better than everyday quality, everyday quality, or unsatisfactory quality. Data were analyzed as a completely randomized design.

Results: There were no observable differences ($P > 0.05$) among thaw methods for consumers' rating of juiciness, tenderness, flavor liking, or overall liking. However, consumers scored all thaw methods at 57 or greater for overall liking, indicating that all steaks were liked. Similarly, there were no differences ($P > 0.05$) among thaw methods for the percentage of steaks rated acceptable by consumers for juiciness, tenderness, flavor, or overall liking. Consumers rated 82% or greater of steaks as acceptable for overall acceptability for all thaw methods. There were no differences ($P > 0.05$) among thaw methods for the percentage of steaks rated as premium quality, better than everyday quality, everyday quality, or unsatisfactory quality. Lastly, consumers rated the majority of steaks (66%) from every thaw method as everyday quality or better than everyday quality.

Conclusion: Thaw method had no effect on the palatability ratings or consumer acceptability ratings of steaks. Therefore, consumers should utilize the thaw method that is the most convenient while choosing from the approved USDA methods to ensure food safety.

Funding Source: Funded by the Beef Checkoff

Keywords: beef, consumers, freezing, palatability, thawing

5 EVALUATION OF FRESH AND FROZEN BEEF STRIP LOINS OF EQUAL AGING PERIODS FOR PALATABILITY TRAITS AND PHYSIOCHEMICAL PROPERTIES

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Objectives: Although freezing studies are prevalent, most have focused on comparing freezing parameters or storage times instead of keeping the aging period constant. The lack of a comprehensive study evaluating equally aged fresh and frozen steaks prevents a true understanding of the impact of freezing. Therefore, the objectives of this study were to determine the eating quality and consumer perception differences between fresh and frozen beef steaks of 3 equal aging periods and to evaluate the physiochemical properties of fresh versus frozen beef.

Materials and Methods: Beef carcasses ($N = 72$; $n = 18$/collection; 6/aging period; A-maturity; USDA Choice) were selected from a beef processing plant on 2 different kill dates, 1 wk apart and brought to Kansas State University. Steaks were fabricated into 2.54-cm steaks, randomly assigned an aging period and one of the following designations: consumer panels, shear force, or lab assays. All steaks were aged for either 21, 28, or 35 d. The frozen steaks were frozen for 1 wk at −20°C. On the same day, all samples of equal aging periods were fed to consumer panelists, sheared for shear force, and powdered for lab assays. Sensory panels were conducted by cooking samples to an internal peak temperature of 71°C monitored with a Thermapen. Consumer sensory panelists were asked to evaluate samples for juiciness, tenderness, flavor liking, and overall liking measured on a 100-point line scale anchored at 0 and 100, indicating extremely dry/tough/dislike or extremely juicy/tender/like extremely, respectively. Consumers were also asked to determine the acceptability for each palatability trait. The first 4 steaks were given with no additional information, whereas the last 4 steaks were served with the labels "previously frozen" or "fresh, never frozen." Shear force was determined using Warner-Bratzler shear force (WBSF) and slice shear force (SSF). Internal color, cook loss, and purge loss were measured. To understand the physiochemical properties, one steak from each treatment was powdered to determine surface hydrophobicity and protein aggregation, lipid oxidation, and metmyoglobin-reducing activity (MRA).

Results: The consumer sensory panelists rated the frozen samples as more tender ($P < 0.05$) than the fresh samples but found no other differences ($P > 0.05$) for palatability traits or acceptability ratings. Even when given additional labeling information, the perception of quality was not impacted ($P > 0.05$). Supporting the sensory data, the frozen steaks were found to have lower ($P < 0.05$) shear force values regardless of the aging period. However, the fresh samples resulted in lower ($P < 0.05$) purge and cook loss. Lastly, the frozen samples resulted in lower ($P < 0.05$) L^* values and higher ($P < 0.05$) MRA, whereas there were no differences ($P > 0.05$) in lipid oxidation or surface hydrophobicity between the fresh and frozen samples.

Conclusion: Although some meat quality factors were impacted by freezing, the overall eating quality and perception of quality were not negatively impacted. Therefore, frozen meat should not be discounted because of the eating quality or perception of the quality of beef steaks. This study can provide guidance for the industry to make supported decisions on cold-chain management strategies.

Funding Source: Funded by the Beef Checkoff

Keywords: beef, consumer, fresh, frozen, sensory

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6 EFFECT OF GARLIC-CITRUS CATTLE FEED SUPPLEMENTATION UPON CONSUMER SENSORY EVALUATION, DESCRIPTIVE TRAINED SENSORY EVALUATION, AND VOLATILE ANALYSES OF BEEF STEAKS AND PATTIES

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Objectives: A garlic-citrus extract (GCE) supplement has shown reduction of enteric methane emissions in ruminants. Limited information exists regarding the effect of feeding GCE on beef palatability. The objective of this study was to evaluate the effect of finishing cattle with a GCE supplement on palatability and volatile compounds of beef steaks and patties.

Materials and Methods: Cattle ($n = 19$) were fed 0 or 27 g/d supplement (Control [CON], GCE) for 9 or 12 mo. From each animal, strip loins (IMPS #180) were cut into steaks, and clods (IMPS #114) and outside rounds (IMPS #171B) were ground and mixed to generate patty samples (mean: 11.98% fat). Consumers ($n = 100$) evaluated steaks and patties for palatability traits (juiciness, tenderness, flavor, overall liking), acceptability, and eating quality (unsatisfactory, everyday quality, better than everyday quality, premium quality). Trained panelists evaluated each sample for tenderness, juiciness, beef flavor identity, bitter, browned, buttery, fat-like, liver-like, metallic, oxidized, roasted, sour, and umami attributes using an unstructured 100-point line scale. Upon detecting garlic odor/flavor, trained panelists defined an additional garlic intensity rating (0 = not present; 100 = roasted garlic). Volatiles (alcohols, aldehydes, carboxylic

acids, ketones, sulfur-containing compounds) were quantified. Data were analyzed via mixed models; fixed effects were diet and feeding duration, and random effects were animal and panel. Treatment comparisons were tested using $\alpha = 0.05$.

Results: No interactions occurred between diet and duration fed for sensory or volatile analysis ($P > 0.05$). Consumers rated palatability traits ($P > 0.17$) and trait acceptability ($P > 0.28$) of patties and steaks similar for CON and GCE. Trained panelists detected greater ($P < 0.04$) garlic intensity for both steaks and patties from cattle fed GCE. Steaks supplemented with GCE were rated greater ($P < 0.01$) for umami and CON patties greater ($P = 0.02$) for browned flavor. Steaks from cattle fed for 9 mo were rated greater ($P < 0.01$) than 12 mo for umami and lower ($P = 0.04$) for oxidized. Patties from cattle fed GCE had greater ($P = 0.03$) ethanol and decanal levels and tended ($P = 0.10$) to have more methanethiol and dimethyl sulfide than CON patties. In contrast, GCE steaks had lower ($P = 0.04$) ethanol levels. No other differences ($P \geq 0.06$) existed in trained panel or volatile analysis across diet or months fed. Consumers rated patties from cattle fed for 12 mo greater ($P = 0.04$) for flavor and tended ($P = 0.08$) to rate patties greater in overall liking than patties from cattle fed for 9 mo. However, the percentage of steaks rated acceptable by consumers for overall liking was greater ($P = 0.03$) for cattle fed for 9 mo versus 12 mo. The percentage of steaks deemed unsatisfactory was greater ($P = 0.05$) for cattle fed for 12 mo. All other quality level ratings were similar ($P \geq 0.08$).

Conclusion: Results indicate cattle finished with GCE supplementation produce similar palatability of steaks and patties when compared with a CON diet, though the prevalence of garlic flavor confirmed initial olfactory detection by trained panelists in beef from GCE-fed cattle. This indicates minimal impact on beef sensory attributes when supplementing finishing cattle diets with a GCE supplement.

Keywords: flavor, palatability

7 CORRELATION BETWEEN CARCASS TRAITS AND CONSUMER PERCEPTION OF PORK EATING QUALITY

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Objectives: There is a growing interest in the pig industry to develop better carcass segregation practices that enhance pork eating quality. However, most studies in the past have assessed the influence of carcass traits on pork eating quality using trained taste panels that may not accurately represent consumer preferences. Instead, use of an untrained consumer panel may be more valuable for providing more accurate information on pork eating quality that can be used for decision-making within the pig industry. As such, the objective of this study was to perform a consumer panel aiming to evaluate the effects of carcass traits on pork eating quality evaluated by consumers.

Materials and Methods: A total of 1,360 pork chops, 824 from ham, and 536 from butt loin positions were sorted based on sex and loin intramuscular fat (IMF) content to produce 340 packages containing 4 pork chops. The loin IMF was determined through ether extraction of fat. The packages were distributed to untrained participants, with each panelist receiving one package of chops that contained 2 chops from barrows and 2 chops from gilts. Participants were able to evaluate pork eating quality for the 4 chops by answering a survey regarding cooking method used and how each pork chop rated in terms of tenderness, juiciness, flavor, and overall acceptability using an 8-point categorical intensity scale (1 = dislike and 8 = like). Carcass and meat quality trait information including hot carcass weight (HCW), backfat thickness (BF thickness), predicted lean yield (PLY), IMF content, Warner-Bratzler shear force (WBSF), and cooking loss data were available for each pig ($n = 288$) used to produce the pork chops. Carcass data and pork eating quality traits were subjected to correlation analysis. Probability values lower than 0.05 were considered significant.

Results: From the total of 340 packages distributed, 182 participants responded to the survey regarding pork eating quality (53.5% response rate), totaling 728 observations. The data revealed that the overall acceptability of pork chops (ham and butt) was strongly correlated ($P < 0.05$) with tenderness ($r = 0.710$) and juiciness ($r = 0.691$) and moderately correlated ($P < 0.05$) with flavor ($r = 0.461$) (Fig. 1). Although trained taste panel studies in the past have reported positive correlations between loin IMF content and pork sensory properties regardless of the loin position cut, there were no significant correlations ($P > 0.05$) between loin IMF content and pork eating quality traits (tenderness, juiciness, flavor, and overall acceptability). Overall, although weak to moderate correlations were observed ($P < 0.05$) between carcass traits and loin IMF content [HCW ($r = 0.133$), BF thickness ($r = 0.407$), and PLY ($r = -0.384$)], there were no significant correlations observed ($P > 0.05$) between carcass traits and pork eating quality. Cooking loss and WBSF were negatively correlated ($P < 0.05$) with tenderness and overall acceptability in butt and ham, respectively. Despite the lack of correlations between loin IMF and pork eating quality traits, loin IMF content was negatively correlated ($P < 0.05$) with WBSF and cooking loss.

Conclusion: Despite the significant negative correlations observed between loin IMF and instrumental analysis (WBSF and cooking loss), there were no significant

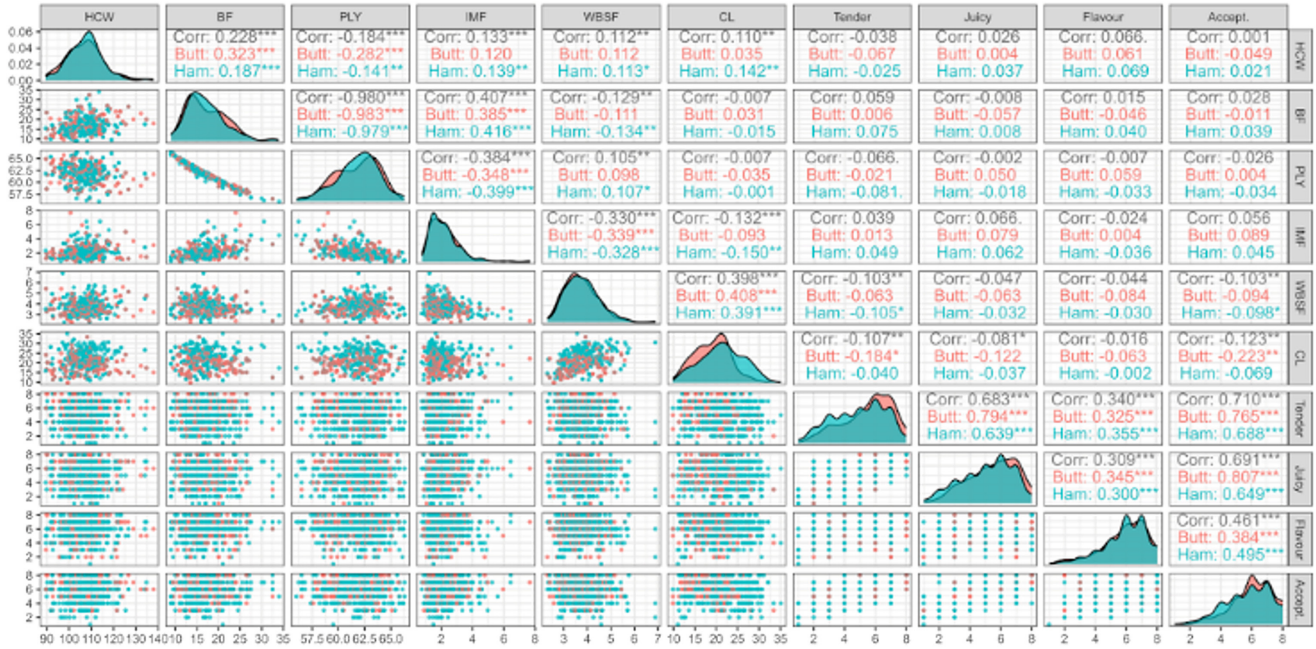

Figure 1. Correlation coefficients between carcass traits, cooking loss, shear force and pork eating quality traits. Abbreviations: HCW = hot carcass weight (kg); BF = backfat thickness (mm); PLY = predicted lean yield (%); IMF = loin intramuscular fat (%); WBSF = Warner-Bratzler shear force; CL = cooking loss (%); Tender = tenderness; Juicy = juiciness; and Accept = overall acceptability. ***P<0.001; **P<0.01; and *P<0.05.

correlations between overall acceptability and the carcass traits evaluated. These results suggests that carcass traits may not impact the overall acceptability of pork by consumers.

Funding Source: Ontario Pork (Project #OPPMB 18-003) and Swine Innovation Porc (Project #1787).

Keywords: final consumer, meat quality, overall acceptability, pig industry

8 USE OF PRINCIPAL COMPONENT ANALYSIS (PCA) TO VISUALIZE A TRAINED PANEL STRIP LOIN EVALUATION DATA

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Objectives: Traditional ANOVA is effective for determining differences in tenderness, juiciness, and flavor. On the other hand, principal component analysis (PCA) allows for summarizing the information contained in large data sets by the calculation of principal components that account for the larger variability (Destefanis et al. 2000).

Materials and Methods: Eighty beef strip loins (IMPS # 180, NAMP, 2011) with 21 d of aging were collected from the TTU Gordon W. Davis Meat Lab representing Prime, Certified Angus Beef (CAB), Low Choice, and Select. The first 2.54-cm steak was obtained from each strip, vacuum packed, and frozen. Then, steaks were thawed for 24 h (0°C to 4°C) and cooked to a medium degree of doneness (71°C ± 2°C) in a Rational oven set to 180°C. After cooking, the slice shear force (SSF) was determined. Then, the remaining steak was cut into 1-cm cubes and offered to 6 to 8 trained panelists throughout 10 sessions. Panelists were asked to grade each steak for tenderness, juiciness, beefy flavor, browned, roasted, sour, fat-like, buttery, umami, and oxidized flavors. All attributes were evaluated on a scale of 0 (not tender or absence of taste) to 100 (very tender or strong flavor), and results were registered in an electronic ballot. Data were analyzed with ANOVA and a PCA with the statistical package R (v. 4.2.3).

Results: Prime steaks presented lower ($P < 0.05$) SSF and a higher score for tenderness, buttery, and fat-like flavor compared with all other quality grades, which did not differ from each other ($P > 0.05$). Also, prime was lower ($P < 0.05$) than select for oxidized flavor. Amazingly, select had a significantly higher roast-like flavor compared with CAB; however, there was no difference ($P > 0.05$) between select, prime, or low choice. On the other hand, after conducting a PCA, 3 PCs were calculated accounting for 77.32% of the variability. By plotting these PCs and the vectors for each characteristic, it was observed that the roasted and browned flavors presented higher variability in the data and principally drove PC1, whereas PC2 was principally driven by tenderness, flavor, and fat-like. On the other hand, small vectors for characteristics like SSF, cook loss, metallic, and liver off-flavor were observed, meaning that they present a lower variability. Finally, in the clustering by quality grade, it is observed that prime quality grade is more related to tenderness, juiciness, browned, and fat-like flavor.

Conclusion: Prime steaks presented higher ($P < 0.05$) tenderness, buttery, and fat-like flavor attributes; on the other hand, select had a higher roast-like flavor compared with CAB; nevertheless, there was no difference ($P > 0.05$) between select, prime, or low choice. After conducting a PCA more information can be pulled from the data. In this case, browned and roasted remained the 2 aspects that brought the higher variability. And finally, the prime quality grade was more associated with tenderness, juiciness, brown, and fat-like flavors.

Keywords: None

Education and Extension Tools

9 ARTIFICIALLY INTELLIGENT DISCUSSION PLATFORM ASSESSMENT OF STUDENT PERFORMANCE CORRELATES WITH IN-CLASS STUDENT PERFORMANCE FOR INTRODUCTORY ANIMAL PRODUCT CLASS

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Objectives: The use of discussion platforms has been shown to increase student learning in a variety of classroom settings. Evaluations of discussion forums are needed to assess the quality of postings and provide consistent feedback to students. The use of artificially intelligent (AI) discussion platforms may provide a valuable tool for instructors to encourage discussion of course topics outside of classroom settings that can result in deeper understanding of the course materials and requires less instructor resources to assess. Therefore, the objective of this study was to determine whether correlations existed between student performance using an AI discussion platform and in-class assessment using 3 different course formats.

Materials and Methods: The AI platform Packback was added to the required course materials for ANSC 255, Principles of Animal Products, in an online version (Online, $n = 12$), in-person version (In-Person, $n = 86$), and hybrid version (Hybrid, $n = 87$) at Purdue University. In Packback, each week, students were required to create one original question post and 2 response posts. Packback uses AI to generate a "curiosity score" (CS) of 0 to 100 (0 = very poor, 100 = outstanding) for each post as a quality measurement evaluating the following parameters: curiosity (was the question close ended, amount of writing, detail of information), credibility (use of sources), communication (use of media leading to more responses), convention (spelling, grammar, errors within writing), and plagiarism (originality of the writing). For each student, the average CS of their posts was used to determine correlations to in-class performance. In-class performance was evaluated using daily quizzes (Quizzes) and exams (Exams) that were combined for the total grade (Grade). Correlation analysis was used to compare CS to all in-class scores for each class offering format (Online, In-Person, and Hybrid) using PROC CORR in SAS (SAS 9.4).

Results: For Online students, a positive correlation was found between CS and Quizzes ($R = 0.61218$; $P = 0.0344$), with no correlations observed between CS and Exams or Grade ($P > 0.05$). For In-Person students, a positive correlation was found between CS and Grade ($R = 0.36089$; $P = 0.0325$) and was approaching significance for Quizzes ($R = 0.2042$; $P = 0.0593$) and Exams ($R = 0.19896$; $P = 0.0663$). Finally, for hybrid students, positive correlations were found between CS and Quizzes ($R = 0.30677$), Exams ($R = 0.35407$), and Grade ($R = 0.36551$), all with $P < 0.004$.

Conclusion: These data indicate student performance with an AI discussion platform correlates with in-class performance of this introductory meat science course to varying degrees depending on course format. CS showed the strongest correlations to Quizzes across all course formats as being significant or approaching significance, whereas CS correlations were found significant to Grades only with In-Person and Hybrid formats. CS correlations were only significant to Exams in Hybrid formats and approaching significance in In-Person formats. Although these data indicate correlations in performance between the AI platform and the in-class performance, further analysis, such as qualitative student responses to surveys and guided reflections, would be needed to determine if students perceived the use of the AI platform enhanced their learning of the course materials.

Keywords: artificial intelligence, assessment, discussion platforms, student performance

10 UTILIZING THE CRAWL-WALK-RUN (CWR) METHODOLOGY TO ASSESS ITS INSTRUCTIONAL EFFECTIVENESS IN ENHANCING STUDENT LEARNING

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Objectives: The objective of this project was to use crawl-walk-run (CWR) methodology to assess its instructional effectiveness in training students in the assembly, operation, and disassembly of meat processing equipment via student participation and student survey feedback.

Materials and Methods: The CWR methodology aims to train individuals to a specified standard regardless of

previous experience. The tenets of this concept will enhance students' knowledge in how to assemble, safely operate, and disassemble various processed meat equipment. This methodology was used in one semester of a stacked (undergraduate/graduate) processed meats course, ANSC 467/667, Industrial Processed Meat Operations.

The CWR concept used in this study consisted of individual and team tasks each student accomplished and "learning gates" that must be completed to participate in the team research and development project. Written and graphical instructions were provided for individual tasks involving the assembly, operation, and disassembly of various processed meat equipment, including the grinder, mixer grinder, vacuum tumbler, injector, patty machine, bowl chopper, and vacuum filler/stuffer.

Students were formed into teams and allowed a 3 h laboratory period ("dry run") to learn how to identify parts, assemble, operate, and disassemble each piece of equipment. The following week, students were assessed on their ability to properly assemble, operate, and disassemble the equipment. Students were assessed as "T" (Trained)," "P" (Needs practice), or "U" (Untrained). Those students assessed as untrained were retrained and then reassessed. Four students were used as "observer-controllers" to assess each student at equipment stations.

Results: From an instructor's perspective, this requires ample time to train and identify students who can serve as observer-controllers to aid in assessment. Not all students were able to complete the training, resulting in the instructor and student(s) finding time outside of class time to complete the training. Students were surveyed ($n = 15$) anonymously via Google Forms to assess the value of this instructional approach. A series of questions were asked, requiring students to respond on a scale from 1 to 5: 1 = Strongly Disagree and 5 = Strongly Agree.

Students agreed that "the pre-lab orientation information (diagrams, text) increased my understanding of the expectations of each lab" (4.07), that "this process has enhanced my ability to identify equipment parts" (4.47). Students agreed that "the CWR methodology has helped me correctly assemble, disassemble and operate processed meat equipment before being required to operate the equipment in lab" (4.47). Students agreed that "working as part of a team aided my ability to identify parts, assemble, disassemble and operate processed meat equipment" (4.27) and also agreed that "this teaching method aided me in preparing for the laboratory practicum on equipment identification and function" (4.20). Students agreed with the statement "I believe this teaching method has aided our team in developing production flowcharts for our research and development project" (3.8) and agreed that "the CWR methodology used in lab should be continued" (4.33).

Conclusion: Overall results indicate that the CWR methodology is an effective teaching tool for students to gain knowledge, skills, and competencies in assembling, operating, and disassembling meat processing equipment.

Keywords: assessment, instruction, meat processing

11 EVALUATING YOUTH AND ADULT PERCEPTIONS AND UNDERSTANDING OF AFRICAN SWINE FEVER AND BIOSECURITY IN THE EXHIBITION SWINE INDUSTRY

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Objectives: African Swine Fever (ASF) is a high-consequence foreign animal disease endemic to sub-Saharan Africa and the island of Sardinia. The United States is the world's third largest pork producer, and ASF introduction would severely disrupt the pork supply chain, emphasizing a need to protect market access for US proteins. However, niche producers raising swine intended for exhibition may not follow stringent biosecurity protocols, and livestock show circuits may promote untracked animal movement across the country, potentially exacerbating virus spread in the event of ASF incursion into the US.

Materials and Methods: Two Qualtrics surveys designed to evaluate knowledge, understanding, and perceptions of ASF and biosecurity principles of youth swine exhibitors and adults involved in the exhibition swine industry were distributed via flyers, emails, and canvassing at livestock shows. Youth exhibitors (age 21 and under) answered questions assessing their knowledge and provided basic demographic information, including their home state and states to which they traveled for exhibitions. Adult respondents ($n = 211$) answered the same questions assessing their knowledge and provided information on their time involved in the swine industry and number of shows attended by the youth they advise (if any). Youth respondents ($n = 127$) lived in 14 states and exhibited in 23 states, with 35% and 28% holding membership in state and national swine organizations, respectively.

Results: When provided with a list of ASF clinical signs, 34 individuals (26.9%) correctly identified all symptoms. Twenty-nine individuals (23%) incorrectly responded that ASF has been found in the US, and 10 (7.9%) believed the virus cannot spread between pigs. Increased biosecurity understanding in youth exhibitors showed a significant relationship with an increase in years involved ($P < 0.05$). Adult respondents had been involved in the swine industry for an average of 21 years, and the youth they advised attended 14 exhibitions in an average year. Nearly all adults (90.5%) identified direct contact with infected animals as a method of ASF transmission, whereas far fewer (36.39%) identified animal feed as a possible mechanism of transmission.

Conclusion: These responses indicate highly varied knowledge of symptoms, routes of transmission, and biosecurity recommendations. Youth membership in state or national swine organizations offers a route for outreach and educational activities to enhance foreign animal disease preparedness, and adult presence at swine exhibitions as parents or advisors allows for a wide variety of education activities for all ages to better serve all levels of understanding.

Funding Source: Colorado Pork Producers' Council

Keywords: African swine fever, education, swine exhibition

Environment, Production Systems

12 PROPORTIONATE MASS OF HEART, LUNG, AND LIVER OF CATTLE IN RESPONSE TO ANIMAL WEIGHT

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Objectives: Finished slaughter cattle increase in size by approximately 2.5 kg of additional carcass weight year over year. Additionally, the frequency with which cattle feeders report late-term mortality has increased concomitant with heavier finished weights. The objective of this project was to evaluate the association of cattle body mass to visceral organ mass in cattle.

Materials and Methods: Cattle ($n = 119$) were harvested in Canyon and Lubbock, TX. Breeds of cattle varied, but most cattle were finished steers with few heifers, cows, and steer calves. Live weight (kg) was recorded immediately after immobilization and prior to exsanguination. After evisceration, heart, lungs, and liver were separated and weighed. Data were subjected to regression analysis to quantify the relationships between organ mass and body mass. Regression analyses were used to identify the association between body mass and mass of each organ (heart [HP]; lung [LuP]; liver [LiP]) expressed as percentage of body mass.

Results: Of the cattle evaluated, the live weight range varied (110 to 882 kg) because of the different stages of cattle finishing that were represented. Variability in percentage of organ mass for heart was moderately associated with body mass ($r^2 = 0.64$; $P < 0.01$); conversely, lung ($r^2 = 0.83$; $P < 0.01$) and liver ($r^2 = 0.81$; $P < 0.01$) mass were strongly associated. In general, as body mass increased, the percentage of organ mass decreased at a logarithmic decreasing rate. Regression analysis indicated the rate of change for HP was best estimated by the following equation: HP = −0.15044ln (live weight, kg) + 1.37286 (root mean square error = 0.07). The rate of change for LuP can be estimated as LuP = −0.50900ln (live weight, kg) + 3.82410 (root mean square error = 0.14). Moreover, the rate of change for LiP was predicted by the equation LiP = −0.78177ln (live weight, kg) + 6.19006 (root mean square error = 0.24).

Conclusion: Results of this study suggest that organ mass as a percentage of live bovine body mass decreases notably as the animal reaches mature weights. Of the 3 organs evaluated, the liver appears to diminish in proportion to body mass at the fastest rate. Moreover, specific to the cardiovascular system, proportional lung mass declined at a rate 3-fold faster than the heart. These data may provide insight into the stress placed upon organs as the animal reaches finishing weights.

Keywords: organ, growth

13 CHANGES IN SALMONELLA CONCENTRATIONS AND SHIGA TOXIN–PRODUCING ESCHERICHIA COLI (STEC) PREVALENCE IN THE LAIRAGE AREAS OF A COMMERCIAL CATTLE HARVESTING FACILITY OVER A YEAR PERIOD

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Objectives: The objective of this study was to evaluate the changes in pathogens using the boot swab sampling method over a year period to monitor the lairage area environment of a commercial beef harvesting facility and use as a tool for strategic in-plant decision-making.

Materials and Methods: This study was conducted at a commercial beef processing facility in Eastern Nebraska over a year period, from March 2022 to February 2023 (excluding August and September 2022), where a total of 454 boot swab samples were taken in the cattle holding pens of the lairage area. Boot swab samples were taken at the end of the production day by placing nonwoven shoe covers over each boot and walking from the front to the back of the pen in a predetermined "Z" pattern. Primary enrichments were created for boot swabs with 100 mL of BPW and a secondary enrichment of 30 mL of the primary enrichment and 30 mL prewarmed (42°C) BAX MP media with 1 mL/L Quant Solution was created for each boot swab sample and incubated at 42°C for 6 to 24 h. The samples were run on the BAX Q7 System and Real-Time PCR Assays for *Salmonella*, *Escherichia coli* O157:H7, and top 6 non-O157 Shiga toxin–producing *E. coli* were utilized. Cycle Threshold (CT) values produced by SalQuant were converted to Log CFU/mL, and data were arranged into boxplots. STEC prevalence data were arranged into line plots to determine changes from month to month, and P values < 0.05 were used to determine significance.

Month	Percent (%) Prevalence						
	Salmonella	O157:H7	O26	O121	O45	O103	O45
March 2022	93.9	21.9	100	88.9	84.8	93.8	0
April 2022	90.9	27.3	90.9	90.9	100	100	0
May 2022	100	40	97.5	62.5	60	97.5	0
June 2022	100	12.1	67.9	67.9	66.7	46	6.3
July 2022	98.2	12.3	74.9	97	93.8	70.6	34
October 2022		43.3					
November 2022	98	33.9	78	98	92	74	8
December 2022		0					
January 2023	0	0	6.7	20	0	0	0
February 2023	6.7	13.3	100	60	93.3	66.7	0

Prevalence (%) 0 10 20 30 40 50 60 70 80 90 100

Table 1: Pathogen prevalence over a year period in the pen floor environment of the lairage area at a commercial beef processing facility collected by boot swab samples.

Results: Data indicated that STEC-O121, O45, O26, and O103 were consistently prevalent in the lairage area throughout the majority of the sampling months. On the other hand, *E. coli* O157:H7 and STEC-O111 and O145 presence was relatively low throughout the year (0% to 43.3%) when compared with other STECs; however, data were helpful in visualizing higher and lower prevalence months for each pathogen throughout the year. Additionally, data indicated that *Salmonella* was the most prevalent pathogen in the lairage area over the monitoring period; however, quantification data indicated this pathogen was not always prevalent at high concentrations, suggesting lower-risk months. *Salmonella* prevalence was over 90% from March to November; however, in April and June, data indicated that *Salmonella* was present in low concentrations (<1 mean Log CFU/mL) versus March and November, when *Salmonella* was present at higher concentrations of 3.00 and 2.29 mean Log CFU/mL, respectively.

Conclusion: Monitoring pathogens in the lairage area environment using boot swabs is a simple and effective tool that requires minimum sampling labor, that allows commercial beef processing facilities to map pathogens in the lairage area and use as an effective tool for strategic in-plant decision-making, postharvest.

Keywords: boot swabs, lairage area, preharvest, Salmonella, Shiga toxin–producing *E. coli*

14 EXAMINATION OF THE EFFECTS OF DIETARY ANHYDROUS CALCIUM CHLORIDE IN EARLY AND LATE FINISHING ON SWINE GROWTH, BODY COMPOSITION, AND PORK QUALITY

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Objectives: The pork industry needs a solution to slow pig growth during market disruptions. Feeding acidogenic salts, specifically anhydrous calcium chloride ($CaCl_2$), can slow pig growth but may reduce pork loin quality. The application of this intervention has not been investigated in earlier finishing phases. This study aimed to determine the effects of dietary anhydrous $CaCl_2$ in early and late finishing on pig growth, body composition, and pork quality. We hypothesized that feeding $CaCl_2$ in only the early phase would slow growth but allow the pigs to regain growth after the removal of $CaCl_2$ from the diet prior to harvest and minimize carcass impacts.

Materials and Methods: Crossbred commercial pigs ($N = 240$; ~52 kg) were allotted treatments and fed in pens ($N = 60$) of 4 barrows or gilts. The 86-d trial was divided into 3 phases. Treatments consisted of control (C); pigs fed $CaCl_2$ in the first phase (IP1), and pigs fed $CaCl_2$ in the third phase (IP3). Pigs were fed ad libitum. Feeders and pigs were weighed at the end of each phase. Average daily feed intake (ADFI), average daily gain (ADG), and gain-to-feed ratio were calculated. Ultrasound was used to determine loineye area and backfat depth at the end of phases one and three. The 2 heaviest pigs per pen were transported to a commercial processing facility and processed using CO_2 stunning and deep chill cooling. Loin and fat depth (Fat-o-Meater) were used to determine fat-free carcass lean (FFL). At 1 d postmortem, one loin per carcass was collected, vacuum packaged, and aged 12 d (2°C). After aging, purge loss, drip loss, pH, color, and marbling were determined. Two 2.54-cm chops were cooked to 68°C. Cook loss and star probe texture were measured. Lipid content was determined (CEM Smart 6 and Oracle; Matthews, NC). Data were analyzed using JMP (JMP Pro 16.1.0, SAS Institute, Cary, NC) with pen as the experimental unit. The effects of treatment, sex, and sex × treatment interaction were analyzed.

Results: In phase 1, pigs in IP1 had lower ADFI, ADG, gain-to-feed ratio, less backfat, and smaller loin eyes than IP3

and C pigs ($P < 0.01$). During phase 2, IP1 pigs had higher ADG and a greater gain-to-feed ratio than IP3 and C pigs ($P < 0.01$). In the final phase, IP3 pigs had lower ADG, ADFI, gain to feed, and smaller loin eye area and backfat than the C and IP1 pigs. Control pigs had the largest loin eye area and most backfat, followed by IP1 and then IP3 pigs. For the entire trial, C pigs had the greatest ADFI, and ADG, followed by IP1 pigs; IP1 pigs had greater ADFI and ADG than IP3 pigs ($P < 0.01$). Sex significantly affected ADFI, ADG, gain to feed, and final weight ($P < 0.05$). Carcasses from C pigs were the heaviest (110.9 kg), followed by IP1 (105.2 kg) and IP3 (89.6 kg) carcasses ($P < 0.01$). Treatment did not affect carcass FFL. Loin chops from IP3 carcasses had higher star probe values (5.0 kg) than IP1 loins (4.6 kg: $P < 0.05$). Loins from barrows had more lipid and greater marbling scores than loins from gilts ($P < 0.01$). Treatment did not affect loin pH, color, marbling, or lipid content ($P > 0.05$).

Conclusion: This study demonstrated that inclusion of $CaCl_2$ in the late phase was most effective at slowing pig growth. Inclusion of anhydrous $CaCl_2$ in the late phase may negatively affect instrumental tenderness, but other pork quality traits were not affected.

Keywords: carcass composition, pork quality, swine growth

15 ENVIRO-MAPPING OF MICROBIAL INDICATORS IN A BEEF FABRICATION PROCESSING FACILITY

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Objectives: The purpose of this in-plant study was to identify microbial harborage sites and concentration overtime throughout the day in the fabrication area of a beef processing facility.

Materials and Methods: The fabrication lines studied were Chuck (L1), Loin (L2), Round (L2), and Trim (L4). Samples were collected during 4 d in 5 timepoints: preoperation, morning (3 h of production), before midday cleaning (5 h of production), after midday cleaning, and at the end of the shift. MicroTally was used for cutting boards 0.5 m^2, $n = 90$; conveyor belts area varies by line, $n = 60$; drains, 320 cm^2, $n = 90$; stairs, 0.25 m^2, $n = 18$; and handrails, 0.37 m^2, $n = 18$. Additional samples were collected using MicroSnap for knives, ~20 cm^2, $n = 90$ and board frames, 90 cm^2, $n = 90$. Aerobic plate counts (APC), Enterobacteriaceae (EB), and *Escherichia coli* (EC) counts were determined using the TEMPO system for MicroTally and the EnSURE Touch system for MicroSnap samples.

Results: The following results are represented in logCFU/mL. Cutting boards started below the limit of quantification (LOQ) in preoperation; after 3 h, counts increased significantly to 3.41, 2.91, and 2.97 for AC; for EB, they went up to 2.62, 2.19, and 2.03; and for EC, counts were 0.55, 1.03, and 1.04 for L1, L2, and L3, respectively. Counts were similar before midday cleaning and at the end of the shift; however, there was a significant reduction in L1 after midday cleaning of 0.87 ($P < 0.05$). Conveyor belt AC counts preoperation were 1.28, <LOQ, 0.17, and 0.58 for L1, L2, L3, and L4 respectively; EB and EC counts were <LOQ. After 3 h, AC counts increased significantly to 3.52, 3.49, 3.36, and 3.69; EB were 2.93, 2.46, 2.42, and 2.92; and for EC, they were 1.26, 1.06, 0.93, and 1.33 for L1, L2, L3, and L4, respectively. Results were similar throughout the day except in L3, when EC counts went up to 2.28 ($P < 0.05$). Board frames preoperation were <LOQ for EB and EC in the 3 lines; AC started in 1.05, 0.76, and <LOQ in L1, L2, and L3, respectively. After 3 h, counts went up to 2.9, 3.75, and 3.86 for AC; for EB, counts increased to 2.65, 2.37, and 2.08; for EC, counts were 0.53, 0.78, and <LOQ for L1, L2, and L3, respectively. No significant increase or reduction was found for the rest of the day in L1 and L2; L3 had a significant reduction after midday cleaning of 0.47 for EB and 0.84 for EC ($P < 0.05$). Drains were already high preoperation with 2.43, 2.86, and 3.7 for AC; 0.74, 2.06, and 2.38 for EB; <LOQ, 0.74, and 0.25 for EC in L1, L2, and L3, respectively. After 3 h, there was no significant increase ($P > 0.05$) for the rest of the day in all lines. Knife loads preoperation were 0.95, 2.06, and 0.77 for AC; 0.57, 0.87, and 0.76 for EB; for EC counts were <LOQ in L1, L2, and L3, respectively. After 3 h, there was no significant increase in any indicator for the 3 lines. Finally, for handrails and stairs, there was no significant reduction or increase from preoperation to the end of the day.

Conclusion: Results can be used as a microbiological baseline for assessing the hygienic conditions during operations in a beef fabrication room. The cleaning and sanitation protocol performed preoperation is effective to remove the buildup of the day. However, by the first 3 h of operation, microbial contamination can reach high levels of contamination that are maintained throughout the day, meaning that the limited cleaning performed at lunch break is not effective to reduce contamination on surfaces.

Funding Source: Funding provided by International Center for Food Industry Excellence (ICFIE).

Keywords: contamination, environmental monitoring, microbial indicators

16 THE F94L MYOSTATIN GENE INCREASED MUSCLE AREA AND TYPE II MUSCLE FIBER QUANTITY AND DECREASED STRIP STEAK ANGULARITY IN BEEF × DAIRY CATTLE

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Objectives: Low muscularity in dairy cattle breeds results in poor carcass conformation, small steak portion sizes, and angular loin strip steaks. An effective method to improve dairy offspring muscle conformation is to mate dairy cows to beef sires. In beef cattle, the F94L myostatin mutation has been shown to increase muscle growth. Utilizing the F94L myostatin gene could mitigate the meat yield and conformation deficiencies observed in dairy cattle breeds. The objective of this study was to determine the effect of the F94L myostatin mutation in carcasses from beef × dairy steers on muscle fiber type, muscle area (*longissimus* and *semitendinosus*), and dimensionality of loin strip steaks.

Materials and Methods: Carcasses ($n = 57$) from steers resulting from the mating of 2 Limousin/Angus sires heterozygous for the F94L myostatin mutation to Jersey/Holstein dams were utilized in this research. As indicated by DNA analysis, 29 carcasses were from steers with one copy of the F94L allele and 28 carcasses were from steers with zero copies of the F94L allele. *Longissimus* and *semitendinosus* muscle samples were excised from the left side of each carcass and fixed for muscle fiber type analysis within 1 h after death. Immunohistochemical analysis was performed according to the procedure of Hergenreder et al. (2016). Strip loins from the right side of each carcass were frozen at 10-d postmortem and cut frozen into 2.5-cm-thick steaks using a band saw. Beginning from the anterior end, individual frozen steaks from the entire strip loin were imaged at a fixed height above the steak on a gridded background. Each digital image was processed using an image analysis software capable of measuring individual pixel size (Fiji Image J). The PROC MIXED procedure in SAS (SAS Institute, Cary, NC) was used to analyze data as a mixed model with F94L genotype and sire as fixed effects, slaughter group as a random effect, and percent Jersey of dam as a linear covariate, with animal serving as the experimental unit.

Results: Carcasses from steers with one F94L allele had larger *longissimus* (105.4 cm^2 versus 99.5 cm^2) and *semitendinosus* (101.8 cm^2 versus 91.4 cm^2) area than carcasses from steers with zero F94L alleles ($P < 0.05$). The F94L allele did not affect fiber size ($P > 0.05$); however, F94L caused a greater number of Type IIA (+17%) and IIX (+21%) fibers in the *semitendinosus*. Strip steaks 4, 5, 7, 8, and 9 from carcasses with one F94L allele had a greater loin muscle area (+6% to +7%) than carcasses with no F94L allele ($P < 0.05$). Strip steaks from carcasses with one F94L allele were less angular throughout the center and posterior portion of the strip loin, specifically steaks 6, 7, and 9 ($P < 0.05$).

Conclusion: Increased muscling from one F94L allele was due to hyperplasia of Type II muscle fibers. Loin strip steak size and angularity were improved by one copy of the F94L allele in carcasses from beef × dairy steers. Use of F94L homozygous terminal beef sires would be an easily implemented strategy for dairy producers to improve steak portion size and shape in carcasses from non-replacement calves.

Funding Source: National Cattleman's Beef Association, University of Arizona

Keywords: beef, dairy, dimensionality, fiber type, myostatin

Meat and Poultry Processing, Ingredient Technology and Packaging

17 EFFECT OF LACTIC ACID AND CITRILO TRIMMING INTERVENTION ON THE GROUND BEEF VISUAL COLOR AND OFF-ODOR STABILITY

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Objectives: Over 46% of all retail beef consumption in the United States is believed to be made up of ground beef, which is consumed at a rate of 27 lb per person. Consumers typically use color to indicate freshness, but antimicrobial treatments, packaging, and extended storage can all impact color quality. Other organic acids, like Citrilow, may be as efficient as lactic acid, which is frequently used to increase shelf life.

Materials and Methods: The chosen beef trimmings from each combo were cut in half (28 chubs each) and were continuously submerged in the 2 antimicrobial treatments. The filling tank treated half of the trimming pieces with lactic acid at a 2% concentration, and the other half was treated with a solution of Citrilow (a mixture of citric and hydrochloric acids used for a variety of direct food contact applications that kills pathogens through bactericidal pH adjustment) at a pH of 1.2 for about 12 s, with the temperature between 22°C and 24.5°C. The ground beef was portioned into containers, finely ground, and covered with oxygen-permeable film. Color and smell were assessed over the course of 48 h while the trays were on show in a retail case. A trained group of experts evaluated color visually and quantitatively, while other experts evaluated odor. Trays were regularly rotated and assessed. The GLIMMIX procedure in SAS was used to evaluate the color, smell, and color panel of chub trays. It fits statistical models to data with correlations or nonconstant variability. At a significance threshold of $P < 0.05$, the SAS PDIFF option was used to separate the treatment means. The Kenward-Roger method provides a more precise small-sample estimator for the variance-covariance.

Results: The findings revealed substantial interactions among variables like antimicrobial treatment, days of chub storage, and retail display hours. The lowest worse point lean color for lactic acid and Citrilow at 0 h, after 7 d, was 1.16 and 1.18. The highest worse point lean color for lactic acid and Citrilow at 48 h was 7.33 and 7.76. To completely comprehend these results, an additional study may be required.

Conclusion: After fabricating the ground beef trays, instrumental and visual color were more stable in trays made from chubs stored for 7 or 14 d, whereas trays made from chubs stored for 21 and 28 d showed a faster degradation of instrumental and visual color as well as the development of off-odors. Nonetheless, the patterns of change in instrumental, visual color, and off-odor were similar for ground beef that had previously been treated with lactic acid and Citrilow. This finding suggests that Citrilow is a viable alternative to lactic acid as an antimicrobial intervention for ground beef trimming.

Keywords: None

18 EFFECT OF CALCIUM ACETATE ON SPENT DUCK MEAT QUALITY

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Objectives: Duck meat has a favorable amino acid profile compared with the meat of broiler chickens (Ali et al., 2007) and is popular in Asian and European countries. Calcium chloride has been applied as a tenderizer to improve spent fowl meat tenderness (Sam, 1997); however, a bitter, metallic taste was also imparted to the cooked product (Scanga et al., 2000). Although calcium acetate has been used as a nutrition fortifier and stabilizer (Fiume et al., 2014), its application in meat tenderization remains unexplored. The objective of this study was to examine the effect of calcium acetate on the quality of breast meat from 24-mo-old Tsaiya layer duck (*Anas platyrhynchos*).

Materials and Methods: Carcasses (~10 min postmortem, $N = 45$) were obtained from a local commercial slaughterhouse and chilled at 53°F for 1 h. Duck breasts (*pectoralis major*) were excised and assigned to 1 of the 3 treatments; each treatment consisted of 15 samples. Samples were individually incubated using 30 mM calcium acetate (ACA) buffer, 30 mM EDTA (EDTA) buffer, or direct vacuum packaging (CON) and stored at 41°F.

Objective color features (CIE L^*, a^*, and b^*) were acquired using a colorimeter (3nh Technology Co., Ltd., China) equipped with an 8-mm aperture and illuminant D65 was used. Myofibril fragmentation index (MFI; Hopkins et al., 2004) were measured on day 0, 1, and 3. Cooking loss (%; Barbut et al., 2005) were measured on day 1 and 3. All data were analyzed using SAS (v. 9.3; SAS Institute, Cary, NC) by split plot, mixed model procedure; P values lower than 0.05 were considered statistically significant.

Results: Our results showed a significant increase in the L^* and b^* values on day 1, which then remained unchanged during storage period in all groups. The L^* values in ACA samples were significantly higher than those in CON and EDTA samples on both day 1 and 3, whereas the a^* values in ACA samples were significantly lower than CON samples on the same days. Although there was no significant difference in cooking loss among all treatments, the MFI values increased significantly in ACA samples compared with CON and EDTA samples on both day 1 and 3.

Table 1. Postmortem changes in cooking loss, color, and Myofibril fragmentation index of control (CON), 30 mM calcium acetate (ACA), and 30 mM EDTA (EDTA) Tsaiya, duck breast samples stored at 41°F.

Measurement	Postmortem time, day	Control	30 mM calcium acetate	30 mM EDTA
Cooking loss, %	Day 1	15.49 ± 1.38	16.55 ± 0.96	17.45 ± 2.93
	Day 3	17.24 ± 1.63	19.07 ± 1.29	18.82 ± 2.85
Lightness (L*)	Day 0	45.67 ± 0.63^{x}	45.78 ± 0.47^{x}	46.19 ± 0.56^{x}
	Day 1	57.91 ± 0.62^{ay}	67.10 ± 0.40^{by}	64.38 ± 0.27^{by}
	Day 3	57.13 ± 0.64^{ay}	68.52 ± 0.28^{by}	63.29 ± 0.69^{by}
Redness (a*)	Day 0	12.98 ± 0.34	13.34 ± 0.23^{y}	13.20 ± 0.40^{y}
	Day 1	12.39 ± 0.28^{b}	8.63 ± 0.18^{ax}	10.61 ± 0.32^{abx}
	Day 3	13.10 ± 0.25^{b}	9.22 ± 0.14^{ax}	11.74 ± 0.33^{abx}
Yellowness (b*)	Day 0	4.94 ± 0.20^{x}	4.97 ± 0.34^{x}	5.06 ± 0.25^{bx}
	Day 1	9.11 ± 0.27^{y}	8.02 ± 0.87^{y}	7.90 ± 0.38^{ay}
	Day 3	8.26 ± 0.22^{y}	8.33 ± 0.12^{y}	7.55 ± 0.27^{y}
Myofibril fragmentation index	Day 0	38.72 ± 0.17^{x}	39.31 ± 0.96^{x}	39.90 ± 1.10^{x}
	Day 1	49.50 ± 0.87^{by}	79.52 ± 0.87^{cy}	41.23 ± 0.38^{axy}
	Day 3	66.23 ± 1.73^{bz}	92.01 ± 2.65^{cz}	44.50 ± 1.21^{ay}

Conclusion: Our results showed that incubation of Tsaiya duck breast meat with 30 mM Ca^{2+} calcium acetate buffer accelerates proteolysis without affecting cooking loss.

Funding Source: This research was supported by a grant from the Ministry of Science and Technology (MOST 110-2313-B-034-003-), Taiwan, R.O.C.

Keywords: calcium acetate, marination, meat quality, spent Tsaiya duck

19 META-ANALYSIS TO CHARACTERIZE THE FACTORS RESPONSIBLE FOR PERSISTENT PINKING IN COOKED AND UNCURED MEAT PRODUCTS

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Objectives: Meat cooking or thermal processing is essential to destroy pathogens and for consumer acceptance. The color of cooked meat depends on various factors, such as myoglobin redox forming in raw meat before cooking or pH. Higher temperatures may lead to denaturation and unfolding of myoglobin's globin portion, exposing the heme group and forming denatured globin hemochrome, providing a dull brown color in cooked meat. However, the meat industry often reports the sporadic occurrence of an undesirable pink appearance known as persistent pinking in cooked and uncured meat. This abnormal pink color in cooked meat is a concern for consumer acceptance rather than a food safety problem. Various studies have been conducted on identifying the possible reasons for persistent pinking, but there is no compilation of such research work through meta-analysis to draw conclusions from. In the present study, a meta-analysis was conducted to combine data from published journal articles to better understand persistent pinking in cooked uncured meats.

Materials and Methods: Published research articles were searched in various scientific databases using the keywords "persistent pinking," "cooked meat," "myoglobin denaturation," "abnormal color," "meat doneness," "thermal stability," and their combinations. The initial search identified 90 references related to the topic, out of which 53 references were selected based on criteria established. Species, pH, a^* values, processing methods, myoglobin forms, types of packaging, lipid oxidation/TBARS values, myoglobin denaturation, aging, and interventions were recorded from each manuscript. The results are expressed as a percentage in each category.

Results: In present meta-analysis, persistent pinking was mostly observed in beef (66.03%) and turkey (15.09%). Out of 53 articles, 40 research articles (75.47%) indicated higher pH (6.0 to 7.24) as the most common reason for persistent pinking. The undesirable pink color was more reported in ground meat products (>52.83) as compared with intact meat/in vitro studies. In addition to myoglobin forms, presence of nitric oxide (13.20%) or nicotinamide hemochrome (7.54%) during processing also induced an undesirable pink color. Dark-cutting beef had higher chances of persistent pinking than normal pH beef and USDA choice cuts. Higher pH was the most common factor responsible for persistent pinking along with packaging conditions, ingredients added during processing, aging period, and oxygen consumption. Various processing strategies have been used successfully to reduce persistent pinking in cooked meat, such as adding ascorbic acid, citric acid, and lactic acids and high-pressure processing.

Conclusion: Persistent pinking has sporadic occurrences in the meat industry, and understanding the mechanistic basis helps to minimize the occurrence. The current meta-analysis indicated that pH greater than normal meat pH is the most important contributing factor for persistent pinking. Hence, monitoring pH of raw materials may be exploited as a strategy to limit the occurrence of uncooked pink appearance.

Keywords: abnormal color, cooked meat, meta-analysis, persistent pinking, pH

20 COLOR DEVELOPMENT IN RESTRUCTURED HAM FORMULATED WITH VARYING CONCENTRATIONS OF SODIUM NITRITE OR NATPRE T-10 AND ITS STABILITY DURING REFRIGERATED STORAGE UNDER LED LIGHTS

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Objectives: To assess the effect of sodium nitrite concentration (0 to 200 ppm) or NATPRE T-10 (1%) on color development in restructured ham and the color stability when exposed to LED lighting during refrigerated storage under a vacuum.

Materials and Methods: Restructured ham samples were manufactured with ground (8 mm) ham inside muscles (*M. adductor*, *M. semimembranosus*) and formulated with 0, 1, 5, 40, 100, 150, or 200 ppm sodium nitrite or 1% NATPRE T-10 (Prosur, Murcia, Spain), a natural spice and fruit extract. Samples were vacuum tumbled at 6 rpm for 2 h, stuffed in 40-mm plastic casings (Viscofan USA, Inc.), and cooked at 82°C (100% RH) to an internal temperature of 71.1°C. After chilling at 2°C for 15 to 16 h, sample logs were sliced into 2-mm-thick

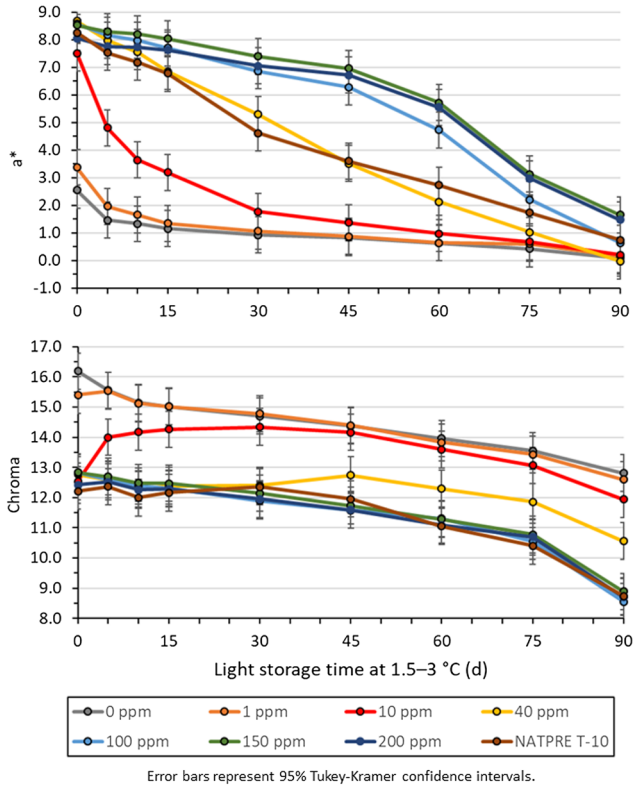
slices, vacuum packaged (6 slices per package, placed side-to-side), and stored at 1.5°C to 3°C, in complete darkness or exposed to cycling (16 h on/8 h off) LED lights (4,100 K; 4,000 lumens) positioned 252 mm above the sample surface. Samples were scanned with a HunterLab MiniScan EZ colorimeter (CIE $L^*a^*b^*$, illuminant D65, 10° observer, 2.54-cm aperture) on days 0, 5, 10, 15, 30, 45, 60, 75, and 90 post-packaging. The study was replicated 3 times. Statistical analysis was conducted as a mixed model using JMP Pro 16.2.0 (SAS Institute, Cary, NC), with significance set at $P < 0.05$.

Results: Color a^* of 0 and 1 ppm nitrite samples was initially lower than in all other treatments ($P < 0.05$), which did not differ from each other at day 0 ($P > 0.05$). In dark-stored samples, a^* remained mostly unchanged for all treatments throughout the entire storage period. In light-stored samples, a^* decreased in all samples throughout the storage period, but at different rates and to a different extent (Fig. 1). By day 5, a^* of 5 ppm nitrite had decreased much more than in all others. In ≥40 ppm nitrite and T-10 samples, a^* decreased at a slower rate until day 15, with the rate of decline increasing in 40 ppm nitrite and T-10 after that. However, a^* of these last 2 remained higher than in 5 ppm nitrite throughout most of the storage time period. b^* was always highest in 0 and 1 ppm nitrite ($P < 0.05$) and remained mostly unchanged in all dark-stored samples. Under light storage, it decreased slightly in 0 and 1 ppm NO_2^-, increased in 5 ppm nitrite by day 5 and in 40 ppm nitrite and T-10 by day 15, and remained mostly stable at ≥100 ppm nitrite until day 75, after which it declined. L^* tended to be higher in 0 and 1 ppm NO_2^-, remained mostly stable in all samples under dark storage, and tended to increase slightly under light storage. Extent of discoloration as measured by a^*/b^* directionally agreed closely with a^* results. Chroma was higher in 0 and 1 ppm nitrite and remained mostly unchanged for all treatments under dark storage; in light-stored samples, it increased at day 5 in 5 ppm nitrite and at day 45 in 40 ppm NO_2^-, after which it declined in all treatments.

Conclusion: Nitrite concentrations ≥ 40 ppm, and NATPRE T-10 at 1%, all resulted in similar color of comparable intensity. All samples underwent discoloration under light storage, with the rate being lowest at ≥100 ppm nitrite, intermediate at 40 ppm nitrite and 1% T-10, and fastest at 5 ppm nitrite. Samples with 0 and 1 ppm nitrite did not develop much appreciable cured color and thus underwent minimal discoloration. Addition of nitrite at ≤5 ppm did not result in a stable cured color.

Funding Source: Prosur, Inc.

Keywords: ham color stability, LED lighting, NATPRE, nitrite



21 EVALUATING THE IMPACT OF PACKAGING TYPE AND EXTENDED AGING ON RETAIL DISPLAY ON BEEF STRIP LOIN STEAKS

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Objectives: Meat color is a primary influencer on consumer purchasing decisions, and deviation from bright cherry-red color, especially regarding beef, results in negative impacts on those decisions. Packaging steaks in modified atmosphere packages (MAP), such as carbon monoxide or high oxygen (80% oxygen), has demonstrated improvement and longevity of meat color over retail display periods. However, these improvements are typically seen when MAP has been employed for shorter-term dark storage. Limited studies have been conducted to evaluate the impact of long-term dark storage while utilizing different packaging methods. Therefore, the objective of this study was to investigate the effects of long-term dark storage on beef strip loins packaged in carbon monoxide MAP (CO-MAP) or vacuum packages.

Materials and Methods: Five USDA Choice strip loins (*longissimus lumborum*) were collected from a commercial processing plant at 7 d postmortem and evaluated at

Oklahoma State University. Vein steaks (containing *gluteus medius*) were removed from each loin. Each loin was then cut in half, with each half randomly assigned a treatment, vacuum package (VP) or carbon monoxide–modified atmosphere package bags (CO-MAP). After packaging, each loin half was then placed in dark storage at 4°C for 45 d. Upon conclusion of the 45-d dark storage period, headspace readings were collected on each modified atmospheric bag to ensure atmospheric levels were reading 0.0% O_2 and were consistent with the initial 0.4% CO, 30% CO_2, and balance N_2 flush. Loin halves were removed from their respective packaging type, and four 2.54 cm steaks were sliced from each half. The 2 most anterior steaks from each half were packaged in foam trays overwrapped with polyvinyl chloride (PVC) film and placed in a coffin-style retail case to initiate day 0 of retail display. Additionally, trained panelists scored steaks for overall lean color appearance and surface discoloration from day 0 to 4 based on a scale of 1 to 7 (1 = bright red color or 0% discoloration). The data were analyzed using the GLIMMIX procedure of SAS, and differences were considered significant at $P < 0.05$.

Results: There was a significant packaging effect on trained panel visual surface discoloration and lean color scores during retail display. Steaks from loins aged in VP had more ($P < 0.05$) discoloration than steaks from loins stored in CO-MAP. VP steaks had no discoloration on day 0, 1, or 2, but trained panelists noted increased discoloration on day 3 and reached unacceptable levels by day 4 (greater than 20% discoloration). Steaks aged in CO-MAP showed less discoloration than VP on days 3 and 4 of retail display. Panelists also reported steaks aged in CO-MAP had redder lean color scores than steaks aged in VP during retail display.

Conclusion: The results of this study indicate that the packaging method does impact visual surface discoloration and lean color scores. Steaks aged in CO-MAP demonstrated more surface redness than VP during retail display. Understanding the mechanistic basis for improved redness in CO-MAP aged samples will help to develop novel MAP-based approaches, especially in extended-aged beef, to improve color during retail display.

Keywords: carbon monoxide MAP, dark storage, packaging, retail display

22 IMPACT OF PACKAGING TYPE ON THE RETAIL COLOR CHARACTERISTICS OF NORMAL PH AND ATYPICAL DARK-CUTTING BEEF LONGISSIMUS LUMBORUM STEAKS SUBJECTED TO 4 D OF RETAIL DISPLAY

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Objectives: Traditional dark-cutting beef is characterized by a pH greater than 6.0 and dark-colored lean in the ribeye; however, atypical dark-cutting beef exhibits a pH of less than 6.0 but with the same dark-colored lean. However, both traditional and atypical dark-cutting beef come with decreased consumer acceptance at the retail case. Therefore, our objective was to evaluate the retail color characteristics of atypical dark-cutting beef and normal pH beef packaged in 3 different types of retail packaging.

Materials and Methods: Atypical dark-cutting (pH = 5.63) and normal pH, USDA Choice (pH = 5.56) strip loins ($n = 6$/loin type) were procured from a commercial beef processing facility and aged for 14 d at 2°C ± 1°C. Strip loins were sliced from the anterior end into 2.54-cm steaks (7 steaks per loin), and 2 steaks from each loin were randomly assigned to 1 of 3 different packaging types: carbon monoxide–modified atmospheric packaging (CO-MAP; 0.4% carbon monoxide, 69.6% nitrogen, and 30% carbon dioxide), high oxygen–modified atmospheric packaging (HiOx-MAP; 80% oxygen and 20% carbon dioxide), and vacuum packaging. Additionally, one steak from each loin was designated for day 0 oxygen consumption and metmyoglobin-reducing activity analysis. Packaged steaks were placed into white coffin-style cases for simulated retail display for 4 d under continuous LED lighting at 3°C ± 1.5°C. Instrumental color was taken each day with 3 readings across the surface of the steak using a HunterLab MiniScan spectrophotometer (2.5 cm aperture, Illuminant A, 10° observer angle), and the spectral data were saved for analysis. Furthermore, oxygen consumption was measured by blooming the sample for 1 h at 2°C, vacuum packaging, reading with the HunterLab as previously described, and the K/S ratios for oxymyoglobin were calculated. Samples for metmyoglobin-reducing activity (MRA) were submerged in a 0.3% sodium nitrite solution for 20 m, vacuum packaged and incubated for 2 h at 30°C, and read with the HunterLab, and the K/S ratio for metmyoglobin was calculated to measure MRA. All data were analyzed using SAS.

Results: Atypical dark-cutting steaks had a lower ($P < 0.05$) initial L^* value and were darker than normal pH steaks on day 0. Additionally, atypical dark-cutting steaks had greater ($P < 0.05$) initial oxygen consumption than normal pH steaks. However, there were no differences ($P > 0.05$) in day 0 MRA for the atypical dark-cutting and normal pH steaks. There was a significant loin type × packaging type × day of display interaction for retail a^* values. Atypical dark-cutting steaks packaged in HiOx-MAP and CO-MAP had higher ($P < 0.05$) a^* values and were redder in color than atypical dark-cutting steaks packaged in vacuum packaging throughout retail display. Furthermore, a^* values were similar ($P < 0.05$) for atypical dark-cutting and normal pH steaks packaged in HiOx-MAP on day 4 of retail display. Finally, atypical dark-cutting and normal

pH steaks packaged in HiOx-MAP had greater ($P < 0.05$) metmyoglobin formation than steaks packaged in CO-MAP.

Conclusion: The use of HiOx and CO-MAP packaging aids in developing and maintaining a cherry-red color of atypical dark-cutting steaks throughout retail display. Furthermore, utilizing MAP packaging of dark-colored steaks has the potential to increase consumer acceptance and marketability at retail.

Keywords: beef, dark-cutting, packaging, retail display

23 ENDOTHELIAL NITRIC OXIDE SYNTHASE ENZYME AS AN ALTERNATIVE CURING SYSTEM IN GROUND CHICKEN MEAT

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Objectives: To evaluate the impact of amino acid type, amino acid concentration, temperature, and time on the enzyme activity of the endothelial nitric oxide synthase (eNOS) system and its ability to generate nitric oxide (NO) as an alternative curing method in ground chicken meat.

Materials and Methods: The study consisted of independent trials based on 2 amino acids (AA), L-arginine (L-arg) or L-citrulline (L-cit), their combination (AC), and nitrite-treated controls. Ground chicken breast (93/7) was purchased from a local supermarket. A 1,600 g base blend was mixed with 0.5% phosphate, 2% salt, and 10% water for 1 min. This blend was divided into four 400 g batches. Each batch was blended with either AA or sodium nitrite ($NaNO_2$, Prague powder, 6.25%) for 1 min to achieve 1 of 4 concentrations (CONC): $NaNO_2$-treated samples (CONT) at 0, 120, 156, or 200 ppm, or an AA (L-arg or L-cit or a combination [AC] at 1,000, 2,000, 1,000/1,000 or 2,000/2,000 ppm, respectively). Sodium erythorbate was added (547 ppm) to all nitrite and AA-treated samples. After mixing, 25 g samples were extruded into two 50 ml centrifuge tubes. Tubes were placed in a water bath and heated to 37°C. At 37°C, samples were removed at 0 min or held for 45 min (TIME) then heated to a final endpoint temperature 73.9°C. Both 37°C and 73.9°C were considered as a temperature (TEMP) effect. After reaching 73.9°C, samples were vacuum packaged and held at 3°C for 7 d, then tested for residual nitrate, residual nitrite, and nitrosylation (nitrosylhemochromagen [NO-H] formation). The treatments were arranged as a 4 CONC × 2 TIME × 2 TEMP factorial for each AA and nitrite treatment in a randomized complete block design, replicated 3 times. Least-squares means and Tukey's HSD were used with a predetermined $P < 0.05$ significance level.

Results: For nitrite-treated samples, as CONC increased ($P < 0.05$) higher values of residual nitrate were observed, whereas in TEMP ($P < 0.05$), a higher value was observed at 37°C. A CONC × TIME and TIME × TEMP ($P < 0.05$) interaction was observed for residual nitrite. A TIME × TEMP interaction ($P < 0.05$) was observed for NO-H values with the greatest values occurring at 0 min and 73.9°C. For AA-treated samples, CONC increased residual nitrate values ($P < 0.05$), whereas TEMP ($P < 0.05$) at 37°C resulted in greater residual nitrate values. This can be attributed to the higher enzyme activity of eNOS at 37°C. Residual nitrite had TIME × TEMP interaction ($P < 0.05$) with increased residual levels as TIME and TEMP increased. A TIME × TEMP interaction was also observed for NO-H values with 0 min and 73.9°C generating the highest values. All NO-H values for AA-treated samples were lower than the nitrite-treated samples.

Conclusion: Results of this study indicate that eNOS can generate nitric oxide to form residual nitrite and NO-H to cure ground poultry meat. Holding meat at 37°C for 45 min with a combination of AA (L-arginine and L-citrulline at 1,000/1,000 or 2,000/2,000 ppm) enhances eNOS activity. Although AA-treated samples generated lower residual nitrate, nitrite, and NO-H values compared with nitrite-treated samples, this study provides evidence that this system holds promise for curing of poultry meat. Future research should investigate eNOS cofactors that may improve the nitric oxide generation.

Funding Source: This work is/was supported by the USDA National Institute of Food and Agriculture, AFRI project 2021-09606.

Keywords: arginine, citrulline, endothelial nitric oxide synthase, nitrosyl hemochromagen

24 THE EFFECT OF BROMELIN ON WARNER-BRATZLER SHEAR FORCE OF BEEF SEMITENDINOSUS STEAKS

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Objectives: The objective of this study was to determine if an increase in bromelin would alter the Warner-Bratzler shear force values of beef semitendinosus steaks.

Materials and Methods: USDA Select eye round roasts (IMPS# 171C; $n = 15$) composed of the semitendinosus muscle were purchased from a federally inspected meat purveyor and were randomly assigned to 1 of 3 treatments. Treatments consisted of no bromelin added (CON), bromelin added at the rate of 1.0% raw weight (TRT1), and bromelin added at the rate of 2.0% raw weight (TRT2). Steaks measuring 2.54 cm in thickness were cut ($n = 40$/treatment), treated with the bromelin, and then vacuum tumbled for

1 h. After tumbling, steaks were vacuum sealed, placed into cooler storage (4°C) for 3 d, and then frozen at −5°C. After freezing, samples were removed (10/treatment) and thawed at 4°C for 24 h. After the 24 h thaw period, steaks were cooked on a clam shell grill to a medium degree of doneness (71°C) and then chilled at 4°C for another 24 h. Following the chilling timeframe, Warner-Bratzler shear force was completed on each steak with multiple cores (4 minimum) taken from each to determine tenderness values. Data were analyzed using the MIXED model procedure of SAS (v. 9.4, SAS Institute, Cary, NC) as a completely randomized design with the fixed effect as bromelin percentage. Least-squares means were computed for each dependent variable and statistically separated by a pairwise *t* test (PDIFF option of SAS) with a predetermined $\alpha = 0.05$.

Results: Results of the study indicated a significant increase ($P < 0.05$) in tenderness scores for each treatment. Steaks from TRT2 (3.46 kg) were significantly more tender ($P < 0.05$) than both the CON (4.46 kg) and TRT1 (3.82 kg) as indicated by lower Warner-Bratzler shear force values. Additionally, steaks treated with 1.0% bromelin were significantly lower in their Warner-Bratzler shear force values than the CON ($P < 0.05$).

Conclusion: In conclusion, these results indicate a positive reduction in shear force values with an increase in bromelin for the semitendinosus muscle in USDA Select beef eye round roasts.

Funding Source: Angelo State University Undergraduate Faculty Mentor Grant

Keywords: bromelin, semitendinosus, Warner-Bratzler shear force

25 THE EFFECT OF ACETIC ACID–TREATED NETS TO CONTROL TYROPHAGUS PUTRESCENTIAE GROWTH AND REPRODUCTION ON DRY-CURED HAM

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Objectives: Dry-cured ham is highly susceptive to ham mite, *Tyrophagus putrescentiae* (Schrank) (Sarcoptiformes: Acaridae), infestations and must be protected from this adulteration. *T. putrescentiae* is considered a zero-tolerant pest in food products. Although to a much less extent now because of the Montreal Protocol, methyl bromide (MB) fumigation is used to control ham mites to prevent adulteration of dry-cured hams. However, MB is a Class I ozone depleting substance and therefore must be eliminated. Previous research has identified polyester ham nets treated with liquid smoke as a viable option to replace MB for dry-cured ham producers. Acetic acid is theorized to be the active ingredient regarding the control of mites from liquid smoke, but it has not been proven. Therefore, the objective of this study is to determine if ham nets treated with acetic acid can reduce mite growth and reproduction on dry-cured hams.

Materials and Methods: To manufacture nets, xanthan gum (XG) powder at 1% concentration was added to a varying acetic acid (0% to 2%) concentrations. After the gum was solubilized, the solution was added into the netting machine to coat nets with resulting acetic acid solutions. Using a double roller system, pickup of polymer solution by the nets was confirmed to be 165 to 185 g/m. Coated nets were then vacuum packaged and stored at 4°C in the James E. Garrison Sensory Evaluation Laboratory of Mississippi State University for 2 wk until mite inoculation. The resulting nets' ability to control ham mites was then subsequently tested against 2 control treatments: exposed ham cubes (negative control [NC]) and ham cubes wrapped in coated polyester nets (positive control [PC]) consisting of 40% propylene glycol, 1% carrageenan, and 1% propylene glycol alginate. Ham cubes (2.58 cm^3) were prepared from whole dry-cured ham samples and stored in the refrigerator (4°C) before testing. Nets coated with varying acetic acid concentrations consist of 0.0%, 0.5%, 1.0%, 1.5%, and 2.0% acetic acid. Net treatments were carefully wrapped onto ham cubes prior to inoculation. Coated ham cubes were then inoculated with 20 adult mites (12 female, 8 male). Inoculated ham cubes ($n = 5$/treatment) were then stored in ventilated 4 oz jars at 25°C and 75% relative humidity for 14 d. After 14 d, total mite counts were taken. A randomized complete block design with 3 replications was used to determine if differences existed ($P \leq 0.05$) among treatments. Tukey's method was used to separate treatment means when differences existed.

Results: All acetic acid treatments harbored fewer mites than the negative control (Table 1). No other differences existed among all treatments, including the positive control. However, all acetic acid treatments were ineffective at controlling mite growth and reproduction, apart from 0%. Results indicate that AA is not effective at controlling mite growth and reproduction.

Conclusion: Although mite growth and reproduction are less than the negative control, acetic acid is not effective at eliminating mite growth and reproduction. Observed mite counts can be attributed to the coated polyester net's physical barrier properties when coated with XG.

Funding Source: USDA NRI Methyl Bromide Transition program (award number 2015-51102-24143).

Keywords: acetic acid, dry-cured ham, ham mites, methyl bromide, *Tyrophagus putrescentiae*

26 EVALUATING AMINO ACID TYPE AND CONCENTRATION FOR ALTERNATIVE CURING OF PORK SEMIMEMBRANOSUS MUSCLE

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Objectives: The objective of this study was to determine the effects of varying concentrations of L-arginine (Arg), L-citrulline (Cit) and a combination of Arg/Cit (AC) at varying concentrations (1,000, 2,000, 3,000, 4,000, or 5,000 ppm) on the ability of the endothelial nitric oxide synthase (eNOS) system to alternatively cure ground pork semimembranosus muscle.

Materials and Methods: Pork semimembranosus muscle (IMPS 402F) was ground (1.27 cm) then separated into batches (0.45 kg) and mixed with a 20% brine consisting of 9% salt, 5.75% sugar, and 1.75% sodium tripolyphosphate, with either 1.6% curing salt (200 ppm sodium nitrite) or either Arg or Cit or AC combinations at varying concentrations (1,000, 2,000, 3,000, 4,000, and 5,000 ppm) with 0.547% sodium erythrobate. After mixing (1 min), the 0.45 kg batches were extruded into two 50 mL centrifuge tubes (25 g samples) and then cooked in a water bath (starting temperature 21°C) until reaching 70°C (~2.5 h). After reaching desired temperature, tubes were pulled and placed on an ice bath, then vacuum sealed in a separate package, wrapped in tinfoil, and placed in the cooler (3°C) for 7 d. Samples were analyzed after 7 d for residual nitrate (RNO3) and nitrite (RNO2) (via ENO30 HPLC) and nitroslyhemochromagen (NO-heme) via spectrophotometry. This experiment was a factorial (3 amino acids × 5 concentrations) randomized complete block design with a nitrite control (200 ppm), with each treatment combination being replicated twice. Least-square means and Tukey's HSD was conducted with a $P < 0.05$ significance.

Results: There were no interactions between amino acid type and concentration ($P > 0.05$); therefore, they were treated as independent main effects. There were no statistical differences found between concentrations (1,000, 2,000, 3,000, 4,000, 5,000) in regard to RNO3 ($P = 0.212$), RNO2 ($P = 0.464$), or NO-heme ($P = 0.361$). Between amino acid types there was a significant difference ($P < 0.0005$) in RNO2 ($P = 0.0001$) with the AC combination exhibiting a greater value (24.36 ppm) than Cit by itself (23.85 ppm), and Cit exhibiting a higher value than Arg (17.50 ppm). Samples were in the optimal activity temperature range (37°C) for the eNOS system for ~10 min. Compared with previous research (Modrow and Osburn 2021), the length of time in the temperature range (32°C to 37°C to maximize eNOS enzyme activity) was shorter (10 min vs. 45 min). This may explain why there were no significant differences observed between amino acid concentrations. Although the eNOS enzyme did generate nitric oxide as indicated by RNO3, RNO2, and NO-heme analyses, the eNOS enzyme may not have had enough time at optimal temperature to fully utilize the amino acid substrates needed for the production of nitric oxide and could explain the lower levels of RNO2 observed.

Conclusion: The RNO3 and RNO2 levels were lower than expected; however, NO-heme levels were similar to previous studies in semimembranosus pork muscle. A combination of Arg/Cit appeared to be a more effective amino acid substrate for the eNOS enzyme, as evidenced by higher RNO2 values. Further research should be conducted to further examine the relationship between amino acid types, concentration, and time to establish the feasibility of the eNOS enzyme as an alternative curing system through the generation of RNO3, RNO2, and NO-heme.

Funding Source: This work is/was supported by the USDA National Institute of Food and Agriculture, AFRI project 2021-09606.

Keywords: alternative curing, endothelial nitric oxide synthase system, L-arginine, L-citrulline

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27 EFFECTS OF A NOVEL, NONALLERGENIC MUSTARD EXTRACT ON BEEF PATTY SHELF STABILITY

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Objectives: Utilization of nonallergenic, plant-based water binders could improve the shelf life of beef patties, thereby reducing food waste. The objective of the current study was to optimize mustard meal extract addition for improvement of shelf stability and physical appearance of fresh beef patties.

Materials and Methods: Nonallergenic water binder treatments included mustard meal extract (0.25%, 1.0%, and 2.0%), potato extract (2%; positive control), rosemary extract (2%; positive control), and no binder (control). Each batch consisted of 10 lb of ground beef along with 1% salt, 15% water, 0.2% onion granules, and the designated binder. The binders and other ingredients were added as a percentage of the meat block. Six batches of each treatment were made with Choice shoulder clod and chuck roll near 18:15 lean ratio. The meat blocks were coarse ground (10 mm) and then fine ground (3 mm). Each treatment batch was mixed for 2.5 min at 29 rpm in a DMX 50 mixer and then formed using a Patty-O-Matic 220A patty former into 16-mm-thick patties weighing 151 g each. The pH of each batch was tested, and 2 patties from each batch were analyzed for each of the following parameters: pH, fluid loss, lipid oxidation, objective color,

and subjective color. Patties were weighed on day 0 and day 4 of retail display to calculate percent retail fluid loss. Lipid oxidation was measured on day 0 and day 4 of retail display. Objective color (L^*, a^*, and b^*) and subjective color (discoloration scored 1 to 8) were evaluated every day of retail display. Data were analyzed using SAS (v. 9.4) software.

Results: There was no significant difference between treatments observed for pH ($P = 0.277$). Differences between treatments for fluid loss were observed ($P = 0.014$), with the control having the highest amount of fluid loss. Lipid oxidation exhibited a treatment by day of retail display interaction ($P < 0.001$). The control had higher values on day 0 than the treatments and subsequently increased to day 4, whereas treated patties' lipid oxidation remained constant from day 0 to day 4. There was an interaction observed between treatment by day of retail display for subjective color ($P = 0.002$). Additionally, there was a treatment by day of retail display interaction observed for a^* ($P = 0.002$). There was no interaction between treatment by day of retail display for b^* ($P = 0.714$) and L^* ($P = 0.255$). However, there were treatment differences observed for b^* ($P = 0.001$) and L^* ($P = 0.001$), with rosemary displaying the lowest b^* and L^* values.

Conclusion: All antioxidant treatments reduced fluid loss and lipid oxidation and improved objective color and subjective color over time when compared with the control. Regardless of mustard extract inclusion level, the mustard extract improved water retention and color stability of beef patties to the same degree as the inclusions of both potato and rosemary extracts

Keywords: beef patties, water binders, lipid oxidation, shelf life, mustard extract

28 EVALUATION OF THE EFFECTS OF HIGH-PRESSURE PROCESSING AND LACTIC ACID TREATMENTS ON QUALITY CHARACTERISTICS OF GROUND PORK THROUGHOUT RETAIL DISPLAY

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Objectives: Within recent years, regulatory bodies in the United States have raised interest in developing *Salmonella* performance standards for the pork industry, like what are commonly used for poultry. Additionally, organic acid and high-pressure processing (HPP) antimicrobial strategies have been shown to be detrimental to pork color, which can ultimately have negative effects on pork product marketability. However, recent research has shown that the combination of lower lactic acid concentrations and mild HPP may provide sufficient *Salmonella* control. The objective of this study was to evaluate antimicrobial treatments (lactic acid, mild HPP, or a combination) that reduce *Salmonella* concentrations in pork and their effects on product quality characteristics during 14 d of simulated retail display.

Materials and Methods: Noninoculated pork trim was treated with a combination of diluted lactic acid solution (Birko Lactic Acid 88%) at 0%, 2%, or 4% in a 30 s dip and HPP at 300 mPa for 3 min (No HPP with 0% LA, HPP with 0% LA, No HPP with 2% LA, HPP with 2% LA, No HPP with 4% LA, HPP with 4% LA). Treated pork trimmings were ground and formed into 112 g patties. Two treated patties were placed in a Styrofoam tray, polyvinylchloride (PVC) film overwrapped, and randomly assigned to a location in a simulated retail display cooler for 14 d at 1.7°C. Samples were evaluated on days 0, 7, and 14 for pH, aerobic plate counts, and lipid oxidation using a thiobarbituric acid reactive substances (TBARS) assay. Instrumental and trained panel ($n = 5$) color evaluation was conducted daily for 14 d simulated display period. Data in 3 replications of the 6 treatments were statistically analyzed within day of storage using the GLIMMIX procedure of SAS as a 3×2 factorial arrangement.

Results: Initial differences of lower aerobic plate counts on day 0 and 7 were observed in both treatments using 4% lactic acid and the combination of HPP and 2% lactic acid ($P < 0.05$). Sample pH was lower in HPP with 0% lactic acid and no HPP with 4% lactic acid on day 0, with no differences on days 7 and 14 ($P < 0.05$). There were no differences among any treatments in lipid oxidation, ground meat initial color, L^* values, and b^* values ($P > 0.05$). No differences in a^* values were observed through the first 6 d of retail display ($P > 0.05$). From day 7 through day 14 of retail display, 0% and 2% lactic acid and HPP samples had the highest a^* values ($P < 0.05$) and no HPP with 4% lactic acid consistently had the lowest a^* readings throughout retail display ($P < 0.05$).

Conclusion: There results suggest that lactic acid applications of 4% can be detrimental to ground pork color and pH, whereas HPP potentially has a positive effect on these characteristics, which are vital for consumer acceptance. Further investigations should be conducted to study the effects of HPP on pork color and its effects when combined with other antimicrobials.

Keywords: color, HPP, lactic acid, pork, retail display

29 EFFECT OF FRESH MEAT TUMBLING AND POSTMORTEM AGING ON TENDERNESS OF BEEF STEAKS

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Objectives: Tenderness is one of the most important eating quality attributes contributing to consumer acceptance of fresh meat products. However, with inconsistencies in tenderness across meat products, the industry is in need of a natural, postharvest processing strategy to ensure uniform product quality. Muscle structure disruption via mechanical force, such as through blade/needle tenderization, has been used by the industry but increases the likelihood of microbial contamination. Recent studies have found that fresh beef tumbling of subprimal muscle sections, without the addition of brine, can significantly improve instrumental and sensory tenderness of meat. Yet, the impact of tumbling on individual steak cut tenderness and the extent of tenderizing action of tumbling on high-marbled beef have not yet been explored. The objective of this study was to determine the effect of fresh meat tumbling application on tenderness and other meat quality attributes of beef loin steaks.

Materials and Methods: Boneless strip loins ($n = 15$) from 15 beef cattle (USDA Top Choice) were received at 2 d postmortem. The loins were cut into 7 sections of 5.72-cm thickness. Each section was randomly assigned a combination of postmortem aging (PM) time, either 2, 7, or 14 d, and tumbling time, either nontumbled (NT), 20 min tumble (T20), or 60 min tumble (T60). After each assigned aging, 3 steaks (2.54 cm thick) were cut from each loin section. The steaks were individually vacuum packaged and tumbled according to treatment in a Lance LT-30 meat tumbler at 8.5 rpm. The steaks were used for biochemical analysis, consumer sensory evaluation ($n = 88$), and Warner-Bratzler shear force (WBSF). Tumbling loss and cook loss were also determined. After tumbling, the steaks were allowed to bloom for 1 h and measured for color, CIE $L^*a^*b^*$. The data were analyzed using a PROC MIXED procedure of SAS with a significance level of $P < 0.05$.

Results: The result of WBSF did not reveal a significant difference between values that was due to tumbling or tumbling by aging interaction. The sensory panel revealed no difference between tumbling treatments but had shown significant differences that were due to aging and tumbling by aging interaction. The 2 d-T20 had tenderness liking scores similar to 7 d-NT and 14 d-NT ($P > 0.05$). In terms of overall liking, 2 d-T20 and 2 d-T60 were statistically similar to the 7 d tumbling treatments. Tumbling loss was more significant between aging treatments, but when tumbled for 60 min at 7 d PM, loss was the highest ($P < 0.05$). In terms of cooking loss, there was no difference found between 2 d PM tumbling treatments ($P > 0.05$). Yet, when tumbled for 60 min, 7 d PM samples had the highest cook loss, whereas 2 d PM samples had similar cook loss to 7 d-NT and 14 d-NT ($P > 0.05$).

Conclusion: Tumbling individual steaks as early as 2 d PM for 20 min can produce similar sensory tenderness liking to steaks aged for 7 d or 14 d and similar overall liking to 7 d tumbled treatments. Thus, tumbling steaks early postmortem can improve sensory tenderness and overall acceptance of higher-quality beef steaks, subsequently reducing the total aging time needed to improve product acceptability. Early PM tumbling for 20 min can also diminish water loss caused by cooking.

Funding Source: This work was supported by NCBA Beef Checkoff fund from the National Cattlemen's Beef Association.

Keywords: beef, fresh meat tumbling, meat quality, tenderness

30 EVALUATION OF EFFICACY OF SMOKE IN COMBINATION WITH ORGANIC ACIDS ON VARIOUS MICROORGANISMS

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Objectives: This study was conducted to assess the in vitro minimum inhibitory concentrations (MIC) of combinations of smokes and organic acids against both spoilage and pathogenic microorganisms.

Materials and Methods: Varying concentrations of up to 2% of smoke products were prepared in De Man, Rogosa, and Sharpe and tryptone soy broth. Smoke products tested are a combination of smoke fractions with lactic and acetic acid (SAL), being SAL1, SAL2, SAL3; a combination of smoke fractions with acetic acid (SA), being SA4, SA5, SA6; and a blank (no smoke fractions, acetic or lactic acid). Samples at pH 6.0 were aliquoted into 100-well honeycomb with inoculums of commonly occurring spoilage bacteria such as *Leuconostoc carnosum* and *Leuconostoc mesenteroides* (~4 log CFU/g) and pathogens such as *Escherichia coli* O157 (non-VTEC), *Listeria monocytogenes*, *Salmonella enterica* (~4 log CFU/g). The plates were placed in the Bioscreen-C at 20°C to generate growth curves. The modified Gompertz equation was used to determine the maximum growth rate (μmax; d^{-1}), which was further used to determine the MIC. The MIC was defined as the lowest concentration at which no growth occurred. Data were analyzed using the Solver tool in Microsoft Excel. MIC values obtained were analyzed using pooled t test to determine significant difference.

Results: All smoke organic acid combinations tested exhibited a similar inhibition pattern for spoilage organisms and pathogens. The study highlights the antimicrobial efficacy of smoke organic acid combination systems against shelf life–related meat microorganisms. SAL and SA inhibited all spoilage microorganisms at 20°C between 1.78% and 2.74%. There was no significant difference between SAL and SA ($P > 0.24$) for spoilage microorganisms. For the pathogens tested, a lower dosage was seen to be effective in most cases at 20°C between 0.44% and 2.2%. There was no significant difference between SAL and SA for

Escherichia coli 0157(non-VTEC), *Listeria monocytogenes*, and *Salmonella enterica* ($P > 0.49$, $P > 0.86$, and $P > 0.98$).

Conclusion: Organic acid/smoke fractions combinations were shown to be able to fully inhibit the growth of both spoilage and pathogenic bacteria, with lower concentrations needed to fully inhibit pathogens compared with spoilage microorganisms.

Keywords: acetate, lactate, predictive modelling, smokes

31 UTILIZATION OF PROSUR PHR AS A PHOSPHATE REPLACER IN INJECTION MARINATED CHICKEN

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Objectives: There is an increased consumer demand for natural and clean-label meat products, especially those marinated, such as chicken breast meat. An experiment was conducted to determine the effectiveness of using a novel phosphate replacer consisting of yeast and citrus extracts (natural flavor PRS PHR; Prosur, Naperville, IL) for improving meat quality compared with ingredients used in typical poultry marinades.

Materials and Methods: Broiler breast fillets were marinated using injection with a 20% target pump. Treatments consisted of marinade formulas containing 0.75% NaCl (based on final product formulation) and one of the following: 0.5% sodium phosphate (CONTROL), 0.5% sodium phosphate + 0.5% PHR (PHOS PHR), 0.5% natural flavor PRS PHR (PHR), 0.5% PHR + 1.5% native rice starch (PHR RICE), 1.5% modified potato starch (MPS), or 1.5% native potato starch (NPS). Fillets were assessed in both fresh and after frozen storage and thawing ($n = 30$ fillets per treatment in each state). Fillet pH, color (L^*), % pickup, % purge (holding overnight after marination), % cook loss, Meullenet-Owens Razor Shear Force (MORSF), and consumer sensory analysis were assessed. Data were subjected to analysis of variance where ingredient treatment and fresh/frozen state served as main effects.

Results: The PHR and PHOS PHR treatments had greater marinade pickup ($P < 0.05$) than the control and potato starches, whereas the PHR RICE was similar to the control and PHOS PHR ($P > 0.05$). Post-marination, pH was higher ($P < 0.05$) in treatments containing phosphates and/or PHR compared with potato starch treatments. L^* value increased with inclusion of starch ingredients post-marination. The MPS, NPS, PHR RICE, and PHR treatments had greater ($P < 0.05$) L^* values than the PHOS PHR and CONTROL, which were similar ($P > 0.05$). There was no difference ($P > 0.05$) in purge in fresh fillets, whereas frozen and thawed fillets had higher ($P < 0.05$) purge overall. In frozen and thawed fillets, the MFS had the highest purge, followed by the NPS and PHR when compared with control, PHOS PHR, and PHR RICE ($P < 0.05$). The frozen and thawed MFS fillets had higher cook loss than CONTROL, PHOS PHR, and PHR RICE ($P < 0.05$), whereas NPS was intermediate in fresh or frozen fillet treatments. PHR RICE and PHOS PHR were similar ($P > 0.05$) in cook loss to CONTROL in frozen and thawed fillet treatments, whereas PHR RICE and CONTROL were similar ($P > 0.05$) in fresh fillet treatments. Cook loss and overall yield (accounting for marination, premarinated through cooking) were inversely correlated ($r = -0.92$), whereas there was no significant correlation between pickup and overall yield. The native starches (NPS and PHR rice) had lower ($P < 0.05$) MORSF than remaining treatments, but all mean values were below 7 N indicating very tender meat. Consumer sensory analysis of the CONTROL, PHR, and MPS fillets indicated no significant differences ($P > 0.05$) in overall liking or texture between CONTROL and PHR. PHR had higher hedonic scores ($P < 0.05$), indicating more likeness, than MPS for these attributes, whereas CONTROL and MPS were similar ($P > 0.05$). Most consumers considered PHR and CONTROL as just about right for tenderness. There were no significant differences ($P < 0.05$) in flavor among the treatments.

Conclusion: The results suggest that the use of PHR as a phosphate replacer in chicken marinades can be used by processors and consumers desiring clean-label marinated products.

Funding Source: Prosur, Inc.

Keywords: chicken, clean ingredient, marination, quality, sensory

32 USE OF BIPHASIC GEL SYSTEMS AS FAT SOURCES IN MEAT AND PLANT-BASED BURGER PATTIES

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Objectives: To evaluate biphasic gel (BPG) systems as fat mimetics in meat and plant-based burger patties.

Materials and Methods: Two BPGs were made by mixing an oleogel phase (92.5% high-oleic soybean oil, 7.5% rice bran wax) with a hydrogel phase (96% water, 2% soy protein isolate, 2% κ-carrageenan) in 2 different ratios: 5:5 and 4:6, respectively. Beef control patties were made with ground 80% lean trimmings. BPG-containing beef patties were made with bottom rounds (*M. biceps femoris*) and 20% of 1 of the 2 BPGs. Control plant-based patties were formulated with textured soy concentrate, various binder ingredients, and ground coconut oil (20%) and in

BPG-containing patties, coconut oil was replaced by the BPGs. All patties were 12.7 cm in diameter and weighed approximately 113 g. Patties were packaged in an 80% O_2/20% CO_2 gas blend, stored at 2°C to 3°C for 14 d, and analyzed on days 0, 7, and 14, for color (CIE $L^*a^*b^*$), cook loss, shrink, instrumental texture (incisor puncture probe), lipid oxidation (TBARS), and sensory evaluation (9-member trained panel, 15-cm line scale). The study was replicated 3 times. Statistical analysis was done as a mixed model using JMP Pro 16.2.0, with significance at $P < 0.05$.

Results: In beef patties, cook loss and shrink were higher in control than in BPG patties and were unaffected by storage time. In raw patties, a^* and b^* were higher in BPG than in control patties on day 0, but not thereafter, and both decreased over time. L^* was highest on day 14 and lowest on day 7 and was unaffected by treatment. In cooked patties, a^* did not differ among treatments but was lower on day 7 and 14. b^* was lowest in control patties. TBARS values increased with time but did not differ between treatments. Instrumental stiffness was higher in control and remained steady over time. Toughness and mean shear force were highest in control patties and increased over time for all treatments. Sensory *Beef Burger Aroma*, *Juiciness*, *Chewiness*, and *Beef Flavor* were higher in control patties. Sensory *Off-flavor* was higher in 5:5 BPG patties on day 7 than in control patties on day 0.

In plant patties, cook loss was unaffected by time and was highest in control and lowest in 4:6 BPG patties. In raw patties, L^* was higher and a^* lower in BPG than in control patties on day 0, and both gradually decreased over time. b^* increased over time for all treatments. In cooked patties, L^* was highest in 4:6 BPG and lowest in control patties, and decreased in all treatments during time. a^* and b^* were always higher in control patties, with a^* decreasing during time among all treatments. b^* was highest on day 14 and lowest on day 7. No treatment or time effects were observed for shrink or TBARS. Instrumental stiffness was higher in control than in BPG patties and was unaffected by time. There were no treatment or time effects for instrumental toughness and mean shear force, and for sensory *Plant-based Burger Aroma*, *Juiciness*, *Tenderness*, *Chewiness*, and *Off-flavor*. *Plant-based Flavor*, decreased in all treatments over time.

Conclusion: This study successfully applied BPGs as fat mimetics in meat and plant-based burger patties. Because BPGs contain less saturated fatty acids, this application could result in a decrease in saturated fats in animal and plant-based products. Future research on this technology with similar applications should focus on the characterization of flavor and the addition of antioxidants.

Funding Source: United Soybean Board

Keywords: biphasic gel, burger patties, fat mimetic, high-oleic soybean oil

33 COMBINATION OF LIPID MODIFICATION AND LUTEIN FORTIFICATION IN HEALTHIER MEAT PRODUCT DEVELOPMENT

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Objectives: Lutein and omega-3 fatty acids can prevent age-related macular degeneration and promote overall health. Unfortunately, their consumption is currently low. Although they can be added to meat, processing, cooking, and storage can destroy or oxidize them. Encapsulation can improve their stability and content in meat. Our goal was to investigate the application of co-encapsulated lutein and omega-3 fatty acids in developing healthier meat products. Fish oil was used as the omega-3 fatty acid source because of its high DHA/EPA content.

Materials and Methods: Two fish oils (FO1: striped oil from Sigma; FO2: oil from Natural Force with antioxidants included) were used to make encapsulates. Chicken breast and pork back fat were obtained from the meat laboratory at Iowa State University. The mixture of fish oil (FO1 or FO2), garlic essential oil (GO), and lutein (LU) was core material (C), ovalbumin/alginate complex (OVA/AL (OVA: AL = 4:1)) was a wall (W) at the W: C ratio of 1:1. The core material was blended with 0.8% OVA solution, then added 0.2% AL solution. Antioxidants were added to stabilize FO-Lutein powder against oxidation. Five emulsified meat products were prepared using chicken breast (80%) and pork fat (20%) (G1: control, G2: free FO1, G3: free FO2, G4: FO1 encapsulates, G5: FO2 encapsulates), where 5% of pork back fat was substituted with FO. The sausages were cooked in a conventional oven until the internal temperature reached 165°F, followed by packaging in an oxygen-permeable plastic bag and stored in a cooler (2°C to 4°C) for 7 d. Proximate composition, lipid oxidation, and lutein retention rate were measured

($n = 3$). The two-way t test was applied to compare the mean values. A P value of <0.05 was considered statistically different.

Results: No significant difference in moisture (60% to 62%), protein (~16%), and lipid content (~20%) among each treatment in fresh meat batters. In cooked meat, G1 showed the lowest TBARS value (4.55 ± 0.58 mg MDA/kg meat), and the G2 group showed the highest (9.15 ± 0.86) until the fifth day, followed by G3 (7.95 ± 0.78). The TBARS values of G4 and G5 were significantly lower than G2 and G3 ($P < 0.05$), indicating that encapsulation effectively prevented lipid oxidation in cooked meat even when the antioxidant was present in initial fish oil (G3). The ratio of n-3/n-6 increased 2 times in cooked meat, from 0.36 (G1) to 0.6 to 0.9 (G2 toG5), upon incorporating FO-Lutein powder. The fatty acid profiles showed that encapsulating fish oil (G4, G5) prevented the decrease of EPA/DHA during cooking. After incorporating FO-Lutein powder, EPA and DHA significantly increased from 0.05% to 0.45% to 0.86% for EPA and 0.16% to 0.40% to 0.80% for DHA. In freshly cooked meat, lutein content was 6 to 7 times higher than control (35.94 µg/100 g meat) in G2 and G3 (181 to 222 µg/100 g meat) and 10 to 13 times higher in G4 and G5 groups (362 to 467 µg/100 g meat). After 7 d, the Lutein retention rate increased to 97.50% and 84.50% from 82.23% and 63.59% for FO1 and FO2 upon encapsulation, respectively.

Conclusion: Encapsulation effectively prevented lipid oxidation of fish oil and increased the lutein retention rate in cooked meat. Adding FO-Lutein powder significantly increases the lutein and EPA/DHA content in meat products, which will help increase the consumers' intake of those bioactive compounds and further promote people's health.

Funding Source: This work was supported by NIFA (Award No. 2019 51300 30244)

Keywords: co-encapsulation, fish oil, lipid modification, lipid oxidation, lutein

34 CONTROLLING GROWTH OF SLIME-PRODUCING LEUCONOSTOC MESENTEROIDES STRAINS IN FRANKFURTERS USING CLEAN-LABEL AND CONVENTIONAL PRESERVATIVE SYSTEMS

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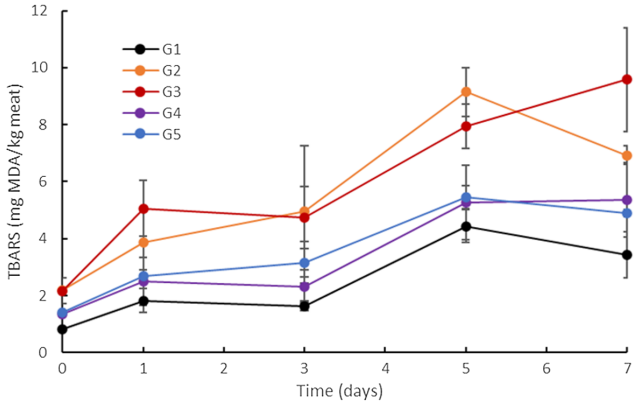
Objectives: The objective of this study was to assess a preservative combination for reduction of slime formation caused by growth of resistant *Leuconostoc mesenteroides* strains.



Materials and Methods: *L. mesenteroides* strains were isolated from spoiled frankfurters showing sliminess issues and spoilage levels larger than 6 log (CFU/g). In vitro studies were set up to determine the most effective preservative systems to reduce growth of these *L. mesenteroides* strains. Organic acid–based preservatives (propionates, acetates, 0% to 2%) and smoke A (Cloud SC100, 0% to 0.5%), smoke B (Red Arrow 20007, 0% to 0.5%), and smoke C (Red Arrow SmokeZ MB-45 GF, 0% to 1.2%) were incorporated in MRS broth, autoclaved, pH adjusted to pH 6, and transferred to 96-well plates. Each well was inoculated with overnight culture, and different plates are inoculated with different strains. Inoculated 96-well plates were covered and incubated at 7°C and measured daily at 600 nm.

Meat blocks for frankfurters were blended with smoke A (0.2% and 0.3%), Provian K (0.75%, 1%, 1.25%), and combinations thereof. Meat blocks were cooked in a water bath of 95°C for 35 min, cooled to room temperature, and inoculated with a cocktail of 2 slime-producing *L. mesenteroides* strains at 3 log (CFU/g). Samples were divided into 15 g portions, vacuum sealed, and incubated at 4°C. At $t = 0$, 4, 7, 9, 14, and 19, samples were plated by homogenizing using a Stomacher and streaking on MRS agar. Plates were incubated anaerobically at 30°C and counted after 48 h. The percentage of shelf-life increase was determined by comparing the time to reach the spoilage threshold of 6 log (CFU/g). Significance of results was determined by one-way ANOVA ($P < 0.05$).

Results: In vitro studies showed that several preservatives have a potential to be effective in reducing growth of the *L. mesenteroides* strains. Controls without preservatives started showing growth within 2 d and were in stationary phase after 10 d. No growth in vitro was seen during 34 d in media containing >0.23% smoke A, >0.23% smoke B, >0.21% smoke C, or >1.9% Provian K.

In application studies, 6 log (CFU/g) outgrowth was observed in the control treatment after 7 d at 4°C. A 14% increase in shelf life is possible by incorporating 0.3% Cloud SC100, 1.25% Provian K, or a combination of 0.5% Provian K+0.15% Cloud SC100 into the meat formulation. The most effective tested solution is a combination of 0.9% Provian K+0.1% Cloud SC100, resulting in a significant ($P < 0.05$) shelf life increase of up to 30%.

Conclusion: Although slime-producing *Leuconostoc mesenteroides* strains are organic acid salt resistant strains and reducing their growth is challenging, addition of Provian K, Cloud SC100, or combinations thereof have proven to be effective. The antimicrobial solution helps to extend shelf life by 30% while also reducing slime formation.

Keywords: preservation, shelf life, sliminess, spoilage control

35 SPOILAGE CONTROL IN FRESH GROUND BEEF WITH A CONVENTIONAL ACETATE-BASED PRESERVATIVE SYSTEM

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Objectives: This research shows control of spoilage flora in fresh ground beef with addition of an acetate-based preservative system at undesirable storage temperatures during storage of 13 d.

Materials and Methods: Three different treatments of fresh ground beef (93% fresh ground beef, 4% water, 3% spice mix) were prepared by blending ingredients in a food processor. Treatments included a control (no preservative), 0.5% potassium-based acetate/diacetate blend (PA/PDA), and 0.75% PA/PDA. Blended fresh ground beef was inoculated with a cocktail of 3 *Listeria* sp. strains at 3 log (CFU/g). The inoculated beef was divided into 20 g samples, vacuum packed, and stored at a consecutive temperature profile of 3 d at 2°C, then 3 d at 4°C, and finally 7 d at 7°C, representing the storage period during production, retail, and at the consumer, respectively. Samples were plated in triplicate on Tryptic Soy Agar (total plate count) and PALCAM agar (*Listeria* counts) at regular time points during storage. Significance of results was determined by one-way ANOVA ($P < 0.05$).

Results: During the first 3 d of storage at 2°C, the control treatment showed 1.7 ± 0.1 log (CFU/g) outgrowth on Tryptic Soy Agar, whereas both treatments containing PA/PDA only showed 0.1 ± 0 log (CFU/g) outgrowth. At 4°C, an additional 1.5 ± 0 log (CFU/g) increase was seen in the control treatment, whereas the PA/PDA treatments remained relatively stable with a 0.3 ± 0.2 log (CFU/g) increase. After 13 d, the control treatment reached 9 ± 0.7 log (CFU/g), whereas 0.5% PA/PDA and 0.75% PA/PDA resulted in 7.6 ± 0.1 and 7.3 ± 0 log (CFU/g) respectively. When taking 6 log (CFU/g) as a spoilage threshold, the addition of 0.5% and 0.75% PA/PDA resulted in a shelf life increase of 6 and 7 d, respectively, compared with the control reaching this threshold after 2 d. At all time points, control of *Listeria* sp., implying less than 2 log (CFU/g) outgrowth, is shown in the PA/PDA treatments.

Conclusion: The results of this study demonstrate the possibility to control spoilage organisms in fresh ground beef using conventional acetate-based preservatives at undesirable temperature storage conditions, in addition to controlling *Listeria* sp. outgrowth.

Keywords: pathogen control, shelf life, spoilage control

36 ENDOTHELIAL NITRIC OXIDE SYNTHASE ENZYME AS AN ALTERNATIVE CURING SYSTEM IN GROUND BEEF AND PORK

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Objectives: The objective is to evaluate amino acid (AA) type and concentration, temperature, and time on the ability of the endothelial nitric oxide synthase (eNOS) system to generate nitric oxide (NO) in ground beef and pork.

Materials and Methods: Independent trials based on 2 species (beef and pork), 2 AA, L-arginine (L-arg) or L-citrulline (L-cit) and their combination (AC), and nitrite-treated ($NaNO_2$, Prague powder) samples were conducted. Ground beef or pork (80/20; ~2,000 g) were mixed with 2% salt and 10% water, then split into 454 g batches. Each batch for each species type was blended with either AA or $NaNO_2$ for 1 min to achieve 1 of 4 concentrations (C): $NaNO_2$-treated beef and pork samples at 0, 120, 156, or 200 ppm and AA beef samples of L-arg or L-cit or AC at 2,000, 4,000, 2,000/2,000, or 4,000/4,000 ppm, respectively. AA-treated pork samples C were 2,000, 3,000, 2,000/2,000, or 3,000/3,000 ppm, respectively. After mixing (1 min), 25 g samples were placed in tubes and heated (water bath) to 37°C. At 37°C, samples were removed at 0 min or held for 45 min (TIME), then heated to a final endpoint temperature (T) of either 55.6 (pork, heat treated) or 70°C (beef and pork, fully cooked). Samples were cooled, vacuum packaged and held at 3°C for 7 d, then tested for residual nitrite (RNO_2) and nitrosylhemochromagen (NO-H) formation. AA content and eNOS activity were also analyzed. The experiment was a 4 C × 2 TIME × 2 T (pork at 3 T) factorial for each species in a randomized complete block design with 3 replications. Least-squares means and Tukey's HSD were used, with predetermined $P < 0.05$ significance level.

Results: C impacted AA content of beef AA-treated samples ($P < 0.01$) for both L-arg and L-cit, with 4,000/4,000 AC having the greatest AA content. A TIME × T interaction ($P < 0.05$) was observed for AA content of AA-treated pork samples. Greater L-arg values were noted at 45 min at higher T, whereas T increased L-cit values ($P < 0.05$). No

differences in AA content were found for $NaNO_2$-treated samples in either beef or pork. A TIME × T interaction ($P > 0.05$) was observed for eNOS activity of AA-treated beef samples, with higher eNOS activity at 45 min and 70°C. T increased ($P < 0.0001$) eNOS activity of pork AA-treated samples. T affected eNOS activity of beef and pork $NaNO_2$-treated samples ($P < 0.05$), with lower eNOS at higher T. AA-treated beef RNO_2 levels increased at higher C ($P < 0.05$) and longer TIME ($P < 0.01$). C × T and TIME × T interactions ($P < 0.0005$) were observed for AA-treated pork. These interactions were also in beef and pork $NaNO_2$-treated samples. C × TIME and TIME × T interactions were observed for NO-H values of AA-treated beef and pork. NO-H levels tended to be higher at 0 min and higher C and lower at 45 min and lower T, respectively. Three 2-way interactions occurred for NO-H levels in $NaNO_2$-treated beef samples with NO-H values tending to increase as each effect increased. A C × T interaction existed for pork $NaNO_2$-treated samples. Higher C and T tended to increase NO-H levels.

Conclusion: AA-treated beef and pork samples showed higher RNO_2 and NO-H levels and were similar to $NaNO_2$-treated samples. Greater L-arg or L-cit C and longer TIME increased RNO_2 and NO-H levels in beef and pork AA-treated samples. Allowing the eNOS enzyme to remain at 37°C for 45 min enhanced enzymatic activity, indicating that these factors must be considered for eNOS to be used an alternative curing system.

Funding Source: This work is/was supported by the USDA National Institute of Food and Agriculture, AFRI project 2021-09606.

Keywords: endothelial nitric oxide synthase, L-arginine, L-citrulline, residual nitrite

37 EFFECT OF PACKAGING TYPE AND EXTENDED FREEZE STORAGE ON COLOR AND LIPID OXIDATION OF GROUND BEEF

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Objectives: Freezing is one of the best methods utilized by food service and export markets for extended storage. However, freezing decreases the redness of ground beef and increases lipid oxidation. Hence, improving the color of frozen products can enhance marketability and consumer preference. However, limited studies have been performed to evaluate the effects of packaging types and extended frozen storage on ground beef color. The objective of this study was to evaluate the effect of 4 packaging types and frozen storage time on the lipid oxidation of ground beef patties.

Materials and Methods: Three beef shoulder clods were obtained from a commercial producer and coarse ground. Patties that were 150-g patties were randomly assigned to polyvinyl chloride overwrap (PVC), vacuum, high oxygen–modified atmospheric packaging (HiOx-MAP), and carbon monoxide–modified atmospheric packaging (CO-MAP). The HiOx-MAP gas composition consisted of 77.78% oxygen and 14.74% carbon dioxide. Before freezing, HiOx-MAP and CO-MAP patties were stored at 2°C for 24 h to facilitate oxymyoglobin and carboxymyoglobin formation, respectively. Patties were frozen in the dark at −5°C for 3, 90, or 180 d. Following each frozen storage time, L^*, a^*, and b^* values were initially recorded using a HunterLab MiniScan spectrophotometer prior to thawing. Patties were then thawed for 24 h at 4°C and cooked to 70°C, at which L^*, a^*, and b^*readings were taken for the external and internal surfaces. Lipid oxidation was conducted utilizing a modified procedure from Witte et al. (1970) after the thawing period had elapsed. The data were analyzed using the Proc GLM Procedure of SAS, and significant difference was noted at $P < 0.05$.

Results: A raw freezing × packaging interaction effect ($P < 0.001$) occurred for L^*, a^*, b^*, chroma, and hue as time under storage increased. CO-MAP retained significantly greater ($P < 0.001$) redness than all other packaging types at 180 d of frozen storage. CO-MAP was also more stable, maintaining significantly similar ($P > 0.05$) redness between day 0 and 180 of storage, whereas all other packaging methods had decreased redness ($P < 0.001$) between day 0 and 180. There were significant freezing × packaging effects ($P < 0.05$) for cooked patties L^*, a^*, b^*, chroma, and lipid oxidation. All packaging types significantly decreased ($P < 0.001$) redness over the duration of the study, with CO-MAP and HiOx-MAP displaying the highest external cooked redness ($P < 0.001$) compared with other packaging methods. Vacuum packaging displayed the highest internal cooked color ($P < 0.01$) at day 0 compared with all other packaging methods but was significantly similar to all other packaging methods ($P > 0.05$) at day 120.

Conclusion: CO-MAP packaging conditions contribute to a higher retention of external redness while maintaining an acceptable degree of internal redness. The current study suggests that CO-MAP could be a viable packaging method for the long-term freezing of ground beef patties.

Keywords: cooking, freezing, ground beef, meat color, packing

38 EVALUATION OF CLEAN-LABEL INGREDIENTS FOR REPLACEMENT OF PHOSPHATES IN ENHANCED FRESH PORK

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Objectives: Phosphates are traditionally used in meat products because of their ability to alter pH, bind water, and extend color life while making the product more tender and juicier. Recently, clean labels have become a trending issue among consumers, with particular concerns for phosphates. The objective of this study was to evaluate potential clean-label ingredients to replace phosphates in enhanced pork loins.

Materials and Methods: Five clean-label phosphate-free brines were injected into boneless pork loins, and the effects on their color, texture, and sensory characteristics were evaluated over a 21-d storage period. Fresh pork loins were injected with 6 different brines and included an uninjected (UNIN) negative control. The injection brines were composed of (1) water, salt, sodium tripolyphosphate, and potassium lactate (SPH) (positive control); (2) water, sodium bicarbonate, potassium chloride, yeast extract, dried vinegar powder, and acerola cherry powder (INCL); (3) the ingredients of INCL plus rice bran extract (RICE); (4) the ingredients of INCL plus plum concentrate (PLUM); (5) the ingredients of INCL plus Proteus (a commercial functional meat protein) (PR13), all injected at 13%; and (6) the ingredients of PR13, but injected to 18%, as recommended by the supplier (PR18). Loins were sliced into chops, packaged, and stored at 2°C for a maximum of 21 d. The chops were analyzed for proximate composition on day 0 and for pH, color (CIE L^*, a^*, b^*), and texture (Warner-Bratzler Shear) on days 0, 7, 14, and 21. Sensory analysis was performed on days 7, 14, and 21. The study was replicated 3 times. Statistical analysis was conducted as a mixed model using JMP Pro 16.2.0 (SAS Institute, Cary, NC), with significance established at $P < 0.05$.

Results: The trained sensory panel found SPH, RICE, PLUM, and PR18-treated chops to be juicier than the uninjected (UNIN) control ($P = 0.003$). RICE and PR18-treated chops were also more tender than UNIN ($P = 0.005$). Considering all treatments, the overall tenderness was greater on day 21 than on days 7 and 14 ($P = 0.009$). The UNIN-treated chops were chewier than those with RICE, PR13, and PR18 treatments ($P = 0.006$). RICE-treated chops had greater pork flavor than all other treatments, whereas the UNIN chops were less flavorful than those injected with RICE, PLUM, and PR18 brines ($P = 0.001$). The RICE brine resulted in darker color than all others, and UNIN chops were lighter than chops from RICE, PLUM, PR13, and PR18 treatments ($P = 0.000$). The chops with INCL, RICE, PLUM, PR13, and PR18 brines were all redder than those with SPH ($P = 0.002$), whereas INCL, PR13, and PR18 brines resulted in chops that were yellower than those from UNIN, SPH, and RICE brines ($P = 0.000$).

Conclusion: The results indicate that the rice bran extract appears to have the greatest potential among the ingredients evaluated to serve as a supplemental phosphate alternative. The treatment containing rice bran extract resulted in similar juiciness, tenderness, and pork flavor to the phosphate-treated chops but with darker color and no noted off-flavors. The rice bran treatment, in conjunction with other clean-label ingredients, may be considered for enhancement of fresh pork loins and chops, although all the ingredients tested would be adequate phosphate replacement choices.

Funding Source: Iowa Pork Producers Association

Keywords: clean label, enhanced pork, phosphate replacement, plum concentrate, rice bran extract

39 EFFECTS OF SODIUM NITRITE AND TOCOPHEROL INCORPORATED POLY (LACTIC ACID) FILMS ON DARK-CUTTING BEEF COLOR

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Objectives: Meat color plays a vital role in purchasing decisions. Thus, consumers discriminate against products that deviate from the traditional bright cherry-red appearance, such as dark-cutting beef. Applying nitrite-embedded packaging to dark-cutting beef has shown improved retail color redness but results in a red color/persistent pink color when cooked at 71°C. Recently, there has been a shift from petroleum-based plastics to biodegradable plastics composed of bio-based polymers like poly(lactic acid) (PLA). However, limited use of PLA was reported in meat systems because of the variable moisture, protein, and lipid content of meat and the packaging characteristics required to maintain meat shelf-life attributes. Moreover, an investigation on the effects of biodegradable films incorporating nitrite and an antioxidant on dark-cutting beef has yet to occur. The purpose of this work was to evaluate the effects of varying levels of sodium nitrite and α-tocopherol in PLA films on the color of dark-cutting beef.

Materials and Methods: A low-concentration (LC) PLA pellet was compounded using a twin screw extruder with 0.12% sodium nitrite and 0.5% α-tocopherol. The protocol was repeated to obtain a high-concentration (HC) PLA pellet that incorporated 0.6% sodium nitrite and 2.5% α-tocopherol. Extruded PLA was oven dried before being compression molded into film sheets. Dark-cutting beef strip loins ($n = 7$; pH = 6.40) and USDA Choice beef strip loins ($n = 7$; pH = 5.55) were selected at a commercial packaging facility.

Dark-cutting loins were sliced into 2.54-cm steaks and were randomly assigned to be packaged with polyvinyl chloride (PVC) overwrap or in a control, LC-PLA, or HC-PLA vacuum package. Normal pH steaks were sliced into 2.54-cm steaks and packaged in PVC. Steaks were placed in simulated retail display for 6 d. Surface color was measured using a HunterLab spectrophotometer and a trained panel ($n = 6$) every 24 h. On day 5 of display, half of the steaks were removed from display and cooked to 71°C on a George Foreman grill to evaluate cooked color appearance instrumentally and visually. Data analysis was conducted using the GLIMMIX procedure of SAS, and significance was considered at $P < 0.05$.

Results: There was a packaging type × day interaction for a^* values and muscle color score during display. HC-PLA film steaks demonstrated greater ($P < 0.05$) redness (a^* values) compared with LC-PLA film steaks and dark-cutting steaks in vacuum packaging after day 1. Additionally, HC-PLA film steaks showed color changes ($P < 0.05$) closer to a bright cherry red during display and were similar to normal pH steaks in PVC on days 5 and 6. Moreover, LC-PLA film steaks had greater a^* values than dark-cutting steaks in vacuum packaging from day 2 until the conclusion of display. In addition, HC-PLA film steaks exhibited a redder ($P < 0.05$) external cooked color appearance than all other treatments. HC-PLA steaks also demonstrated greater ($P < 0.05$) internal cooked color redness compared with normal pH steaks in PVC and dark-cutting steaks in PVC and vacuum packaging. Alternatively, LC-PLA film steaks showed a similar ($P > 0.05$) external and internal cooked color appearance to dark-cutting steaks in vacuum packaging.

Conclusion: The results indicate that LC-PLA films allow for improved retail color redness without negatively impacting the cooked color appearance compared with dark-cutting steaks in vacuum packaging.

Funding Source: This research was funded by the Oklahoma Center for the Advancement of Science and Technology.

Keywords: cooked color, dark-cutting beef, nitrite-embedded packaging, retail color

Meat and Poultry Quality

40 TEXTURE PROFILE ANALYSIS AND CONSUMER SENSORY RATINGS OF GROUND BEEF FROM US RETAIL STORES

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Objectives: The objectives of this study were to collect market data on type (lean point, primal-specific, packaging, etc.) of ground beef sold in United States retail stores and to assess texture profile and sensory characteristics.

Materials and Methods: Ground beef was collected between October 2021 and February 2022 from 11 cities: Atlanta, GA; Chicago, IL; Denver, CO; Houston, TX; Kansas City, MO; Los Angeles, CA; Las Vegas, NV; New York, NY; Philadelphia, PA; Seattle, WA; and Tampa, FL. Retail chains represented at least one-third of the city's total market share. Ground beef was packed with ice and shipped to Texas A&M University. Upon arrival, products were refrigerated. Packages destined for color evaluation were opened and allowed to bloom for 30 mins before objective and subjective color measures were taken. Ground beef patties were formed and frozen until subsequent thawing and cooking on an electric charbroil grill for texture or consumer analyses. Texas A&M Institutional Review Board approved consumer panel procedures for Use of Humans in Research (IRB2020-1233M), and panelists were recruited using a Qualtrics survey. Consumer panelists evaluated up to 7 samples using a 10-point scale for overall like, flavor like, tenderness like, level of tenderness, and juiciness like. For texture assessment, cooked patties were refrigerated for 12 to 18 h, removed from the cooler and equilibrated to room temperature before two 2.54 cm cores were removed for compression using TMS-Pro Food Texture Analyzer. Data were analyzed using JMP Pro, v. 16.0.0. Analysis variance (ANOVA) was performed using the Student's *t* test function, and least-squares mean comparisons were separated using an alpha level of <0.05. Least-squares mean comparisons were analyzed for subjective color panel, pH, objective color, consumer ratings, and texture profile results.

Results: Approximately 68.26% of the ground beef packages in self-service cases had at least one brand/claim on the package, with natural being the most prevalent followed by hormone and antibiotic free. Chuck was the predominant primal-specific item, followed by sirloin and then brisket. The most frequently reported lean point was 80/20, followed by 90/10 and 85/15. The brightest color, bright red to very bright red, was observed in the 90% to 99% lean group across all package types. Consumer panelists rated products in polyvinyl chloride overwrapped trays the lowest for overall like, flavor like, and juiciness like. Data also revealed that as lean percentage increased, consumers' preference for tenderness like and level decreased ($P < 0.05$). Texture profile analysis data for cohesiveness, hardness, gumminess, and chewiness generally decreased as fat level of ground beef increased. Ground beef containing 90% to 99% lean from chub packaging had the highest means for hardness 1 and 2 in conjunction with the highest means for gumminess and cohesiveness, indicating that the product had a tough first and second bite and required the most energy to chew.

Conclusion: Results showed that package type and lean point played a role in the overall texture and sensory attributes of the ground beef products. These data provide a national baseline of ground beef in the US retail market for factors such as color, consumer sensory ratings, and texture profile analyses based on different lean percentages and package type.

Funding Source: This study was funded, in part, by the Beef Checkoff.

Keywords: ground beef, lean point, packaging, sensory, texture profile analysis

41 EVALUATION OF GROUND BEEF COLOR UNDER NITRIC OXIDE–MODIFIED ATMOSPHERE IN COMPARISON WITH CARBON MONOXIDE, AND HIGH OXYGEN–MODIFIED ATMOSPHERES

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Objectives: The objective of this study was to evaluate the viability and performance of nitric oxide–modified atmosphere packaging (MAP) as a novel alternative to high oxygen and carbon monoxide MAP for ground beef.

Materials and Methods: Fifteen 4.5 kg chubs of fresh commodity ground beef were allocated to 1 of 3 MAP treatments: 80% O_2 and 20% CO_2 (HI-OX; $n = 5$), 0.4% CO, 30% CO_2, and 69.6% N_2 (CO; $n = 5$), or 0.4% NO and 99.6% N_2 (NO; $n = 5$). Each chub was ground and formed into 0.45 kg bricks before being placed into deep rigid plastic trays and flushed with the designated gas. Packages were allowed to equilibrate in the dark at 2°C to 4°C for 48 h prior to display in coffin-style retail display cases under fluorescent lighting. Descriptive color and instrumental color were evaluated every 12 h for 120 h. Three scans were averaged for each sample for instrumental data. Descriptive color was evaluated by 6 trained panelists using an 8-point scale from 1 = very bright red to 8 = tan to brown. Discoloration was evaluated on a percentage basis. Metmyoglobin (MMb), oxymyoglobin (OMb), and deoxymyoglobin (DMb) were calculated based on absorbances at 470, 530, 570, and 700 nm wavelengths. Data were analyzed as randomized block design with repeated measures with MAP type, display time, and their interaction as fixed effects and chub as the block. Significance was determined at $P \leq 0.05$.

Results: There was a MAP × time interaction for descriptive color scores ($P < 0.001$) in which HI-OX packages from 96 to 120 h were tan to brown, whereas CO packages at 0, 24, and 36 h and HI-OX packages from 0 to 24 h were bright red ($P < 0.05$). NO packages were moderately dark red at 12 and 24 h and were dull red at 120 h ($P < 0.05$). CO packages were bright red at 0 h and slightly dark red at 120 h ($P < 0.05$). Percent discoloration had a MAP × time interaction ($P < 0.001$) in which CO had the least discoloration ($P < 0.05$). HI-OX had more discoloration at 120 h than at 0 h ($P < 0.05$). NO had less discoloration at 120 h than at 0 h ($P < 0.05$). L^* values were greater ($P < 0.001$) in CO, intermediary in HI-OX, and less in NO ($P < 0.05$). L^* were greatest ($P = 0.002$) at 0, 12, and 24 h and least at 60 h ($P < 0.05$). There was a MAP × time interaction ($P < 0.001$) for a^*, where CO and HI-OX were the greatest at 0 and 12 h; however HI-OX was the least at 108 and 120 h ($P < 0.05$). There was a MAP × time interaction for b^* ($P < 0.001$), where HI-OX packages at 0 to 24 h were the greatest, whereas HI-OX packages at 108 and 120 h were the least ($P < 0.05$). There was a MAP × time interaction for MMb ($P < 0.001$) where HI-OX had the most at 120 h and NO had the least at 120 h ($P < 0.05$). CO had intermediary levels of MMb but did not vary with time ($P > 0.05$). There was a MAP × time interaction for OMb ($P < 0.001$) where NO had the most at 0 h, CO had the least, and HI-OX had intermediate levels ($P < 0.05$). There was a MAP × time interaction for DMb ($P < 0.001$) where HI-OX had the least at 108 and 120 h and CO had the most ($P < 0.05$). NO had more DMb at 108 and 120 h than at 0 h ($P < 0.05$).

Conclusion: Despite an initial darker-red color, NO samples became more red and decreased in discoloration over the display period, whereas HI-OX became more brown and increased in discoloration. CO packages maintained less discoloration and more redness than NO and HI-OX over the display period. This work warrants further research to optimize the use of NO-MAP for ground beef.

Keywords: carbon monoxide, ground beef, meat color, modified atmosphere packaging, nitric oxide

42 SUPPLEMENTATION OF OMEGA-3 FATTY ACIDS IN FINISHING DIETS ON BEEF TENDERNESS AND COLOR

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Objectives: The objectives were to determine if omega-3 fatty acid supplementation to beef steers impacts meat color and tenderness.

Materials and Methods: Black-hided yearling steers ($n = 700$) were purchased from regional sale barns and transported to Kansas State University Beef Cattle Research Center between March 30 and April 8, 2022 (Kansas State University Institutional Animal Care and Use Protocol

4760). After a 2-wk acclimation, cattle were weighed, implanted, blocked by body weight, and allocated to 28 pens. Pens were randomly assigned to a treatment consisting of a control diet without supplemental omega-3 fatty acids or an omega-3 diet (10% of an extruded proprietary blend of flaxseed, wheat middlings, and *Nannochloropsis* algae replacing soybean meal and a portion of corn). Cattle were transitioned to diets over 3 wk using 3 step-up diets and were fed twice daily, ad libitum. Cattle were reimplanted on day 90 of the study and fed for a total of 175 d.

On day 173 of the experiment, one animal was selected at random from each pen, weighed, and transported to a commercial abattoir in Butler, MO, for harvest. Cattle ($n = 28$) were harvested as 2 cohorts spaced 24 h apart. A loin muscle sample was collected between the 12th and 13th rib on day 3 postmortem and stored at −80°C. Three days after the last harvest, carcasses were fabricated into subprimals. Short loins were transferred to North Dakota State University for further analysis. At day 10 postmortem, short loins were fabricated into steaks (~2.5-cm) for Warner-Bratzler shear force (WBSF) and retail display. A sample was also collected for desmin degradation by western blotting and stored at -80°C until analysis. WBSF and cook loss analysis were conducted in accordance with AMSA guidelines. Strip steaks for retail display were placed onto Styrofoam trays and overwrapped with polyvinylchloride overwrap and placed in an open cooler at 4°C. Using a Minolta CR410 colorimeter, steaks were scanned daily for 7 d for L^*, a^*, and b^*. SDS-PAGE and western blotting for desmin degradation were done on day 3 and day 10 samples. Immunoreactive bands for desmin were observed at 56 and 48 kDa. Data for shear force and desmin were analyzed using PROC MIXED of SAS (Cary, NC) with means considered significant when $P \leq 0.05$. Repeated measures were used for analysis of retail display.

Results: Treatment did not influence WBSF values ($P = 0.17$), desmin degradation ($P \geq 0.17$), or Minolta L^*, a^*, and b^* values over time ($P \geq 0.15$). There was a day effect ($P < 0.03$) in which L^*, a^*, and b^* values decreased throughout the 7-d period.

Conclusion: Supplementation with omega-3 fatty acids in steer finishing diets did not affect measurements of tenderness or color, indicating omega-3 fatty acids can be supplemented in beef diets without impacting meat quality.

Funding Source: Funded by the Beef Checkoff program

Keywords: beef, omega-3, quality

43 COMPARISON OF EATING QUALITY FROM GRAIN FED USDA A-MATURITY TO C, D AND E MATURITY BEEF CARCASSES

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Objectives: The objective of this study is to compare the palatability traits between young A skeletal maturity to old C, D, and E skeletal maturity. Utilization of old cull cows that have C, D, or E skeletal maturity as a palatable, economically friendly alternative to conventional young cattle can create a more sustainable beef industry. With the demand for high-quality beef and the Choice-Select spread increasing, there is a need for a product that has a comparable eating experience to young cattle and can fulfill the consumers' desire for USDA Prime Beef.

Materials and Methods: Sections measuring ~10 cm were removed from the anterior portion of the strip loin from carcasses representing Old (O) maturity ($n = 448$) and Young (Y) maturity ($n = 423$) and were equally selected across marbling scores: Abundant to Slightly Abundant (PR), Moderate (MD), Modest (MT), Small (SM), and Slight (SL). For each sample, the muscle was denuded, weighed, and divided into three 2.5 cm-thick samples, one of which was used for consumer sensory panels, and then frozen after a 21-d wet-aging period. Steaks were pulled ($n = 25$; 5 per quality grade) and thawed in a refrigerator for 16 to 18 h at 2°C prior to being cooked for consumer panels. Five George Foreman Grills, one for each quality grade, were assigned to cook unseasoned steaks. Each 1-in consumer panel steak was cut in half prior to being placed on the grill. The half steaks were cooked to an internal temperature of 70°C, cut in half, plated, and served to consumers. A 10×10 Latin square was utilized to create a randomized eating order for the consumer panel ($n = 320$; 20 per panel). Consumers received 10 steaks representing all quality grades × age combinations to evaluate overall liking, tenderness, juiciness, beef flavor intensity, and flavor liking as well as acceptability of these traits. Additionally, consumers were asked their willingness to pay (WTP) on an individual sample basis. Consumer data were recorded utilizing Qualtrics.

Results: PR-Y and MD-Y were liked more ($P < 0.05$) for overall liking, tenderness, and juiciness compared with any other treatment combination. Consumers found MT-Y to be similar ($P > 0.05$) in tenderness compared with PR-O but more tender ($P < 0.05$) than MD-O. Consumers found PR-Y and PR-O to have a greater flavor liking ($P < 0.05$) than MD-Y, MT-Y, and MD-O, which were alike ($P > 0.05$). SL-O was liked less ($P < 0.05$) than all other treatment combinations in overall liking, tenderness, juiciness, and flavor liking. PR-Y, MD-Y, and PR-O were alike in juiciness and flavor-liking acceptability ($P > 0.05$). Consumers found PR-O and MD-O higher in overall liking ($P < 0.05$) and WTP than MT-Y and SM-Y.

Conclusion: Consumers found beef carcasses that exhibited a skeletal maturity coupled with Prime and Moderate marbling to have greater overall liking, tenderness,

and juiciness; however, steaks from cattle over 30 mo of age were still highly acceptable, especially in flavor liking and juiciness. Follow-up studies should include analysis of the chemical composition of old and young beef steaks through proximate analysis and REIMS.

Funding Source: Texas Tech University

Keywords: consumer panels, maturity, sustainability

44 EFFECTS OF ELECTRICAL STIMULATION ON TOTAL PEPTIDES AND FREE AMINO ACIDS IN BEEF SEMIMEMBRANOSUS MUSCLE

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Objectives: Electrical stimulation (ES) accelerates postmortem metabolism in muscles, thus altering the concentration of water-soluble flavor compounds (WSFC). This study examined the effects of ES on total peptides and free amino acids, a subgroup of WSFC, in postmortem beef *semimembranosus* muscle.

Materials and Methods: Tissue samples from ES carcasses (20 s at 20 V; $n = 14$) were collected immediately after exsanguination (PRE: before stimulation), immediately after stimulation (POST), and at 24 h postmortem (H24). CON carcasses were sampled with similar time intervals. The samples were snap-frozen in liquid nitrogen and stored at −80°C. Water-soluble flavor compounds were extracted in a solvent mixture of perchloric acid, water, and acetonitrile, neutralized by potassium carbonate, and filtered through a 3-kDa membrane. Total peptides were analyzed using a Pierce Quantitative Colorimetric Peptide Assay kit (#23275, Thermo Scientific, Waltham, MA). Free amino acids were derivatized by propyl chloroformate and separated, identified, and quantified using gas chromatography–mass spectrometry. Data were analyzed in a generalized linear mixed model with treatment and time as fixed effects and animal as a random effect, and an appropriate covariance structure for repeated measurement was selected. Actual probability values were reported.

Results: There was a 2-way treatment × time interaction for total peptides, glutamine, histidine, lysine, methionine, tryptophan, and phenylalanine ($P \leq 0.036$). For total peptides, ES and CON did not differ at PRE and POST ($P \geq 0.111$); however, ES was 1.21 mg/g greater than CON at H24 ($P = 0.007$). Twenty-eight amino acids were quantified in the water-soluble fraction of the beef *semimembranosus* muscle. The predominant amino acids were alanine, β-alanine, and histidine, ranging from 0.92 to 2.18 mmol/kg. Cysteine, hydroxylysine, and serine had the least concentrations, ranging from 0.01 to 0.03 mmol/kg. Glutamine was above the taste threshold of 0.04 mmol/kg and only greater by 0.05 ($P = 0.028$) and 0.06 mmol/kg ($P = 0.006$) in CON at PRE and POST, respectively. Histidine was also above the taste threshold of 0.73 mmol/kg and only greater in CON at both PRE (by 0.34 mmol/kg; $P < 0.001$) and H24 (by 0.28 mmol/kg; $P < 0.001$). Lysine was above the threshold of 0.04 mmol/kg and greater in ES at H24 (by 0.14 mmol/kg; $P = 0.002$). Methionine was greater in CON at PRE (by 0.01 mmol/kg; $P = 0.004$) but was similar between CON and ES at POST and H24 ($P = 0.076$). Tryptophan was greater in CON at POST (0.01 mmol/kg; $P = 0.017$) but was similar between CON and ES at PRE ($P = 0.219$) and H24 ($P = 0.328$). Phenylalanine was greater in CON at POST (by 0.01 mmol/kg; $P = 0.025$), although it was greater in ES at H24 (by 0.01 mmol/kg; $P = 0.025$).

Conclusion: Beef flavor precursors such as glutamine, methionine, and tryptophan were greater in CON samples at PRE and POST, although by H24 ES content was similar to CON in semimembranosus muscle. Phenylalanine and lysine, important Maillard reaction amino acids, were greater in ES by H24. Therefore, ES increases the postmortem concentration of some WSFC precursors in beef semimembranosus muscle that contribute to beef flavor.

Funding Source: This work was supported by the National Institute of Food and Agriculture, US Department of Agriculture, Hatch project under accession # 1014643.

Keywords: amino acids, beef, electrical stimulation, peptides, water-soluble flavor compounds

45 2022 NATIONAL BEEF QUALITY AUDIT: PHASE 1 - INTERVIEWS

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Objectives: The National Beef Quality Audit (NBQA) has been conducted 6 times over the past 30 years to assess and benchmark quality in the US beef industry. The audits provide insights to cattle producers as they develop policy, resulting in improvements in US beef quality and safety. The 2022 audit will allow the industry to gauge progress since the 2016 audit. Phase I of NBQA consists of interviews with persons involved in purchasing beef at each sector of the supply chain and with peripherally related government and allied entities.

Materials and Methods: Interviews ($n = 130$) were conducted with the aid of a software tool (Qualtrics) via mixed modalities of telephone, face-to-face, and video calls. Virtual interviews were necessitated in this version of NBQA because of the COVID-19 pandemic. Interviews were conducted with person(s) in companies that were knowledgeable about their company's cattle or beef purchasing practices including packers ($n = 24$), retailers ($n = 20$), further processors ($n = 26$), food service companies ($n = 18$), and allied government agencies and trade organizations ($n = 42$). As indicated by the interviewee, interviews were routed based on their involvement in either the fed or cow/bull markets, or both. Interviews were split into sections to determine Willingness to Pay (WTP) for quality factors, Must-Haves (quality factors that are required to make a purchase), Best/Worst (ranking of quality factors based on importance), how interviewees defined quality terms, a SWOT (Strengths, Weakness, Opportunities, Threats) analysis, general beef industry questions, and sustainability goals (the latter 4 being free response). Categories for differing aspects of cattle/beef quality included 1) visual characteristics, 2) cattle genetics, 3) food safety, 4) eating satisfaction, 5) animal well-being, 6) weight and size, 7) lean, fat, and bone, and 8) sustainability. Must-Haves, WTP, and Best/Worst were analyzed according to NBQA 2016, and all free-response answers were aggregated by market sector, coded for themes, and reported as frequency.

Results: Best/Worst analysis revealed that food safety was the most ($P < 0.05$) important factor in beef purchasing decisions for all sectors and was frequently described as "everything" and "a way of business." The SWOT analysis indicated that "eating quality of US beef" was the greatest strength. In the market cow/bull portion, the biggest concern identified in all market sectors was foreign material contamination in beef, such as "bird-shot." Irrespective of whether companies' products were fed or market cow/bull beef, respondents said that they believed "environmental concerns" were among the most major threats to the industry. Additionally, when interviewees were asked about their company's sustainability goals, most were aware that their company had sustainability goals, but nearly 1/3 of respondents were unaware of what and how these goals would be achieved. Lastly, the market sectors showed a desire for improved traceability within the supply chain.

Conclusion: Compared with previous NBQAs, interviewees no longer considered food safety as a purchasing criterion but rather as a market expectation. The beef industry's image has improved across market sectors since NBQA 2016 for both fed and market cow/bull beef. Respondents also indicated that the market cow/bull industry has improved practices tied to animal well-being; however, continued producer education on animal well-being is warranted.

Funding Source: National Cattlemen's Beef Association, National Beef Checkoff

Keywords: National Beef Quality Audit

46 IMPACT OF PRODUCT SIZE AND SUBSEQUENT CONSUMER FREEZING ON COLOR AND WATER-HOLDING CAPACITY OF DIFFERENT BEEF MUSCLES

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Objectives: Freezing is the most common method to prolong the shelf life of meat products. However, different product sizes could impact the freezing rate and impair the final meat quality. Furthermore, multiple freeze-thaw cycles are prevalent during distribution, retail storage, and even within consumer households. Although the effect of a repeated freeze-thaw cycle on meat quality has often been reported in the industry, the impact of subsequent freezing using consumer freezing methods is still limited. The objective of this study was to determine the impact of different product sizes and subsequent freezing on the color and water-holding ability of different beef muscles.

Materials and Methods: Paired *M. longissimus lumborum* (LL), *M. gluteus medius* (GM), and *M. semitendinosus* (ST) muscles were obtained at 3 d postmortem from beef carcasses ($n = 12$; USDA Low Choice) and aged until 28 d postmortem. At the end of the aging period, paired muscles were assigned to either section freezing (SEC) or steak freezing (STK). All samples were then cut into 3 equal sections and randomly assigned into 3 different freezing methods (blast freezer [BLS], chest freezer [CST] and refrigerator freezer [FRI]). Samples assigned for SEC were weighed and individually vacuum packaged. Sections assigned to STK were further cut into at least 4 steaks prior to weighing and vacuum packaging. All samples were then placed in a closed box, frozen and stored at −20°C for 5 wk. Samples

were then thawed until an internal temperature of 2°C and were then refrozen and stored at the assigned freezer type for 5 wk. At the end of the freezing treatments, samples were thawed similar to previous methods. SEC samples were cut into steaks and STK samples were immediately used for pH, purge loss, drip loss, and 5 d simulated color display analyses. Data were analyzed in a balanced complete block design with a split-plot arrangement using the PROC GLIMMIX procedure of SAS.

Results: No treatment effects were observed for the final pH of LL and ST samples ($P > 0.05$). Significant treatment interaction was observed for the final pH of GM, where STK-CST had the highest pH, whereas SEC-BLS had the lowest. For LL, drip and purge loss was not impacted by the treatment ($P > 0.05$). The GM muscle showed a significant interaction effect for drip loss where STK-CST had the highest loss ($P < 0.05$). Size effect was observed in both GM and ST muscles, exhibiting greater purge loss in SEC samples compared with STK samples ($P < 0.05$). Product size plays a key role in determining the meat color during the display compared with the freezer type. A size × day interaction was observed on all muscles, indicating lower CIE a^* and greater hue angle in STK samples compared with SEC ($P < 0.05$). Similarly, sensory color evaluation also indicated significant interaction ($P < 0.05$), where STK samples display rapid discoloration and loss of lean color compared with SEC.

Conclusion: The results of this study suggest that product size plays a role in determining the final frozen meat quality. SEC was observed to induce greater purge loss in both GM and ST muscles. However, SEC freezing generated products with superior color stability compared with STK during display, exhibiting greater redness and lower discoloration development. Further studies to identify the oxidative stability and palatability of the products are currently under investigation.

Funding Source: Funded in part by The Beef Checkoff

Keywords: beef, color stability, consumer freezing, double freezing, retail ready cut

47 COMPARISON OF COLOR CHARACTERISTICS AND OXIDATIVE STABILITY OF 5 BOVINE MUSCLES WITH PROLONGED POSTMORTEM AGING IN RETAIL DISPLAY

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Objectives: Postmortem (PM) aging is an effective method to improve the organoleptic properties of meat. However, longer aging is often accompanied by a decrease in meat quality characteristics such as color degradation. It is known that color and lipid oxidative stability may deteriorate during aging, but the extent of deterioration may vary between individual muscles. Because meat color is the first factor affecting consumer purchase decisions, it is essential to comprehend the effect of extended aging on color and oxidative stability and relevant biochemical attributes of different muscles. The aim of this study was to determine color characteristics and oxidative stability of 5 bovine muscles during retail display after postmortem aging.

Materials and Methods: Pairs of 5 muscles, *bicep femoris* (BF), *gluteus medius* (GM), *infraspinatus* (IF), *longissimus lumborum* (LL), and *semitendinosus* (ST), were obtained at 1 d PM from 16 beef carcasses. Muscles were divided into 4 equal sections, vacuum packaged, and randomly assigned 1 of 4 aging times (2, 21, 42, or 63 d). After aging, 2-cm-thick steaks were cut, covered with PVC film and displayed for 7 d under light for instrumental and trained color panel evaluations. Biochemical analyses including 2-thibarbituric acid reactive substances (TBARS), thiol content and total reducing activity (TRA) were conducted. All treatment levels were analyzed using PROC MIXED procedure of SAS 9.4 to examine the main effects of muscle, aging, and display duration, as well as their interactions.

Results: As aging time increased, the CIE a^* of all muscles decreased after retail display ($P < 0.05$). At this time, LL and ST showed higher CIE a^* than other muscles, and similar chroma values ($P < 0.05$). Hue angle values did not differ at the start of retail display, regardless of aging time ($P < 0.05$) but increased with PM time after display ($P < 0.05$). The trained color panel determined that lean color score increased in all muscles at the beginning of retail display with longer aging time and decreased with PM time after display ($P < 0.05$). Lean color scores of LL and ST were higher than the other muscles for all aging times ($P < 0.05$). LL and ST showed the lowest discoloration score at the end of retail display ($P < 0.05$). At the initial display, there was no difference in lipid oxidation between muscles because of aging time ($P < 0.05$). However, TBARS values increased in all muscles according to postmortem time after display, with the highest value at 63 d ($P < 0.05$). IF, LL, and ST exhibited lower TBARS levels than other muscles after retail display ($P < 0.05$). Thiol decreased in all muscles as aging time increased, and ST showed the lowest protein oxidation during display ($P < 0.05$). Throughout aging periods, TRA was higher in IF than other muscles, which was consistent after display ($P < 0.05$).

Conclusion: The results from the present study found that prolonged aging can negatively affect color and oxidative stability of muscles. However, the extent of discoloration and lipid and protein oxidation with aging varied between muscles. Of the 5 bovine muscles, LL and ST exhibited superior color and oxidative stability during retail display, suggesting that LL and ST muscles can undergo longer aging than other muscles.

Funding Source: This work was supported in part by Agriculture and Food Research Initiative Grant

2020-67017-31270 from the USDA National Institute of Food and Agriculture.

Keywords: beef quality, meat color, muscle specific, oxidation, postmortem aging

48 PREDICTIVE MICROBIOLOGY TECHNIQUES FOR PREDICTING ANTIMICROBIAL CONCENTRATIONS FOR SPOILAGE CONTROL

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Objectives: The objective of this study was to utilize predictive modelling techniques to determine use rates of different blends at different temperatures for potassium-based acetic acid salts (Provian K) preservatives.

Materials and Methods: A total of 5,000 hot dogs for different treatment formulations (0.25% to 0.75% Provian K, 1.25% to 3.5% Potassium lactate/sodium diacetate blend, 1.17% to 3.25% potassium lactate) and control (no antimicrobials) were inoculated (2 to 3 log CFU/g) with *L. sakei*, massaged in bags to disperse inoculum, vacuum packaged and stored at 2°C to 12°C for up to 120 d. At each sampling, sample homogenate was plated onto deMan, Rogosa, Sharpe agar for enumeration. Spoilage threshold and maximum population density at end of stationary phase was considered as 6 and 8 log CFU/g, respectively. Data generated through the experiments was used for primary modelling using modified Gompertz equation to calculate maximum growth rate (μmax; log/day) and days to reach spoilage threshold for each treatment. To incorporate the effect of temperature and use rates for each treatment, μmax values were used to generate a secondary model using multiple regression. Statistical analysis and model building was carried out using JMP Pro version 15.1.0 (SAS Institute, Cary, NC), with significance set at $P < 0.05$.

Results: Inoculation level of ca. 3 log CFU/g of *L. sakei* was achieved on day 0 for all the treatments. Results to reach 6 log CFU/g for different treatments at different temperatures are presented in Table 1. Control treatments showed fastest growth of *L. sakei* at all temperatures, reaching 6 log CFU/g on 34-, 24-, 10-, 7- and 7-d storage at 2°C, 4°C, 7°C, 10°C, and 12°C, respectively. Provian K (0.75%) showed significantly enhanced shelf life compared with control ($P < 0.0032$) imparting 14-, 11-, 3-, 3- and 1-d shelf-life extension at 2°C, 4°C, 7°C, 10°C, and 12°C, respectively. The μmax obtained using these data for Provian K (0.75%) at 2°C, 4°C, 7°C, 10°C, and 12°C were 0.26, 0.28, 0.51, 0.54, and 0.69 log/d.

A high positive linear relationship was found between the predicted and the experimental values ($P < 0.001$) for all the antimicrobials. The model predicted μmax for each temperature and use rate of antimicrobial with 90% to 97% accuracy.

Conclusion: The model could help formulate and compare dosage rates of Provian K to control shelf life at different exposed temperature without repeating costly validation studies.

Keywords: frankfurters, Lactobacillus, predictive modelling, preservatives, spoilage control

49 IMPACT OF TRIMMING EXTERNAL FAT BEFORE COOKING ON PALATABILITY AND CALORIE CONTENT OF BEEF RIBEYE STEAKS

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Table 1. Time (days) to reach 6 log CFU/g for *L. sakei* at different temperatures

Treatment	Days to 6 logs for *L. sakei* at different temperatures				
	2°C	4°C	7°C	10°C	12°C
Control	34	24	10	7	6
0.25% Provian K	38	30	11	10	7
0.5% Provian K	42	32	11	10	7
0.75% Provian K	48	35	13	10	7
1.25% K Lactate/Na Diacetate*	39	29	11	9	8
2.5% K Lactate/ Na Diacetate*	43	33	11	10	8
3.5% K Lactate/Na Diacetate*	43	34	12	10	8
1.17% K Lactate**	40	29	12	9	8
2.34% K Lactate**	47	31	12	10	8
3.25% K Lactate**	48	35	13	10	8

*K Lactate/Na Diacetate: Potassium Lactate/Sodium Diacetate; **K Lactate: Potassium Lactate

Objectives: Consumer concerns about excess dietary fat have increased the practice of removing external fat from beef steaks prior to cooking. This practice, however, may be detrimental to meat eating quality. The objective of this study was to determine the effects of removing the external fat before cooking on the eating quality and calorie content of ribeye steaks.

Materials and Methods: Twenty *longissimus thoracis* muscles with Canada AAA ($n = 10$) and AA ($n = 10$) quality grades (equivalent to USDA Choice and Select, respectively) were obtained from a federally inspected commercial slaughter plant, vacuum packaged and transported under refrigerated conditions to the Lacombe Research and Development Centre (Agriculture and Agri-Food Canada). After an average of 28 d of aging, the muscles were removed from the vacuum packaging and fabricated into four 2.54-cm steaks. Half of the steaks were trimmed to 0.635 cm of external fat (cap on). The remaining steaks were completely trimmed of external and seam (kernel) fats (cap off), and the *longissimus* and *spinalis dorsi* muscles were combined with butcher's twine. Steaks were cooked on an electric grill to an endpoint temperature of 74°C. Subsequently, descriptive sensory analyses were performed by a 10-member trained meat evaluation panel and calorie analyses were conducted.

Results: Compared with muscles of AA steaks cooked with cap off, the AA steaks cooked with cap on had *longissimus* with higher initial and sustained juiciness ($P < 0.01$) and a tendency towards a smaller proportion of panelists detecting livery off-flavor ($P = 0.058$) and mealy texture ($P = 0.071$), and *spinalis* with a tendency towards fewer panelists detecting unidentified off-flavors ($P = 0.096$) and spongy texture ($P = 0.096$). When cooking the AAA steaks with cap on, the *longissimus* had a lower frequency of panelists detecting "other" off-flavors (i.e., burnt, rancid, barnyard, stale; $P<0.05$) and mushy texture ($P < 0.05$) and tended to have lower off-flavor intensities ($P = 0.083$), whereas the *spinalis* had higher beef flavor intensity and desirability ($P < 0.05$) and fewer panelists tending to detect "other" off-flavors (i.e., burnt, fatty, oily, rancid; $P = 0.052$), compared with steaks cooked with cap off. The more pronounced flavor effects in the *spinalis* compared with the *longissimus* of AAA steaks cooked with cap on could be due to the *spinalis* having higher endpoint temperatures than the *longissimus* muscles, which probably caused more Maillard reactions and more efficient fat melting. Regardless of the quality grade and muscle type, cooking steaks with cap on did not increase the calorie content ($P > 0.10$).

Conclusion: Overall, cooking ribeye steaks with external fat had positive effects on juiciness, flavor and texture without increasing the calorie content compared with steaks cooked without external fat. Educating consumers on the benefits of maintaining the external fat while cooking will improve the eating experience of Canadian beef.

Funding Source: Funding was provided by Canada Beef and this research was conducted as part of the Canada Beef Meat Quality Strategy.

Keywords: beef, calories, eating quality, fat

50 EFFECT OF DIFFERENT ELECTRICAL STIMULATION SYSTEMS ON BEEF QUALITY AND PALATABILITY: CONSTANT CURRENT VERSUS CONSTANT VOLTAGE

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Objectives: In North America, commercial carcass weights continue to increase and the efficacy of constant voltage electrical stimulation (CVES), also known as high voltage electrical stimulation, has been questioned. Comparing with previous studies using CVES, Prieto et al. (2022) have shown a higher efficacy of constant current electrical stimulation (CCES) to improve beef quality. Nevertheless, to date there are no studies comparing both electrical stimulation systems on the same carcass. Hence, the objective of this study was to evaluate the effect of 2 electrical stimulation systems (CVES vs. CCES) applied to the same carcasses on meat quality and palatability of finished steers.

Materials and Methods: In total, 38 crossbred steers within a wide range of hot carcass weight (348 to 476 kg) and fatness (7 to 26 mm) were used. At approximately 45 min pm, one carcass side was CCES (2.04 A for 1 min with 2 s ON/2 s OFF pulses), using a stimulator designed and built by Agriculture and Agri-Food Canada's Lacombe Research and Development Centre, whereas the other side was CVES with a commercial stimulator (480 V; Koch–Britton, Kansas City, MO). After slaughter, in *longissimus* muscle pH (45 min, 3 h, 3 d, 6 d) and subjective color (Japanese Meat Grading Association–JMGA–3 d) and objective color (L^*, a^*, b^*, hue, chroma–3 and 6 d, and after 4 d in retail display) were measured. Subsequently, purge loss (6 d), drip loss during retail display and cooking loss and shear force (3, 6, 12 d) were evaluated. Sensory analyses were performed by trained panelists on frozen-thawed 6 d aged steaks.

Results: The CCES resulted in a more pronounced decline of meat pH at 3 h pm (5.68 vs. 5.78, $P < 0.01$) and lower purge (12.30 vs. 13.70 mg/g, $P < 0.05$) and drip losses (45.21 vs. 47.98 mg/g, $P < 0.01$) compared with CVES. This faster pH reduction could prevent cold shortening in CCES carcasses by ensuring earlier rigor onset and less rigor contraction. Regarding color, CCES resulted in meat with better subjective JMGA scores (4.05 vs. 4.37,

$P < 0.05$) and a redder (higher a^*: 22.68 vs. 22.21, $P < 0.05$; higher hue: 34.79 vs. 34.47, $P < 0.01$), yellower (higher b^*: 15.78 vs. 15.25, $P < 0.01$), and more intense color (higher chroma: 27.64 vs. 26.94, $P < 0.05$) compared with meat from CVES carcasses. The improvement in color persisted at 6 d pm and also after 4 d in retail display, as meat from CCES carcasses was lighter (higher L^*: 40.73 vs. 40.03, $P < 0.05$), redder (higher hue: 35.46 vs. 34.98, $P < 0.05$) and yellower (higher b^*: 15.54 vs. 15.08, $P < 0.05$) than meat from CVES. The CCES tended to decrease shear force at 6 d pm (54.0 vs. 57.4 N, $P = 0.09$), however, this tendency did not translate into differences in either initial or overall tenderness evaluated by trained panelists ($P > 0.05$). Unexpectedly, meat from CVES carcasses had higher initial juiciness after 5 to 7 chews than meat from CCES (6.67 vs. 6.48, $P < 0.05$), but this difference did not persist for sustained juiciness after 15 to 20 chews ($P > 0.05$). The CCES resulted in meat with higher corn aroma (0.177 vs. 0.042, $P < 0.05$) and bloody/serumy flavor (0.765 vs. 0.487, $P < 0.05$), both attributes being considered positive by consumers.

Conclusion: These results show CCES as a more effective electrical stimulation method than CVES to enhance meat quality and flavor profile of finished steers, which could benefit the beef industry.

Funding Source: Financial support was provided by Results Driven Agriculture Research (RDAR) as well as by the Canadian Beef Cattle Industry Science Cluster through funding provided by the Beef Cattle Research Council (BCRC) and Agriculture and Agri-Food Canada.

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Keywords: beef, constant current, constant voltage, electrical stimulation, meat quality

51 INCREASING THE SHELF LIFE OF FRESH GROUND BEEF USING NATURAL FLAVORS

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Objectives: This study aimed to test the effects of natural flavors on the shelf life of fresh ground beef based on color, oxidative stability, and sensory assessment.

Materials and Methods: Fresh coarse ground beef (80% lean) was sourced from a commercial meat processor 7 d postmortem and processed at Corbion meat processing facility controlled at 2.2°C. The ground beef was mixed in 18.14 kg batches for 3 min in 30 s intervals of forward reverse cycles, followed by adding 0.2% Origin Powder RO2 (Natural Flavor; NF1) or 0.2% Origin Powder RB900 (Natural Flavor; NF2), respectively, while mixing for 5 min. Mixed beef was ground through a ¼'' plate, and 454 g samples were put on Styrofoam trays. The trays with samples were aerobically packaged with PVC film and stored in a display case with LED light (4,000 Kelvin) at 2°C for 8 d. The shelf-life study involved measuring color values (L^*, a^*, and b^*), TBARS, microbial analysis (aerobic plate count), conducting a sensory evaluation on day 1, and taking photos on days 1, 2, 3, 6, 7, and 8. A sensory assessment was performed using a trained sensory panel.

Results: Fresh ground beef with 0.2% Origin Powder RB900 (Natural Flavor; NF2) demonstrated the least amount of color change over 8 d of storage at 2°C, followed by samples with 0.2% Origin Powder RO2 (Natural Flavor; NF1), then negative control samples. The a^* and a^*/b^* values of the samples are shown in Table 1. The fresh ground beef samples with 0.2% NF2 had the lowest TBARS over 8 d of storage at 2°C, followed by the samples with 0.2% NF1, then the negative control samples. The aerobic plate count (APC) increased from day 1 through day 8, and all treatments reached >6 log CFU/g after 6 d of storage. The sensory test indicated that the fresh ground beef samples with NF1 had a saltier and more herbal flavor when compared with the negative control samples. Samples with NF2 were the closest in flavor when compared with the negative control samples.

Table 1. a^*, a^*/b^*, and TBARS value for the tested treatments during 8 days storage at 2°C

	a^* (Redness)			a^*/b^*			TBARS		
Day	Control	0.2% NF1	0.2% NF2	Control	0.2% NF1	0.2% NF2	Control	0.2% NF1	0.2% NF2
1	20.08 ± 0.95^{a}	20.11 ± 0.38^{a}	21.12 ± 0.98^{a}	1.01 ± 0.03^{a}	1.02 ± 0.02^{a}	1.06 ± 0.04^{a}	0.728 ± 0.041^{a}	0.520 ± 0.034^{b}	0.261 ± 0.025^{c}
2	17.54 ± 0.48^{a}	18.51 ± 0.52^{a}	17.92 ± 0.15^{a}	0.95 ± 0.01^{a}	0.96 ± 0.03^{a}	0.99 ± 0.01^{a}			
3	14.63 ± 0.79^{b}	16.25 ± 1.08^{a}	15.58 ± 0.78^{a}	0.89 ± 0.03^{a}	0.93 ± 0.03^{a}	0.95 ± 0.02^{a}	0.962 ± 0.098^{a}	0.566 ± 0.034^{b}	0.299 ± 0.009^{c}
6	7.47 ± 037^{c}	8.75 ± 0.77^{b}	10.49 ± 0.77^{a}	0.53 ± 0 01^{c}	0.6 ± 0.01^{b}	0.72 ± 0.02^{a}	1.325 ± 0.013^{a}	0.554 ± 0.059^{b}	0.280 ± 0.018^{c}
7	6.85 ± 0.37^{c}	7.69 ± 0.79^{b}	9.74 ± 0.79^{a}	0.48 ± 0.01^{b}	0.53 ± 0.03$^{b:}$	0.68 ± 0.02^{a}			
8	6.63 ± 0.46^{c}	7.35 ± 0.51^{b}	8.8 ± 0.77^{a}	0.46 ± 0.01^{b}	0.51 ± 0.02^{b}	0.62 ± 0.03^{a}	1.629 ± 0.059^{a}	0.529 ± 0.047^{b}	0.243 ± 0.052^{c}

Values presented in the table are mean ± standard deviation

$^{a\text{-}c}$Values with a different letter within the same row are significantly different ($p<0.05$)

Conclusion: Fresh ground beef samples containing Origin Powder RB900 (Natural Flavor; NF2) demonstrated more color retention and oxidative stability than samples containing Origin Powder RO2 (Natural Flavor; NF1) and negative control. The flavor of fresh ground beef samples with 0.2% NF2 had fewer off-flavors than 0.2% NF1 without negatively impacting the organoleptic properties of the fresh ground beef.

Funding Source: Corbion

Keywords: color stability, fresh ground beef, natural flavor, oxidative stability

52 EFFICACY OF SODIUM AND POTASSIUM ORGANIC ACID SALTS AGAINST FRANKFURTER SPOILAGE ORGANISMS AT REFRIGERATION AND ABUSE TEMPERATURES

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Objectives: The objective of this study was to assess the antimicrobial efficacy of sodium and potassium organic acid salts against *Lactobacillus sakei* and *Carnobacterium divergens* in a frankfurter system at refrigeration and abuse temperatures.

Materials and Methods: Mechanically separated chicken was processed into frankfurter treatments ranging from 0.25% to 0.75% potassium acetate/diacetate blend (Provian K), 0.06% to 0.16% sodium acetate and 1.17% to 3.25% potassium lactate and control (no antimicrobials). For each inoculum, 1,300 frankfurters were prepared per treatment. Frankfurters were separately inoculated with 2 to 3 $\log_{10}$ CFU/g *C. divergens* or *L. sakei*. Packages were vacuum sealed; stored at 4°C, 7°C, and 10°C; and sampled in duplicate up to 120 d. Additionally, uninoculated samples were kept for each treatment and monitored over the sampling period. For sampling, frankfurters were homogenized with sterile peptone diluent. Spread plating of homogenate was performed on BHI agar for *C. divergens*; MRS agar was used for *L. sakei*. Additionally, pH was measured on sample homogenate. Microbial outgrowth was compared via one-way ANOVA ($P < 0.05$), and spoilage time (6 log accrual) was estimated with Gompertz modelling in SAS JMP.

Results: A 2.5 $\log_{10}$ CFU/g microbial load was achieved in all inoculated samples. Uninoculated samples stored at 4°C did not spoil within the 120 d of sampling, ensuring background loads of bacteria were low. With *C. divergens* inoculum, 0.75% potassium acetate/diacetate blend showed optimal performance across all temperatures. Control treatments reached 6 $\log_{10}$ CFU/g on 15-, 5- and 5-d storage at 4°C, 7°C, and 10°C, respectively. Blend (0.75%) significantly ($P \leq 0.0001$) enhanced shelf life compared with control at these storage temperatures, imparting 11-, 12- and 3-d shelf-life extension. For *L. sakei*, potassium acetate/diacetate blend (0.75%) and potassium lactate (3.25%) conferred advantage. Although controls spoiled at 34, 24, and 10 d, potassium acetate/diacetate blend (0.75%) provided significant ($P \leq 0.0032$) extension of 11, 2, and 3 d at 4°C, 7°C, and 10°C respectively.

Conclusion: Potassium acetate/diacetate blend exhibited antimicrobial efficacy against spoilage organisms in processed meat at lower utilization rate compared with potassium lactate-based preservatives across a variety of spoilage organisms and temperature ranges.

Keywords: preservation, processed meat, spoilage

53 CHARACTERIZATION OF SPECIES-LEVEL SPOILAGE BACTERIA IN FRESH PORK BREAKFAST SAUSAGES USING NANOPORE AMPLICON LONG-READ SEQUENCING

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Objectives: Fresh pork sausages are highly perishable. The composition and abundance of microbiota that are present in meat products play important roles in the quality and shelf life of those meat products. The Oxford Nanopore amplicon sequencing technique is capable of sequencing the entire *16S rRNA* gene, which allows for species-level classification of bacteria. The objective of this study was to use Nanopore amplicon long-read sequencing to identify bacterial species that contribute to the spoilage of fresh pork sausages.

Materials and Methods: The treatments included (1) control with no antimicrobials (C); (2) buffered dry vinegar (BDV, 0.8%), and (3) rosemary extract (RE, 2,500 ppm). Sausage patties were packaged in polystyrene trays, overwrapped, and placed in a meat display case (2°C to 4°C) under fluorescent lights (1,000 to 1,200 lux) for 6 d. A split-plot design (sausage treatment as the main plot factor and evaluation day as the subplot factor) with 3 replications was used to determine the effect of antimicrobials on instrumental color, pH, visual color, descriptive sensory attributes, lactic acid bacteria (LAB) counts, aerobic bacteria plate

counts (APC), and bacterial composition and abundance using Nanopore sequencing.

Results: No differences existed ($P > 0.05$) in pH, lightness, yellowness, and sensory attributes/acceptability for all treatments. Furthermore, no differences ($P > 0.05$) existed among treatments regarding instrumental redness and visual color on day 6. Degree of difference (DOD) from the ideal fresh sausage sample was greater ($P < 0.05$) for all samples on day 4 than those on day 1, indicative of diminishing quality. LAB counts and APC did not differ ($P > 0.05$) among treatments on day 1. LAB counts increased ($P < 0.05$) on each storage day for each treatment; however, LAB counts on day 6 were greater ($P < 0.05$) for sausages C and RE than BDV. APC counts on day 6 for C and RE were greater ($P < 0.05$) than counts on days 1 and 4. In contrast, APC counts for BDV did not differ ($P > 0.05$) over 6 d of storage.

Each individual full-length *16S rRNA* amplicon was barcoded and pooled with Nanopore Native Barcoding Kit and Ligation Sequencing Kit. The DNA library pool (containing 81 barcoded library samples) was loaded onto a R9.4.1 MinION flow cell and sequenced on a GridION sequencer for 72 h. After processing, a total of 4,409,438 reads were generated with an average base accuracy of 95%. The sequence reads were aligned against the NCBI *16S rRNA* database using BLASTn, resulting in 93% of sequences being classified. A total of 2,917 bacterial species were detected in all samples. On day 1, the most prevalent bacterial species that was present in all 3 treatment sausages was *Brochothrix thermosphacta*. *B. thermosphacta* remained the dominant spoilage bacteria for sausages C and RE throughout 6 d of storage. For sausage BDV on day 6, however, the most predominant species were *Lactobacillus sakei*, followed by *Leuconostoc gelidum* subsp. *gasicomitatum* and *B. thermosphacta*.

Conclusion: In conclusion, BDV was effective at controlling bacterial growth, especially when *B. thermosphacta* is a major microbial concern in meat production. Further research will be conducted to determine the effect of *B. thermosphacta* on meat spoilage and track the source of bacterial contamination in meat production.

Funding Source: This publication is a contribution of the Mississippi Agricultural and Forestry Experiment Station, Mississippi State University.

Keywords: buffered dry vinegar, nanopore sequencing, sausage, spoilage bacteria

54 INFLUENCE OF FREEZING DURATION AND PACKAGING TYPE ON VOLATILE COMPOUND ANALYSIS OF BEEF STEAKS FROM 2 MUSCLES

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Objectives: The objective of this study was to determine the impact of extended freezing durations of various muscle types in differing packaging systems on final beef flavor development.

Materials and Methods: Paired beef strip loins and top sirloin butts were collected from USDA Choice carcasses ($n = 20$ carcasses). Vacuum packaged subprimals were aged for 14 d at 0°C to 2°C in the dark. Subprimals were portioned into 2.54-cm-thick steaks representing the *longissimus lumborum* (LL) and the *gluteus medius* (GM) and allotted to the randomly assigned packaging treatments: vacuum packaging (VAC) or overwrap packaging (OW). Once packaged, the steaks were transported from Canyon, TX to Fayetteville, AR to simulate product shipment from a case ready plant to retail. The steaks were then placed in a 3-d simulated retail display and then randomly assigned to 1 of 4 storage treatments: fresh (not frozen), 1-wk freeze, 1-mo freeze, 6-mo freeze, and 9-mo freeze, with frozen storage being maintained at −20°C. Prior to sliced volatile compound analysis, steaks were thawed at 2°C to 4°C, then cooked to an internal temperature of 71°C using clamshell grills. Following the cook process, steaks were homogenized in liquid nitrogen for volatile analysis. Volatile compounds were extracted by solid phase microextraction (SPME), and compound identity was conducted by gas chromatography–mass spectrometry (GC-MS). Seventy-one compounds were selected from major flavor pathways, including the Maillard reaction and lipid oxidation. Data were analyzed as a completely randomized $2 \times 2 \times 4$ factorial design where storage duration, muscle and packaging type served as the main effects. Significance was determined at $\alpha \leq 0.05$.

Results: Of the 71 compounds evaluated, the majority of compounds evaluated were impacted by the interaction of packaging, storage duration, and muscle (31 compounds; $P < 0.05$). Maillard reaction products, such as carbon disulfide ($P < 0.05$), 3-methylbutanal ($P < 0.05$), and methylpyrazine ($P < 0.05$) were primarily influenced by storage duration, where concentration linearly decreased from fresh with the highest concentration to 9-mo steaks with the lowest concentration. The majority of lipid-derived compounds from lipid oxidation were impacted by either the interaction of muscle × duration (3 compounds) or packaging × duration (3 compounds). As storage time increased, steaks stored in OW produced a greater concentration of 2-pentanone ($P < 0.05$), nonane ($P < 0.05$), and 1-penten-3-ol ($P < 0.05$), which are produced during lipid oxidation. Eighteen compounds were impacted by either the main effect of duration or packaging type. Nineteen compounds were not impacted by packaging, storage duration, or muscle type ($P > 0.05$).

Conclusion: These results indicate that the majority of flavor compounds, especially lipid-derived compounds, are impacted by a combination of storage duration, packaging

type, and muscle, however these factors are not independent of each other. This indicates that each of these factors have a strong influence over final beef flavor development. With the focus on case ready product at retail, considering how consumers store beef products for longer durations may be a factor in choosing packaging schemes for different muscle types.

Funding Source: This study was funded by the Beef Checkoff

Keywords: beef, flavor development, freezing duration, muscle type, packaging type

55 INFLUENCE OF FREEZING TYPE AND STORAGE DURATION ON CONSUMER PALATABILITY RATINGS OF GROUND BEEF PATTIES

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Objectives: The objective of this study was to evaluate the impact of freezing type and storage duration on consumer ratings of ground beef palatability traits.

Materials and Methods: 80:20 ground beef was procured from a commercial purveyor. Ground beef was fine ground through a 0.95 cm plate to create 10 batches and immediately formed into 130 g patties using an automatic patty maker. Patties were assigned at random to 1 of 3 freezer types ($n = 120$ patties/freezer): commercial blast freezer (BF), chest freezer (CF), and refrigerator top freezer (RF). Prior to frozen storage, patties ($n = 360$) were subjected to a 5-d simulated retail display under continuous fluorescent lighting in PVC overwrap packaging. Following display, patties were randomly allotted to a freezing duration: 1 mo, 6 mo, 9 mo, or 12 mo and vacuum packaged. Upon completion of the assigned storage duration, patties designated for consumer sensory evaluation ($n = 120$) were shipped to Manhattan, KS. Consumers ($n = 120$) evaluated each sample on a 100-point continuous line scales for flavor-liking, tenderness, texture, juiciness, and overall liking. At the end of each session, panelists were instructed to answer questions pertaining to household freezing habits for fresh meat products. Data were analyzed as a completely randomized 3×4 factorial design in which freezer type and storage duration served as the main effects and panel served as a random effect. Peak temperature was used as a covariate.

Results: No impacts were observed from the interaction of freezer treatment storage duration for any of the consumer ratings evaluated ($P < 0.05$). However, juiciness was influenced by the main effect of freezing treatment ($P = 0.01$). In comparison, patties from RF were rated as the least juicy ($P < 0.001$), whereas patties from the BF were rated as the juiciest ($P < 0.001$). Furthermore, freezing treatment also impacted consumer tenderness ratings ($P = 0.001$). Similarly, patties from the BF were rated as the most tender ($P < 0.001$), whereas RF patties were rated the toughest ($P < 0.001$). Consumer ratings for flavor, texture, and overall liking were contrastingly not impacted by the main effects of freezing treatment ($P < 0.05$). Additionally, the main effect of storage duration imparted no impact on any of the consumer ratings evaluated ($P < 0.05$). When asked about storage practices of meat products, it was found that 50.0% of consumers store meat in a refrigerator top freezer, compared with 38.5% that use a chest freezer and 9.0% that store product in a refrigerator and do not freeze. Additionally, survey results indicated that most (56.6%) consumers choose to store meat in the same retail packaging system, with the next most frequent packaging type being Ziploc (21.3%). Finally, results indicated that the length of storage among consumers is variable, with 33.6% stating they stored product from 2 to 4 wk, 21.3% from 3 to 4 mo, and 13.9% for 1 to 2 mo.

Conclusion: These results indicate that freezer type, regardless of storage duration, impacts consumer ratings for ground beef tenderness and juiciness, despite RF being the most common method of frozen storage among consumers. The negative impact of RF on tenderness and juiciness is likely a result of reduced WHC because of an increased incidence of ice crystallization and freezer burn as a result of fluctuations in air flow because of the more densely packed area and time spent open of RF when compared with both BF and CF.

Funding Source: This study was funded by the Arkansas Beef Council.

Keywords: beef, consumers, freezing duration, ground beef, storage

56 EVALUATION OF FRESH AND FROZEN BEEF STRIP LOINS OF EQUAL AGING PERIODS BY TRAINED SENSORY EVALUATION

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Objectives: Freezing is imperative for the meat industry for cold-chain management; however, previous studies have often compared freezing treatments across varied aging periods. Comparing fresh and frozen steaks of various aging periods has created conflicting sensory results, especially around tenderness. Therefore, the objective of this study was to determine the trained sensory palatability traits between fresh and frozen beef of equal aging periods.

Materials and Methods: Beef carcasses ($N = 72$; $n = 18$/collection; 6/aging period) were selected from a Midwestern

beef processing plant on 2 different kill dates, 1 wk apart and brought to Kansas State University (KSU) for processing. All carcasses were A-maturity and graded USDA Choice. Steaks were fabricated into 2.54-cm steaks and aged for either 21, 28, or 35 d. The frozen steaks were frozen for 1 wk at −20°C and the fresh steaks were held at 2°C to 4°C in the absence of light. On 21, 28, or 35 d of aging, all fresh and frozen samples were fed to trained panelists. Descriptive panelists were trained on common sensory panels conducted at KSU, which includes the use of a 100-point scale with anchors. Trained sensory panels were conducted by cooking samples to an internal peak temperature of 71°C monitored with a Thermapen inserted into the geometric center of the steak. Trained sensory panelists were asked to evaluate samples for initial juiciness, sustained juiciness, myofibrillar tenderness, connective tissue amount, overall tenderness, beef flavor intensity, and off-flavor intensity measured on a 100-point line scales anchored at 0 (extremely dry/tough/bland/none), 50 (neither juicy/dry/tough/tender), and 100 (extremely juicy/tender/abundant/intense). The data were analyzed as a 2 × 3 factorial between fresh and frozen and 3 aging periods with an alpha set at 0.05.

Results: Trained descriptive panelists determined the fresh samples were juicier ($P < 0.05$) than the frozen samples for both initial juiciness and sustained juiciness, while determining the frozen steaks were more tender ($P < 0.05$) for overall tenderness in comparison with the fresh steaks. No other differences ($P > 0.05$) were identified within the trained sensory results comparing fresh and frozen steaks. Surprisingly, there were no differences ($P > 0.05$) identified between the 3 aging periods. However, all 3 aging periods resulted in a minimum rating of 67 for myofibrillar tenderness and 65 for overall tenderness.

Conclusion: Trained panelists identified frozen samples as more tender than their fresh counterparts, whereas the fresh samples were juicier regardless of the aging period. These differences can be associated with the well-known processes of ice crystal formation and their impact on tenderness and water-holding capacity. This study provides more information about the impact of freezing between equally aged beef steaks.

Funding Source: Funded by the Beef Checkoff

Keywords: descriptive panels, fresh, frozen, meat quality, sensory

57 THE EFFECTS OF SOUS VIDE PREPARATION, AGING TIME, AND STEAK LOCATION WITHIN THE SERRATUS VENTRALIS ON TENDERNESS AND SENSORY CHARACTERISTICS OF THE DENVER STEAK

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Objectives: Study objectives were to test sous vide (SV) preparation as a method to improve tenderness and palatability within the *serratus ventralis* and compare the effects of aging and steak location on Denver steaks.

Materials and Methods: Paired *serratus ventralis* ($n = 40$) muscles from A-Maturity, USDA Prime carcasses ($n = 20$) were used to assess the effects of aging time (4 and 25 d; DOA), preparation method [SV heating, and control (CON);PREP], and steak location (posterior and anterior; LOC) on composition, color, and palatability traits. Paired muscles from the first 10 carcasses were aged 4 d and from the remaining 10 to 25 d. Within paired muscles left sides were assigned to SV and right sides to CON. Muscles designated for SV were vacuum packaged, submerged in a 57.6°C water bath for 12 h, then chilled to 4°C. Muscles were separated into anterior and posterior portions, and five 2.5 cm steaks were removed for analysis. Analysis included instrumental color, proximate composition, WBSF, and trained sensory panel. Instrumental color and proximate analysis were taken on SV heated and raw steaks, CON. For WBSF and trained sensory panels, all steaks were cooked on a clam shell grill to an internal temperature of 62°C.

Results: There was no DOA effect ($P = 0.75$) for percent protein, but 4 d steaks had greater fat and less moisture percent than 25 d steaks ($P < 0.04$). There was no PREP effect ($P = 0.80$) for percent fat, but SV steaks had more protein and less moisture than CON steaks ($P < 0.01$). Anterior steaks had more protein and moisture and less fat than posterior steaks ($P \leq 0.01$). All color attributes were affected ($P < 0.01$) by cookery as SV steaks had increased L^*, a^*, and b^* values. Anterior L^* values increased ($P < 0.01$) compared with posterior. In 4 d steaks, a^* and b^* values increase ($P < 0.01$) compared with 25 d steaks. There was a PREP × DOA effect ($P < 0.01$) for L^*, a^*, and b^* values and a PREP × LOC effect ($P < 0.01$) for a^* and b^* values. There was a DOA × PREP × LOC interaction ($P = 0.02$) for hue angle. Anterior SV steaks aged 25 d had the greatest hue angle, and posterior CON steaks aged 4 d had the smallest hue angle. There was a PREP × DOA interaction ($P < 0.01$) for juiciness as 4 d SV steaks were the juiciest. Trained panelist rankings and WBSF showed no tenderness increase ($P > 0.57$) in SV steaks compared with CON steaks and while not negating tenderness variation within the muscle for WBSF ($P < 0.01$). A DOA effect was found for initial and sustained tenderness ($P < 0.02$) as 25 d steaks values increased compared with 4 d. A tendency ($P = 0.08$) for initial tenderness was found as posterior steaks tended to be more tender than anterior steaks. The SV steaks showed decreases in juiciness and beef flavor intensity ($P < 0.01$).

Conclusion: This study found SV preparation negatively impacted subsequent juiciness while not improving tenderness within the muscle. Palatability differences could

be caused by differences in proximate composition as SV negatively impacted moisture and posterior steaks had a 4.6% greater fat percentage than anterior steaks. Sous vide preparation resulted in a less red, more yellow appearance. Further research is needed to understand composition differences within the *serratus ventralis* to possibly map a tenderness pattern and to optimize low-temperature long-time sous vide heating conditions to maximize palatability traits.

Funding Source: Georgia Agricultural Commodity Commission for Beef

Keywords: serratus ventralis, sous vide

58 DETERMINING THE EFFECTIVENESS OF ROSEMARY EXTRACT ON THE INSTRUMENTAL COLOR OF GROUND BEEF UNDER DIFFERENT LIGHTING CONDITIONS

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Objectives: The objective of this study was to determine the effectiveness of rosemary extract on the instrumental color of ground beef patties under varied lighting intensities in a simulated retail display.

Materials and Methods: Ground beef patties were produced using an 85% lean:15% fat blend purchased from a local retailer. This product was finely ground through a 0.953 cm plate and separated into 151.2 g patties ($n = 64$). During grinding, Kalsec Oleoresin Rosemary, Herbalox Brand XT-25 was added with a concentration of 0.20%. Patties were randomly assigned into a control group (no rosemary extract) or a rosemary extract group. A polyvinyl chloride overwrap was used to pack each patty individually. Two lighting intensity groups were formed (3,000 K vs. 3,500 K), and each patty was randomly assigned again. The patties were then placed in a simulated retail display for 5 d under continuous light emitting diode (LED) lighting and rotated once a day within a multideck display case. Three color samples were taken and averaged each day using the Hunter Lab MiniScan Easy Spectrophotometer (2.54 cm aperture, 10* observer, illuminant A) to obtain L^*, a^*, b^*, chroma, and hue angle values. Data were analyzed as a split-split plot design, with batch serving as the whole plot and patty serving as the subplot. Fixed effects in the model were lighting temperature, antioxidant treatment, and day of display. The Kenward-Rogers adjustment was used with all analyses. Statistical differences were considered significant at $\alpha \leq 0.05$.

Results: There were no 3-way interactions observed for any of the traits evaluated ($P = 0.3578$). There was an interaction for L^* between antioxidant and light ($P = 0.0029$), indicating that lightness value increases as lighting temperature increases. A 2-way interaction was observed between antioxidant and day a^* values ($P = 0.0003$). The antioxidant patties were redder throughout the display period compared with the control, implying that the antioxidant group has an extension of shelf life. A 2-way interaction was observed between day and antioxidant treatment b^* values ($P = 0.008$). Patties treated with antioxidant were more yellow than the control, extending the shelf life of b^* values by 1 day in the antioxidant patties. Chroma data indicated an interaction between antioxidant and day ($P = 0.0008$). Saturation values were statically similar on day 3 in the control group to day 4 values in the antioxidant group. A day and antioxidant interaction was present for hue angle ($P = 0.0008$), showing that hue angle values on day 3 in the control matched day 4 in the antioxidant. This pattern continued throughout the duration of the study following day 3, suggesting that the use of antioxidants could be useful in gaining an additional day in hue angle values.

Conclusion: Throughout the duration of this study, antioxidants continued to behave in a manner found in the recorded literature, regardless of lighting temperature. The use of antioxidants appears to decrease the degradation of color values throughout a 5 d retail period and could be used as a means of extending the shelf life of ground beef products.

Funding Source: This study was funded by the University of Arkansas Dale Bumpers College of Agricultural, Food, and Life Sciences Research and Creative Project Grant Funding Program.

Keywords: antioxidants, color, ground beef, lighting, retail display

59 FREEZING DURATION AND PACKAGING TYPE INFLUENCE TRAINED PANEL RATINGS OF BEEF STEAKS

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Objectives: Our objective was to evaluate the sensory traits of beef steaks originating from 2 muscles packaged via 2 methods and subjected to 4 freezing durations.

Materials and Methods: Paired strip loins (USDA IMPS #180) and top sirloin butts (USDA IMPS #184) from USDA Choice carcasses ($n = 20$) were cut into 2.54-cm-thick steaks

represented by the *M. longissimus lumborum* (LL) and *M. gluteus medius* (GM). Individually vacuum-packaged steaks were transported from Canyon, TX, to Fayetteville, AR, and repackaged according to randomly assigned treatment: vacuum (VAC) or overwrap (OW) packaging. After 3 d continuous light emitting diode retail display, steaks were separated by storage treatment: fresh; 1-wk, 1-mo, 6-mo, and 9-mo frozen (−20°C). Analysis was conducted after each respected duration and steaks were transported back to Canyon, TX for trained sensory panels. During each panel, 4 steaks (VAC LL, VAC GM, OW LL and OW GM) were cooked to 71°C using clamshell grills, then cut into 2.54 cm^3. Panelists evaluated samples for beef flavor identity, brown/roasted, bloody/serumy, fat-like, umami, overall tenderness, overall juiciness, and off-flavors (bitter, cardboard, fishy, liver-like, oxidized, rancid, refrigerator/stale, sour). Statistical analyses were conducted using mixed model procedures; fixed effects were package type, duration, and muscle; random effect was order served within panel. Treatment comparisons were tested for significance at $\alpha = 0.05$.

Results: Muscle by storage duration interaction was observed for beef flavor identity, oxidized and sour ($P \leq 0.04$). Trained panelists found no difference in beef flavor for LL across duration; however, beef flavor of GM decreased as duration increased. Panelists rated GM greater ($P = 0.04$) than LL for oxidized and sour at 9 mo frozen storage. The interaction ($P < 0.01$) between packaging type and muscle indicated OW GM rated lower for juiciness than all other muscle/packaging types. An interaction was observed between package type and cold storage duration for beef flavor identity, oxidized, refrigerator-stale, and sour ($P < 0.01$). Steaks VAC packaged had higher beef flavor ratings at 9-mo frozen storage, whereas beef flavor of OW-packaged steaks decreased ($P < 0.01$) as duration increased. Steaks in OW packaging increased ($P < 0.01$) in oxidized, refrigerator/stale, and sour ratings as storage duration increased. Steaks VAC packaged were more sour ($P < 0.01$) at 6 and 9 mo frozen storage than OW. Brown roasted, fishy, and cardboard off-flavor ratings were higher ($P \leq 0.04$) for OW steaks than VAC steaks. Bloody serumy, umami, and tenderness outcomes were rated higher ($P < 0.01$) for VAC steaks than OW steaks. Bloody serumy, fat-like, umami, and tenderness were rated higher ($P < 0.04$) for LL steaks, whereas liver-like, rancid, and refrigerator/stale were rated higher ($P \leq 0.02$) for GM steaks. Cardboard, bitter, and rancid off-flavors were higher after 9 mo of frozen storage compared with fresh steaks ($P \leq 0.02$). Overall tenderness and juiciness of fresh and 9 mo frozen steaks did not differ ($P > 0.05$).

Conclusion: In conclusion, there was no detrimental effect on tenderness, juiciness, or flavor when freezing VAC steaks for up to 9 mo. Steaks packaged OW were less tender, and the OW GM was less juicy when compared with VAC steaks. Undesirable off-flavors were higher in GM vs. LL, in OW vs. VAC, and after longer cold storage durations.

Funding Source: Beef Checkoff

Keywords: overwrap, sensory, vacuum

60 EFFECTS OF THE DIETARY CONCENTRATE LEVEL ON CARCASS CUTABILITY TRAITS AND CUTOUT PERCENTAGES OF BOER AND BOER × SPANISH CASTRATED AND INTACT MALES

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Objectives: The objective of the study was to determine effects of dietary concentrate level and sex on carcass traits of Boer and Boer × Spanish castrated and intact males.

Materials and Methods: At approximately 4 mo of age, 72 kids: 36 Boer (18 intact and 18 castrated) and 36 Boer × Spanish (18 intact and 18 castrated) male goats were weaned and randomly assigned to 1 of the 3 feeding programs. The concentrate (C) diet treatments included 30% (30C-27) fed to 27.2 kg, 30% fed to 36.3 kg (30C-36), and 30% fed to 27.2 kg then transitioned to 70% (70C) concentrate until 36.3 kg. Other than concentrate percentages, all other feed ingredients were the same to minimize subsequent variation in diets. Diets were fed free choice for ad libitum consumption. Goats were harvested following typical commercial procedures at approximately 8 (30C-27) and 10 (30C-36 and 70C) months of age. All carcass data were collected following the Meat Goat Selection, Carcass Evaluation and Fabrication Guide from Louisiana State University. Fabrication into the major wholesale cuts (IMPS 11 series) occurred 48 h postmortem and all weights recorded to ensure 99% to 100% recovery of cold carcass side weight (only left sides of carcasses). Data were analyzed using the GLIMMIX procedure in SAS. Sex, diet treatment, and their interactions were analyzed as the main effects.

Results: Overall, intact males had heavier hot and cold carcass weights and were heavier muscled ($P < 0.05$) than the castrated males regardless of diet. Additionally, intact males had a higher ($P < 0.05$) percentage of closely trimmed retail cuts than castrated males. Boer × Spanish bred goats were heavier, heavier muscled with larger ribeyes as well as had more internal and external fat ($P < 0.05$) than Boer goats. Moreover, castrated males presented more ($P < 0.05$) internal fat than intact males. Goats fed the 70C diet fed had the heaviest ($P < 0.05$) hot carcass and cold carcass weight and heaviest leg, loin, shoulder, breast and rib weight as well as the largest leg circumference and most kidney fat compared with other feeding treatments. Furthermore, the goats fed 70C were fatter than the goats fed the 30C-36 diet.

Conclusion: In conclusion, the intact males and the Boer × Spanish goats were larger and trimmer than the castrated males. Finally, the goats fed the 70C diet were the most market ready based on weight and muscling. Therefore, this diet can be a viable option for producers.

Keywords: carcass, concentrate, goat

61 NATIONAL LAMB QUALITY AUDIT—2022: IN-PLANT SURVEY OF CARCASS CHARACTERISTICS RELATED TO QUALITY AND VALUE OF FED LAMBS AND MUTTON

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Objectives: The United States sheep and lamb population has been declining slowly over the last 8 decades. In addition, the sheep industry faces stiff competition because of lamb imported from Australia and New Zealand. This, along with increased production costs, has raised concerns about the future of the lamb industry. Even then, the US lacks data on lamb carcass characteristics, especially data captured in the production settings. Therefore, an in-plant survey was conducted as part of the 2022 National Lamb Quality Audit (NLQA) audit to quantify carcass characteristics associated with carcass yield and value to benchmark the current state of the fed lamb and mutton industry.

Materials and Methods: In-plant assessments were conducted in 4 of the largest commercial processing lamb facilities in the US from June to September 2022 over 6 production days. On each production day, 50% of carcasses harvested and chilled were surveyed. Both hide-on and hide-off hot carcasses ($n = 2{,}605$) and chilled carcasses ($n = 2{,}464$) were surveyed. On the harvest floor, trained auditors collected data of mud scores, breed type, horns, sex, wool length, and physiological maturity indicators (dentition and joints). Additionally, hot carcass weight (HCW), measured fat thickness, and reported USDA yield and quality grades were collected in the cooler. The distribution and summary functions of JMP Software were used to determine the frequency distributions, means, standard deviations, and minimum and maximum values.

Results: Among sheep audited on the harvest floor, 63.0% were wethers, 32.0% ewes, and 5.4% rams, and 2.0% of them had horns. Of those, 40.2% were speckle-faced (white-face and black-face cross), 38.8% were white-faced, 18.3% were black-faced, 1.4% had natural characteristics, and 1.2% were hair sheep. The average mud score was 2.12 ± 1.09 (mean ± SD), and the average wool length was 5.03 ± 2.36 cm. Additionally, 81.5% of the sheep audited presented 2 break joints (lamb), 5.7% with one break joint (yearling mutton), and 7.2% with no break joints (mutton). The average HCW was 39.9 ± 9.08 kg, whereas the fat thickness was 0.97 ± 0.38 cm. The USDA stamped yield grade was 2.71 ± 0.97, and 22.6% of carcasses were graded Prime, 68.5% were graded Choice, and 8.9% were not graded.

Conclusion: The 2022 NLQA in-plant survey of carcass characteristics is the first one to provide a benchmark for carcass characteristics of lamb processed in the US. The data from this study can be used by all industry segments to understand and develop strategic initiatives to improve the quality of fed lamb and mutton.

Funding Source: American Lamb Board

Keywords: carcass, lamb, meat grading, quality

62 THAW CURVES OF BEEF STRIP LOIN STEAKS USING VARIOUS THAW METHODS

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Objectives: Freezing of beef products is beneficial for both industry and consumers alike, allowing for longer preservation and cold-chain management. However, the process of thawing is widely undocumented in research. Therefore, the objective of this study was to determine the thaw rate and time of strip loin steaks using various thaw methods.

Materials and Methods: USDA Low Choice strip loins ($n = 6$) were collected from a beef packing facility and transported to the Kansas State University Meat Lab. At 11 d postmortem, the loins were fabricated into 2.5-cm steaks. Steaks were randomly assigned a thawing method and a 4-digit identification number. Temperature probes were inserted in the geometric center of each steak. Steaks were vacuum packaged and then frozen (−40°C) until thawing and analysis. The thaw methods tested were 2 USDA-approved thaw methods—thawing in the refrigerator (REF) and thawing in cold water (CW)—and 2 methods commonly used by consumers—thawing on the counter (CT) and in hot water (HW). Steaks were considered thawed when the internal temperature reached at least 0°C. REF steaks were thawed in the refrigerator at 2°C to 3°C until thawed. CW steaks were thawed in cold water and maintained at 2°C to 3°C until thawed. CT steaks were thawed on the counter (20°C) until thawed. HW steaks were placed in 40°C water until thawed. Immediately upon removal from the freezer, data loggers (ThermaData 4 Channel Logger) were connected to the probes. CW and REF loggers were programmed to record the temperature every 30 min. CT loggers were programmed to record the temperature every

10 min. HW loggers were set to record the temperature every 30 s. Thaw rate, thaw time, and temperature at specific times prior to thawing were all recorded from –6.67°C to 0°C. Data were analyzed as a completely randomized design.

Results: HW had the shortest thaw time ($P < 0.05$), followed by CT, CW, then REF (HW < CT < CW < REF). Moreover, HW had the highest thawing rate ($P < 0.05$), followed by CT, then CW and REF, which were not different (HW > CT > CW = REF). When temperature was analyzed by time until thawed, there was no difference between temperature at the time of thawing ($P > 0.05$). At 10 min prior to being thawed, HW was at a lower temperature than CT ($P < 0.05$), whereas no data were collected for CW and REF. From 30 min to 1 h until thawed, there was no temperature difference among CT, CW, and REF ($P > 0.05$), whereas HW steaks had no data after 10 min. CT steaks were at lower temperatures from 1.5 to 5 h until they thawed than CW and REF steaks ($P > 0.05$). Moreover, CW steaks were at a lower temperature from 6 to 13 h till thawed ($P < 0.05$).

Conclusion: The method of thawing has a significant impact on thawing of samples. Methods can affect the total thawing time, thawing rate, and temperature at specific times during the thawing process. Consumers and food service establishments should take the time, rate, and safety of each method into consideration when selecting a thawing method.

Funding Source: Funded by the Beef Checkoff.

Keywords: beef, freezing, thawing, thawing rate, thawing time

63 THE EFFECTS OF THAWING METHODS ON TRAINED SENSORY EVALUATION OF BEEF PALATABILITY TRAITS

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Objectives: The impact of freezing on beef quality is well-studied, whereas the effect of thawing on beef palatability is largely unexplored. Therefore, the objective of this study was to determine the impact of thawing method on beef quality as determined by a trained sensory panel.

Materials and Methods: Paired Low Choice strip loins ($n = 15$) were collected from a beef packing facility and fabricated into 2.5-cm-thick steaks at 11 d postmortem. Each pair of loins was sectioned into 6 equal blocks, assigned 1 of 6 thaw methods, and aged 21 d postmortem prior to freezing. Thaw methods consisted of the USDA-approved thaw methods- refrigerator (REF), cold water (CW), microwave (TM), cooking from frozen (COOK), and 2 methods commonly used by consumers—countertop (CT) and hot water (HW). REF were thawed in a refrigerator at 2°C to 3°C and CW steaks were thawed in individual containers of 2°C to 3°C water for 24 h prior to cooking. COOK steaks were cooked immediately upon removal from the freezer while still in a frozen state. CT steaks were thawed at ambient temperature (20°C) for 5 h. HW steaks were thawed in 40°C water for 20 min (±2 min) prior to cooking. TM steaks were microwaved at 50% power for 3.5 min, flipped, and repeated in a retail microwave. Steaks were cooked to 71°C on clamshell-style grills. Fifteen sensory panels consisting of 8 trained panelists were performed, with each panelist evaluating 1 sample from each treatment. The samples were rated on a 100-point line scale with anchors at 0 (extremely dry/tough/bland/none), 50 (neither dry nor juicy, tough nor tender), and 100 (extremely juicy/tender/abundant/intense). Moreover, slice shear force (SSF), Warner-Bratzler shear force (WBSF), expressible moisture, internal instrumental cooked color, thaw loss, and cook loss assays were performed. Data were analyzed as a completely randomized block design.

Results: There were no ($P > 0.05$) differences among thawing method for initial juiciness, sustained juiciness, connective tissue, WBSF, and SSF. For myofibrillar tenderness, COOK steaks were tougher ($P < 0.05$) than REF and CW. Also, MIC and COOK steaks were lower ($P < 0.05$) than CW and REF steaks for overall tenderness, whereas all other treatments were similar ($P > 0.05$). COOK steaks were rated higher ($P < 0.05$) than all other treatments for beef flavor intensity. MIC steaks had lower ($P < 0.05$) cooked a^* and b^* values than TR, HW, and CW steaks, whereas CT samples had higher ($P < 0.05$) a^* and b^* values than COOK and MIC. MIC steaks had the highest ($P < 0.05$) cook loss, followed by COOK ($P < 0.05$), with all other treatments being similar (MIC > COOK > REF = CT = CW). TM and HW had a higher ($P < 0.05$) thaw loss than CW, CT, and REF (MIC = HW > CW = CT = TR). COOK steaks had higher ($P < 0.05$) expressible moisture than CT, CW, and REF.

Conclusion: The differences observed by trained panelists indicate that thawing method has minimal effects on beef palatability. However, cooked color traits were impacted by thawing method, indicating visual cooked degree of doneness may vary because of thawing method. These results show that consumers and food service establishments may use whichever thawing method is the most economical and convenient for them because it does not impact eating quality.

Funding Source: Funded by the Beef Checkoff.

Keywords: beef, palatability, sensory, thawing, trained panel

64 EVALUATING THE IMPACT OF EARLY POSTMORTEM TEMPERATURE VARIATION ON BEEF MUSCLE TENDERNESS AND COLOR DEVELOPMENT

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Objectives: Significant variation in color and tenderness performance exists in beef products that are not easily explained by well-known factors such as breed type, quality grade, muscle fiber type, and pH. The inherent variation in carcass size and fatness are the greatest obstacles to a one-size fits all chilling approach. Today's larger, fatter carcasses and high-throughput production speeds coupled with modern intervention systems to address food safety and meat quality issues create a myriad of factors contributing to the performance of beef. The objective of this study was to evaluate the effects of varying temperatures in the early postmortem period on the tenderness and color development of beef.

Materials and Methods: From 8 beef carcasses, 3 muscles—*semimembranosus* (SM), *longissimus lumborum* (LL), and *psoas major* (PM)—from each side were collected pre-rigor, sliced in half sections and vacuum packaged, then randomly assigned to 4 different temperatures (30°C, 35°C, 40°C, and 45°C) in a water immersion bath for 30 min. Then, all muscle sections were transferred to a 2°C cooler. Temperature and pH decline measurements were collected during the 24 h chilling process. Following chilling, samples were obtained and designated for mitochondrial quantification, myoglobin, and NADH measurements; analysis were performed in relation to color chemical analysis. Muscle sections were then wet aged 14 d in the dark at 4°C and then fabricated into 2.54-cm steaks and randomly assigned for tenderness and color analysis. Slice shear force and Warner-Bratzler tenderness values were obtained from steaks cooked to an internal temperature of 71°C. In addition, sarcomere length and desmin degradation analysis were performed. Instrumental color values were obtained for the first hour of blooming steaks, and trained panelists were used to evaluate lean color attributes for 96 h at retail display. Data collected over time were analyzed with an analysis of variance model comparing the interaction of immersion temperature and time as main effects and data without repeated measures were only analyzed with immersion temperature as the main effect; $\alpha = 0.10$.

Results: Tenderness measurements were not affected by immersion temperature treatments ($P > 0.1$). Across muscles, values obtained for WBSF, SSF, and sarcomere length were the same across all treatments ($P > 0.19$). No interactions existed between immersion temperature treatment and timepoint for the objective and subjective lean color traits evaluated in retail case display for the 3 muscles ($P > 0.85$). In addition, myoglobin quantification ($P = 0.53$), NADH at 0 and 24 h were not affected by the immersion temperature treatments ($P \geq 0.1$). However, the interaction between immersion temperature and timepoint influenced pH decline measurements for PM ($P = 0.07$) and SM ($P = 0.02$), wherein greater temperatures declined more rapidly. Ultimately, the final pH at 24 h postmortem was not different between treatments for every muscle.

Conclusion: Pre-rigor temperature variation did not influence tenderness and color measurements for the 3 muscles evaluated in this study. Chemical analysis in relation to color development did not show a treatment difference and pH changed during the decline for the SM and PM, ultimately not affecting final pH. No interaction between time and treatment effect was observed for the subjective and objective color traits.

Funding Source: National Cattlemen's Beef Association (NCBA)

Keywords: desmin degradation, myoglobin, pH, pre-rigor beef, shear force

65 SPAGHETTI MEAT'S IMPACT ON TEXTURE AND QUALITY PARAMETERS WHEN INCORPORATED INTO GROUND CHICKEN PATTIES

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Objectives: Spaghetti meat (SM) myopathy affects broilers' pectorals major muscle characterized by impaired muscle bundle integrity, loss, separation, and endomysium and perimysium rarefaction resulting in meat which resembles spaghetti pasta. Research focused on SM functional properties when incorporated into processed products is limited. Therefore, the objective of this study was to examine and benchmark quality and textural characters of comminuted SM incorporated into patties.

Materials and Methods: Unaffected breast meat and severe SM was collected from a commercial processing plant, coarse ground, blended into treatment levels, fine ground, and formed into patties with a patty attachment on a vacuum stuffer for each of the 3 replications. Severe SM was formulated into chicken patties at 0%, 25%, 50%, 75%, and 100% replacement of normal breast (NB) for 5 treatment levels. Patties were cooked on an open-top induction cooktop for 3.5 min each side, until internal temperature reached 74°C, and allowed to cool to 24°C prior to any analysis. Objective color was collected on whole raw breasts' skin and bone side prior to grinding, patties after formation, and on cooked patties. Raw breasts and patties myofibrillar water properties were measured by time domain-nuclear magnetic resonance. Proximate composition and pH were collected on raw breasts and patties. Individual patties were weighed pre- and post- cook to determine yield. Cooked patties were subject to Allo-Kramer

(AK) shear force, texture profile analysis (TPA) hardness, cohesion, chewiness, and trained sensory evaluation. Data were analyzed using SAS v. 9.4 as a CRBD with treatment as the fixed effect, replication as block, and breast or patty as the experimental unit.

Results: SM skin had greater b^* values than NB bone and NB skin ($P < 0.01$). SM breasts had greater moisture than NB ($P < 0.01$) with no difference for fat or protein abundance ($P > 0.11$). SM75 and SM100 patties had greater moisture and fat than NB patties ($P < 0.03$). SM breasts had greater pH values than NB ($P = 0.04$). NB patties had pH was less than SM50, SM75, and SM100 patties ($P < 0.01$). Bound water percentage did not differ for breast or patty treatments ($P > 0.31$). NB patties had greater ($P = 0.03$) extra- and less ($P = 0.03$) intra-myofibrillar water than SM75 patties. SM25 patties had greater cook yields than SM100 and NB patties ($P < 0.01$). NB patties had the greatest shear force value compared to all other treatments ($P < 0.01$) which did not differ from each other ($P > 0.08$). NB patties had greater cohesion and hardness values than all other treatments ($P < 0.01$). There were no treatment effects for sensory attributes ($P > 0.15$), except for visual Sear ($P = 0.01$). SM25 and SM50 patties visual had greater visual sear color than NB patties ($P < 0.01$).

Conclusion: This study found that when SM was incorporated into a chicken patty TPA and AK shear force values were negatively impacted; however, differences were not noticeable to panelists during sensory evaluation. These results indicate SM could be incorporated into chicken patties with minimal detectable impact by consumers.

Funding Source: This work is supported by Critical Agricultural Research and Extension [2020-68008-315 31463] from the USDA National Institute of Food and Agriculture.

Keywords: chicken, quality, sensory, spaghetti meat, texture

66 DESCRIPTIVE FLAVOR AND TEXTURE PROFILE OF GROUND BEEF AND PLANT-BASED MEAT ALTERNATIVES

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Objectives: The objective of this study was to evaluate the flavor and texture attributes of plant-based meat alternatives (PBMA) and ground beef (GB).

Materials and Methods: The Beyond Burger (BEY), Impossible Burger (IMP), a third available brand of plant-based protein (GEN), regular ground beef (RGB), and lean ground beef (LGB) were collected from local and national chain grocery stores in 6 different cities representing the east (University Park, PA, and Athens, GA), central (West Lafayette, IN and Lubbock, TX), and west (Fresno, CA, and Reno, NV) regions of the United States. One-hundred and fifty grams of product were weighed out and formed into a patty using a patty press. Patties were cooked to 71°C on an enamel-lined cast iron skillet. Panelist ($n = 9$) were trained to evaluate 17 flavor and 4 texture attributes. Data were analyzed as randomized block design with product type as the fixed effect and collection city serving as the block. Significance was determined at $P < 0.05$.

Results: Both GB products possessed more intense beef flavor identity and roasted aromatics compared with PBMA ($P < 0.05$). Moreover, RGB was beefier than LGB ($P < 0.05$). Both GB products produced more intense brown aromatics compared with GEN ($P < 0.05$). Roasted intensity was greater in RGB compared with all PBMA ($P < 0.05$). IMP and BEY had more intense fat-like compared with both GB products and GEN ($P < 0.05$). Bloody/serumy was not detected in PBMA. Both GB products had increased liver-like, metallic, and oxidized intensities compared with all PBMA ($P < 0.05$). All PBMA were more intense for overall sweet, smokey-charcoal, umami, nutty, musty/earthy, and salty descriptive attributes compared with GB ($P < 0.05$). BEY patties were juicier than all other products ($P < 0.05$). Juiciness was similar between both GB products and IMP ($P > 0.05$). GEN patties were the driest compared with all other products ($P < 0.05$). IMP patties were more cohesive than LGB, BEY, and GEN ($P < 0.05$). Both GB products were harder than PBMA ($P < 0.05$). GEN patties were softer compared with all other products ($P < 0.05$). Particle size of masticated patties was similar among both GB products and BEY and IMP ($P < 0.05$). BEY patties had larger particle size compared with IMP and GEN patties ($P < 0.05$).

Conclusion: These data show the texture and flavor of PBMA is distinct from GB. A clear difference in beef flavor intensity was observed. The flavor profile of PBMA was composed of flavor attributes not always present in beef. These data support the conclusion that ground beef and PBMA possess different flavor and texture characteristics. Furthermore, the flavor of PBMA varied among available retail brands.

Funding Source: The Beef Checkoff, a contractor of the National Cattlemen's Beef Association

Keywords: flavor, ground beef, meat analogue, plant-based, texture

67 IMPACT OF DRY-AGING PARAMETERS ON BEEF FLAVOR

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Objectives: Dry-aged beef has gained consumer interest for its desirable flavor, stemming from the concentration of flavor precursors (moisture loss) and creation of new flavor precursors (proteolytic aging). However, dry-aging conditions vary in the literature, making it challenging to compare creation and concentration effects. Therefore, our objective was to evaluate the influence of moisture loss and aging time on dry-aged flavor development.

Materials and Methods: Eleven pairs of upper 2/3 Choice strip loins were collected and split, totaling 4 halved loins per animal ($n = 44$). Halves were randomly assigned 1 of 4 treatments: Wet, 2-d age (control), 7-d boneless dry-age (Bnls-7), 28-d boneless dry-age (Bnls-28), or 28-d bone-in dry-age (Bone-28). Halves were weighed and individually dry-aged at 70% relative humidity (±0.1%), 0.8 m^3/min air flow (±0.015), and 2°C (±0.5°C) while continuously recording weight (±5 g). After aging, loins were evaluated for moisture, trim and yield loss, composition, water activity (a_w), pH, lipid oxidation, fatty acids, free amino acids (FAA), volatile aroma compounds (VAC), and consumer and trained sensory evaluation with Principal Component Analysis (PCA). Data were analyzed as a completely randomized block, with animal set as block. Significance was set at $P < 0.05$.

Results: Control had the least moisture and trim losses and the greatest yield ($P < 0.0001$), whereas Bnls-28 had the greatest moisture and trim losses and the lowest yield. Bone-28 had the lowest trim loss and Bnls-7 had the greatest percent yield ($P < 0.0001$). Bnls-28 had greater ($P < 0.05$) polyunsaturated fatty acids, C18:2, C20:4, and C22:5 than other treatments. Dry-aging increased pH and lipid oxidation compared with control ($P < 0.05$). Dry-aging increased FAA content compared with control, the greatest amount in Bnls-28 and Bone-28 ($P < 0.05$). Comparing Bnls-28 and Bone-28, Bnls-28 was greater in 14 FAA, and Bone-28 was greater in 1 ($P < 0.05$). For VAC, Bnls-7 had greater 2,3-butanedione (buttery odor) and 4-methyl-undecane ($P < 0.05$). Bnls-28 had greater lipid degradation products, 1-octen-3-ol (mushroom), 3-ethyl-2,5-dimethyl-pyrazine (roasted), 1-pentanol (green), 2-heptanone (floral), 3-methyl-butanal (fatty), and benzeneacetaldehyde (rosy) compared with Bnls-7 and control. Using PCA, increased aging (Bnls-28 and Bone-28) elicited more dry-aged flavors compared with Bnls-7 or Control. Bnls-28 was strongly tied to basic sensory attributes in beef (salty, sweet, umami, beef ID, brown roasted) and oxidation (burnt, metallic, fishy, bitter, cardboardy). In contrast, Bone-28 flavor was linked to fundamental meat palatability traits (juiciness, tenderness, and connective tissue) with more buttery and fat-like flavor and more pungent aromas (barnyard, animal hair).

Conclusion: Dry-aging altered product composition, beef flavor, and flavor precursors. Treatments associated with increased aging time and similar moisture loss (Bnls-7 vs. Bone-28) generated more flavor precursors (volatiles, amino acids, fatty acids) and enhanced flavor volatiles. By comparison, treatments with greater moisture loss across similar aging times (Bone-28 vs. Bnls-28) resulted in more flavor precursors and intense scores (volatiles and trained panel). PCA and panel data suggest aging time (creation) is first required to elicit dry-aged flavor, whereas moisture loss (concentration) changes dry-aged flavor development and palatability.

Keywords: beef, dry-aging, moisture, palatability, sensory

68 EFFECTS OF LIVER ABSCESS ON CARCASS PERFORMANCE IN BEEF × DAIRY CROSSBRED CATTLE

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Objectives: The condemnation of livers, especially because of the presence of purulent masses known as abscesses, has become a prominent and troublesome issue for the beef industry, especially the dairy-beef producer, exacerbated by the inestimable economic loss associated with a potential decrease in animal performance because of this multifactorial disease. Thus, the objective of this study was to evaluate the effects of liver abscesses presence and severity on beef × dairy crossbred carcass performance.

Materials and Methods: Liver abscess severity scores were obtained from beef × dairy crossbred cattle ($N = 1{,}938$) at a packing plant located in the Midwestern USA. The Elanco Liver Check System was used to evaluate liver abnormality with "A+O" indicating a liver with an open abscess, "A+AD" indicating a liver with an abscess and adherence of the diaphragm or gut pile, "A+" indicating several large abscesses, "A" indicating several small abscesses or 1 to 2 large abscesses, "A−" indicating 1 to 2 small abscesses, and "0" indicating a healthy liver. Additionally, observations of abscess size (small and large) were recorded for each liver with a small abscess being an abscess <4 cm in diameter and a large abscess being greater than 4 cm in diameter. Then, hot carcass weight (HCW), amount of kidney, pelvic, and heart (KPH) weight, ribeye area (REA), fat thickness, marbling score, quality grade, yield grade, predicted red meat yield, and color were measured. An analysis of variance (ANOVA) was conducted to analyze the effect of liver abscess severity on each numerical measure using liver score as a fixed effect.

Results: Liver score impacted HCW ($P = 0.03$), KPH amount ($P = 0.004$), 12th rib fat thickness ($P = 0.012$), and number of days on feed estimated to achieve low choice quality grade ($P = 0.02$). Most notably, carcasses with more

severe liver abscess scores (A+, A+AD, and A+O) were most different from carcasses with 0 liver score. In most cases, carcasses with more severe liver abscess showed decreased performance as measured by lower HCW and lower USDA yield grade except for A+O severity which, on average, yielded more estimated carcass fat, a smaller number of days estimated to achieve low choice quality grade, lower feedlot arrival weight, and less predicted red meat yield. Despite notable differences in carcass performance, REA and marbling score were not different from healthy animals (0). Interestingly, cattle with large liver abscess (greater than 4 cm) were most different from cattle with no abscess because they were lower yielding ($P = 0.03$) and required more days on feed (17.36; $P = 0.02$) to achieve a quality grade of low choice.

Conclusion: The finding of this study indicates beef × dairy cattle with more severe liver scores were most different from cattle with no abscesses in their ability to deposit fat externally but were not negatively impacted in their REA and marbling score. The findings of this study also indicate that beef × dairy cattle, especially those with more severe and/or large abscess, are hindered in their carcass and live performance as compared with nonabscess cattle. This work warrants the need to further investigate the causation of liver abscess severity in a longitudinal manner.

Funding Source: United State Department of Agriculture (USDA), National Institute of Food and Agriculture (NIFA), Food & Agriculture Research (FFAR), International Consortium for Antimicrobial Stewardship in Agriculture (ICASA)

Keywords: beef, beef × dairy, carcass performance, liver abscess, marbling

69 IMPACTS OF AGING PRIOR TO FREEZING AND REPEATED FREEZING ON QUALITY ATTRIBUTES OF BEEF LOINS

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Objectives: Freezing is a common preservation method to prolong the shelf life of meat. Nevertheless, the freezing-related adverse impacts on meat quality are well-documented (freeze/thaw loss, in particular). Additionally, repeated cycles of freezing and thawing can inflict continuous damage on the muscle structure and subsequently meat quality attributes. Postmortem aging improves tenderness and water-holding capacity through endogenous proteolytic enzyme activities. Thus, it can be hypothesized that aging prior to freezing can minimize quality defects associated with frozen/thawed meat. The objective of this study was to investigate the impact of aging prior to freezing and repeated freezing on the quality attributes of beef loins.

Materials and Methods: At 2-d postmortem, 60 strip loins (*M. longissimus lumborum*) were collected from 30 beef carcasses (USDA Top Choice) and divided into 4 groups of different aging times (0, 2, 3, and 4 wk) at 2°C and then frozen for 5, 3, 2, and 1 wk, respectively. Prior to freezing, subsections were collected from loins at each assigned aging time serving as never-frozen samples. Also, additional sections from the loins assigned 4 wk aging were collected and aged for one additional week serving as 5 wk never-frozen control. After completion of first freezing, the loins were thawed for 2 d in a cooler and a portion of samples was collected for freeze-thaw loss, display weight loss, Warner-Bratzler shear force (WBSF), and display meat color measurements. The remaining sections were repeatedly frozen for an additional 5 wk, thawed, and analyzed for the aforementioned meat quality analyses. Consumer sensory evaluation ($n = 90$) was conducted for eating quality attributes. Data were analyzed through two-way interaction linear mixed model by using SAS software (v. 9.4, SAS Institute, Cary, NC).

Results: Freezing resulted in significant thaw loss and display weight loss for the loins with no aging. However, the loins assigned to aging prior to freezing had significantly lower freeze/thaw loss and display weight loss compared with the frozen-only loins without aging ($P < 0.05$). Also, repeated freezing/thawing did not affect the freeze/thaw loss and display weight loss of the aged/frozen loins ($P > 0.05$). For cooking loss, no significant difference was found between never frozen and aged/frozen samples. Freezing and repeated freezing/thawing significantly decreased WBSF values of the frozen-only loins, but no difference was found between aged/frozen beef samples and aged only (never-frozen control). The sensory panel found no significant differences in sensory attributes between aged/frozen and unfrozen beef loins, regardless of aging time. Freezing decreased L^* and a^* values, regardless of aging treatment ($P < 0.05$).

Conclusion: The results of this study found that aging prior to freezing significantly improved meat quality attributes by reducing freeze/thaw loss and display weight loss of frozen/thawed meat. Also, aging prior to freezing had positive impacts on repeated frozen/thawed meat by decreasing purge loss, but no difference in tenderness was found. This study suggests that aging prior to freezing can be an effective strategy to improve meat quality characteristics of frozen/thawed beef with multiple freezing/thawing cycles.

Funding Source: This work was supported by the NCBA Beef Checkoff fund from the National Cattlemen's Beef Association.

Keywords: sequential aging/freezing, repeated freezing, meat quality

70 NATIONAL BEEF QUALITY AUDIT 2022: TRANSPORTATION AND MOBILITY, LIVE CATTLE, AND HARVEST FLOOR ASSESSMENTS OF FED CATTLE

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Objectives: The objective of the audit was to identify and quantify producer-related defects for fed cattle, thereby allowing comparison with previous audits and development of educational materials for producers.

Materials and Methods: Data were collected by 13 universities between September 2021 and November 2022 at 22 beef harvest facilities in 11 states. Harvest facilities were selected to represent beef harvest capacity in the United States by size and geographical location. A total of 7,800 head were evaluated exiting the trailer, and approximately 23,000 carcasses were evaluated on the harvest floor. Data were collected throughout production of one full shift and were analyzed using JMP Pro, v. 16.0.0 (SAS Institute, Cary, NC) and Microsoft Excel 2018 (Microsoft Corporation, Redmond VA). Where appropriate, frequency distributions were utilized to calculate mean, minimum, maximum, and standard deviation. Microsoft Excel was used to calculate simple means and percentages.

Results: Cattle were transported on average 245.3 km with a travel time of 2.9 h and 36-head per load. Trailer dimensions averaged 41.3 m^2, provided 1.2 m^2 per animal with an average of 3.7 compartments. Most cattle (91.72%) exiting the trailer had mobility scores of 1. Of the cattle evaluated, 93.3% had identification: lot visual (61.3%), individual (58.1%), electronic (29.4%), metal clip (11%), bar code (2.4%), wattles (0.2%), and other (4.3%). Most of the cattle were black-hided (62.3%), followed by Holstein (12.3%), red (11.3%), tan (4.9%), yellow (2.6%), gray (2.0%), brown (2.0%), non-Holstein dairy (1.7%), and white (1.1%). Cattle with no brand was 70.5%, followed by butt brands (22.4%), side brands (7.0%), and shoulder brands (1.1%). Evaluation of mud/manure resulted in 49.6% of cattle being mud/manure free, and for those with mud/manure the most common location was on the legs (38.7%). Most cattle had no horns (84.1%). Bruising rates were as follows: 1 bruise (29.8%), 2 bruises (14.9%), 3 bruises (5.9%), 4 bruises (1.7%), more than 4 bruises (0.0%). Bruises were found in the loin (30%), rib (23.7%), chuck (19.7%), round (19.3%), and brisket/plate/flank (7.3%). Maturity via dentition resulted in 4.6% of carcasses over 30 mo of age. Total condemnations found in the offal/byproducts: liver (28.5%), lung (20.9%), viscera (12.5%), head (4.5%), and tongue (1.8%). Compared with the NBQA-2016, travel time increased, area allotted per animal increased, cattle mobility exiting the trailer decreased, the use of electronic tags increased, number of black-hided cattle increased, Holstein cattle decreased, cattle with multiple brands increased, presence of mud/manure decreased, and cattle over 30 mo of age increased. Additionally, carcasses found with 1 or more bruises increased drastically (13.4% increase). There was a decrease in liver, viscera, and tongue condemnations but an increase in lung and head condemnations.

Conclusion: The National Beef Quality Audit serves as a benchmark for the beef industry and identifies areas for further beef research. Although some areas improved from the last audit, others declined. These findings will allow cattle producers and stakeholders to address current challenges associated with beef production.

Funding Source: This study was funded, in part, by the Beef Checkoff.

Keywords: audit, beef quality, bruising, carcass, harvest defects

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71 EVALUATION OF RAPID EVAPORATIVE IONIZATION MASS SPECTROMETRY (REIMS) FOR SLICE SHEAR FORCE TENDERNESS CATEGORY PREDICTION IN BEEF STEAKS

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Objectives: Slice shear force (SSF) is an industry standard for tenderness measurement that is labor intensive and destructive. Rapid evaporative ionization mass spectrometry (REIMS) has been shown to have application in the food industry as a rapid, nondestructive method for predicting food quality attributes. The objective of this study was to assess the ability of REIMS to predict the tenderness classification of beef *longissimus lumborum* steaks using machine learning algorithms.

Materials and Methods: Samples were randomly collected from beef carcasses (AA, $n = 1{,}505$; AAA, $n = 1{,}363$) at 2 commercial beef processing facilities in Canada over a 3-year period. A 5.08-cm-thick steak was cut from the anterior end of the strip loin, vacuum packaged, and aged for 14 d. Once aged, steaks were sliced to a thickness of 2.54 cm, and tenderness was determined using slice shear force. The residual sample portions were vacuum packaged, frozen at −30°C, and shipped to Texas Tech University for further analysis. Metabolomic profiling of beef samples was performed using REIMS. Before analysis, REIMS samples were thawed at 0°C to 4°C for 16 to 24 h. Each sample was burned within the lean using the iKnife 3 to 5 times. Data were collected from the time of flight (ToF) in the mass range from 50 to 1,500 m/z. REIMS data were normalized across cleaning and were mean centered to the cleaning intervals of the corresponding external standard. Highly correlated REIMS bins were removed, resulting in 1,741 variables. To improve machine learning performance, data were further reduced using feature selection (FS), principal component analysis (PCA), and PCA-FS. Fourteen machine learning algorithms (MLA) were used to predict tenderness category. Because most steaks were "very tender" ($n = 1{,}615$) and "tender" ($n = 645$), samples were removed to match the number of samples in the "tough" category to prevent overfitting models ($n = 477$/group).

Results: FS, PCA, and PCA-FS reduced REIMS variables to 465, 1,429, and 474 variables, respectively. Algorithms were trained with all variables to build models. Model accuracies ranged from 37.2% (K-nearest neighbor) to 42.9% (extreme gradient boosting) for FS, 32.0% (linear discriminant analysis) to 39.9% (recursive partitioning decision trees) for PCA, and 42.9% (K-nearest neighbor) to 100% (extreme gradient boosting) for PCA-FS. Ten PCA-FS models had accuracies between 99.8% and 100%, so models were reanalyzed using 80% of the data to train the model and the remaining 20% of the data to test the model. The overall accuracies for these models ranged from 32.3% to 40.0% using the training/testing data split; therefore, models were overfit when given 100% of the data. Random forest (RF) and support vector machine linear 3 (SVM Linear 3) generated models with a higher overall accuracy than the no information rate (33.3%), which is equivalent to guessing ($P = 0.01$ and $P = 0.05$, respectively).

Conclusion: RF and SVM Linear 3 produced predictive models to categorize steaks into an SSF tenderness category based on REIMS data with a higher accuracy rate (40.0% and 38.3%, respectively) compared with the no information rate (33.3%). Additional tenderness measurements coupled with SSF values could be useful in improving predictability. Further optimization of RF and SVM Linear 3 algorithms is required for improvement of model accuracy.

Funding Source: Beef Cattle Research Council

Keywords: beef, machine learning algorithms, REIMS, tenderness

72 ASSESSMENT OF MEAT SPOILAGE CHARACTERISTICS UTILIZING BEEF EXUDATE FOR MICROBIAL ANALYSIS AND METABOLOMICS PROFILING

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Objectives: Meat spoilage is a complex process that involves the growth of spoilage bacteria and the production of various metabolites that contribute to off-odors, off-flavors, and discoloration of the meat. Temperature abuse is one of the major causes of spoilage in chilled meat. Metabolomics has been extensively utilized to provide better understanding of the spoilage mechanism in chilled meat by identifying metabolites related to spoilage-associated bacteria. Meat exudate has a great potential to be used as an analytical matrix for detecting spoilage as it contains various metabolites. However, its efficacy has not been fully evaluated. The objective of this study was to determine the feasibility of using beef exudate for assessment of meat spoilage through microbial analysis and metabolomics profiling.

Materials and Methods: Beef loins (*M. longissimus lumborum*) from 6 beef carcasses (USDA Utility grade) were received at 2 d postmortem. Each loin was divided into 6 sections, vacuum packaged, and assigned to either 4°C (control) or 10°C (spoilage) treatment for 2, 4, and 6 wk of aging. Upon completion of each aging time, exudate was collected for the metabolomics analysis using UPLC-ESI-MS system. Bloomed meat surface color and pH were measured. Total bacterial count (TBC), lactic acid bacterial count (LAC) count in meat and exudate samples were measured. The data were

analyzed using PROC MIXED procedure of SAS v. 9.4. Metabolomics data were analyzed using R software, where feature intensities were normalized, ANOVA ($P < 0.05$).

Results: Overall, pH value of loin steaks remained consistent with no significant differences between storage weeks or temperature. Lightness (L^* value) increased significantly over time, whereas redness (a^* value) and yellowness (b^* value) were not significantly affected by storage conditions. A significant interaction of temperature by aging time was found in TBC and LAC, where more accelerated growth rates were found in meat stored at 10°C compared at 4°C storage ($P < 0.01$). TBC and LAC counts of exudate samples were significantly higher compared with tissue samples, indicating comparable exudate sensitivity to tissue samples. MS metabolome profiling of exudate samples identified 4,664 features, out of which 31 candidates were selected to maximize discrimination of time and temperature treatments. The abundance of certain metabolites, including carnitines, amino acids (Lys-Val, Arginine), peptides, nucleotides (AMP and NAD), and nucleosides, decreased faster in the spoilage group over time because of degradation by spoilage microorganisms. However, lipids and free fatty acids increased over time at 10°C relative to control. Carbohydrates such as galactose 6-sulfate and glycosides were abundant only in the early stages of aging but declined over time, particularly in spoilage samples.

Conclusion: Meat exudate has the potential to serve as an excellent medium for the assessment of meat spoilage grounded on microbial analysis. The changes in microbial counts in fresh meat during storage resulted in complex shifts in the metabolites present in meat exudate, indicating its validity and efficacy as a spoilage-assessing medium. The results obtained in this study will provide novel insights on the future development of rapid diagnostic tests for quality control of spoilage in meats.

Keywords: spoilage, metabolites, TBC, meat exudate

73 EFFECTS OF THE INCLUSION OF OMEGA-3 FISH OIL IN CALF DIETS ON FATTY ACID PROFILE OF VEAL

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Objectives: The United States meat industry produced 80.2 million pounds of veal in 2017 and current consumer trends indicate that consumption of veal will increase in the next years. Therefore, improving the nutritional quality of American veal will allow the US industry to participate with a higher share in the protein market. The aim of this study was to evaluate the effects of omega-3 inclusion in calf diets on fatty acid profile and health indexes of veal as a tool to improve its nutritional value.

Materials and Methods: Twenty-three Holstein nursing bull calves were randomly assigned to 1 of 3 dietary treatments (control $n = 7$, starch, $n = 8$, and omega-3 fish oil, $n = 8$). Diets were formulated with nonmedicated milk replacer, 120 g of microbreweries spent grains, and mineral mix supplement (control); control + maize starch (starch); control + 3% of omega-3 fish oil (omega-3 fish oil). All animals were offered ad libitum amounts of nonmedicated milk replacer and free access to the commercial mineral mix (NaCl 96%, manganese 2,400 ppm, iron 2,400 ppm, copper 260 ppm, zinc 70 ppm, cobalt 40 ppm). Preweighed corn starch and fish oil were incorporated with the milk replacer into separate containers and calves were fed ad libitum in stainless steel buckets. Animals were allocated to individual pens and adapted to diets and management for 67 d. Subsequently, veal calves were fed for 68 d, twice daily at 06h00 and 16h00, and slaughtered around 5 mo old. Calves were slaughtered a commercial plant. After 24 h of chilling, the *M. longissimus thoracis et lumborum* was excised from loins and aged for 14 days. Total lipids were extracted from pulverized tissues by using a chloroform and methanol (2:1, v/v) mixture and were converted to fatty acids methyl esters (FAME) and BF3 was used as the catalyst. FAMEs were analyzed by GC (Nexis GC-2030, Shimadzu Corporation, Kyoto, Japan). Fatty acids were identified by comparison of retention times with known standards (NuChek-767) and expressed as a percentage of total FAME extracted. Data were analyzed as a completely randomized design using the GLIMMIX procedure of SAS. The level of significance was $P \leq 0.05$.

Results: Overall, veal from calves fed omega-3 had higher concentrations of C20:5 n-3 (EPA) ($P = 0.004$), C22:6 n-3 (DHA) ($P = 0.002$), total omega-3 ($P = 0.006$), and lower total trans fatty acids ($P = 0.006$). Omega-3–fed veal also had lower n-6:n3 ($P = 0.002$). Veal from control and omega-3–fed calves had higher concentrations of C18:1 n9 ($P = 0.013$), total monounsaturated ($P = 0.018$) and lower omega-6 fatty acids. The inclusion of omega-3 in the diet did not alter atherogenic, thrombogenic, health and hypocholesterolemic indices.

Conclusion: Although concentrations of EPA and DHA and total omega-3 were higher in veal supplemented with fish oil, the increase of those fatty acids may not directly impact human health (EPA = 0.06^b, 0.18^b, 0.49^a; DHA = 0.15^b, 0.31^b, 0.80^a; Σn-3 = 0.68^b, 1.17^b, 1.94^a, for Control, Starch, and Omega-3, respectively). However, feeding fish oil lowered n6:n:3 by 62% and 54% when compared with ratios observed in veal fed control and starch, which may improve n6:n3 contents of diets as a whole.

Keywords: omega-3, veal

74 SHORT-TERM IMPLANTING STRATEGIES DO NOT ALTER THE FATTY ACID PROFILE OF BEEF

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Objectives: Feedlot cattle are usually implanted with growth stimulants at least twice during the finishing phase. Previous research showed that implants containing trenbolone and estradiol significantly alter the fatty acid profile of the lean. In this study, we evaluated the effects of a short-term implanting strategy on the fatty acid profile of beef-fed identical diets.

Materials and Methods: Sixteen 12-mo-old Angus steers weighing approximately 1,052.80 ± 12.15 lb were randomly allocated to treatment groups (Revalor-XS implant $n = 8$ and nonimplant $n = 8$ animals). Implanted steers received one pellet of Revalor-XS (200 mg of trenbolone acetate and 40 mg 17ß-oestradiol) for 100 d prior to slaughter. All steers were finished with fed a diet containing 39.96% alfalfa and 40.24% corn for the same period of implanting. Animals were harvested at a commercial processing plant and after 24 h of chilling, the strip loin was removed from the carcass, vacuum packaged and transferred under refrigeration to the University of Nevada, Reno Meat Quality Laboratory. Strip loin steaks were pulverized with liquid nitrogen and analyzed for fatty acid profile. Total lipids were extracted by using a chloroform and methanol (2:1, v/v) mixture and converted to fatty acids methyl esters (FAMEs) using BF_3 as the catalyst. FAMEs were analyzed using a gas chromatographer (Nexis GC-2030, Shimadzu Corporation, Kyoto, Japan) and separated in a capillary column (CP-Sil 88 100 m × 0.25 mm × 0.2 µm, Agilent Technologies, CA). The oven temperature raised from 140°C to 220°C at 2°C/min and held at 220°C for 20 min. Injector and detector temperatures were maintained at 270°C and 300°C, respectively. The carrier gas was helium at a flow rate of 30 mL/min. FAMEs were identified by comparison of retention times with known standards (NuChek Prep-767). Data were analyzed as a completely randomized design using the GLIMMIX procedure of SAS. The level of significance was $P \leq 0.05$.

Results: Concentrations of all saturated, polyunsaturated, omega-3, omega-6, and total trans fatty acids were similar when comparing implanted with nonimplanted beef. Similar results were observed for monounsaturated fatty acids, with the exception of C20:1 n12, which was significantly higher in implanted beef ($P = 0.023$). Implanting did not alter atherogenic, thrombogenic, hazard, and hypocholesterolemic indices.

Conclusion: Short-term implant strategies do not alter the fatty acid profile of beef.

Keywords: beef, estradiol, implant, trenbolone

75 TRAINED SENSORY EVALUATION OF BEEF LONGISSIMUS LUMBORUM STEAKS FROM VARYING QUALITY GRADES

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Objectives: Meat quality is an intrinsic factor influencing a consumer's eating experience. Though many research studies have identified "tenderness" as the most important factor affecting beef tenderness, there have been recent studies showing that as tenderness reaches acceptable levels, flavor becomes the next important factor. It has been shown, increased marbling percentages have repeatedly been associated with an increased eating experience. Studies have shown consumers are willing to pay a premium for a product with a higher-quality grade, as most consumers perceive a higher-quality grade as more valuable and will lead to a more enjoyable eating experience. Therefore, the objective of this study was to investigate the differences of desirable and undesirable flavor attributes of beef *longissimus lumborum* steaks of varying quality grades.

Materials and Methods: Eighty striploins were selected at the TTU Gordon W. Davis Meat Lab, representing 4 different quality grades (Prime, Certified Angus Beef [CAB], Low Choice, and Select). From each striploin, the most posterior steak was cut into 2.54-cm steak ($n = 20$/quality grade). Each steak was then vacuum packaged and frozen for further analysis. Prior to trained sensory panels, steaks were thawed for 24 h. Each steak was cooked to a medium degree of doneness (70°C to 72°C ± 1°C) in a rational oven. Each steak was allowed to rest for 5 min, then cut into 1-cm^3 pieces, with panelists receiving 2 to 3 pieces/sample. Trained panels were conducted in 10 sessions with 6 to 8 panelists. Panelists were asked to evaluate each sample for the following flavor attributes: beef, browned, roasted, sour, metallic, fat-like, buttery, umami, liver, and oxidized. All flavor attributes were evaluated on a scale of 0 (absence of flavor) to 100 (strong flavor attribute) points. The experimental design was a complete random design. The fixed effect was quality grade, and the random effect was the panel, whereas steaks were considered a pseudo replication. All data were analyzed using PROC GLIMMIX, where main effects were each flavor attribute, quality grade, and their interactions. Least-square means were calculated and considered significant at $P < 0.05$, using ANOVA testing to indicate significance. Using PDIFF option, means were separated and deemed significant at $P < 0.05$.

Results: There were significant effects of quality grade on flavor attributes. Prime was significantly higher

($P < 0.05$) for buttery and fat-like flavor attributes compared with all other quality grades, which did not differ from each other ($P > 0.05$). Additionally, Prime was significantly higher ($P < 0.05$) than Select for umami but was significantly lower ($P < 0.05$) than Select for oxidized and liver flavor. Surprisingly, for roast flavor Select had a significantly higher roast-like flavor compared with CAB; however, there was no difference ($P > 0.05$) between Select, Prime, or Low Choice. For brown flavor, Prime and Low Choice were significantly higher ($P < 0.05$) than CAB.

Conclusion: It is well known that higher-quality grading beef results in increased palatability attributes. Although tenderness is an important factor affecting a consumer's eating experience, marbling should also be taken into account because it has an impact of the flavor profile of the overall product.

Keywords: beef, quality, flavor, eating experience, consumer satisfaction

76 GUANIDINOACETIC ACID SUPPLEMENTATION INFLUENCE ON CARCASS CHARACTERISTICS, MEAT QUALITY, AND COMPOSITION IN FINISHING BEEF STEERS

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Objectives: Guanidinoacetic acid (GAA) is a chemical precursor to creatine and is initially formed in the kidneys through the synthesis of arginine and glycine, produced naturally, allowing for the facilitation of energy storage in skeletal muscle. Our study assessed the effects of GAA on carcass characteristics, meat quality, and composition in a dose-dependent manner.

Materials and Methods: A 146 d feedlot study was conducted using Red Angus crossbred steers ($n = 30$; 10/treatment). Steers were individually housed and randomly assigned to each treatment. Treatments included basal diet (CON), 1 g of GAA/100 kg BW (LOWGAA), and 2 g of GAA/100 kg BW (HIGHGAA). Following 146 d of trial, steers were transported to the abattoir, where they were harvested and chilled prior to sample collection. At 48 h postmortem, pH, instrumental color values (L^*, a^*, b^*), and carcass data, including hot carcass weight (HCW), ribeye area (REA), preliminary yield grade (PYG), percent kidney, pelvic, and heart fat (KPH), final yield grade (YG), and marbling score were collected. Approximately 7.5 to 10 cm of the anterior-most portion of the strip loin from both sides were obtained from each carcass. Steaks were cut 2.54 cm thick, vacuum sealed, and held in refrigeration (2°C to 4°C) until 3-, 14-, or 28-d postmortem for shear force or compositional analysis. Warner-Bratzler shear force (WBSF) samples were cooked on a clamshell grill to an internal temperature of 70°C. Shear force samples were cored after chilling for 24 h. Compositional data (protein, moisture, and fat) were collected through near-infrared spectroscopy (FOSS NIR FoodScan). Statistical analysis was conducted using GraphPad Prism and PROC GLIMMIX of SAS with treatment as the fixed effect. Differences between least-square means ($P < 0.05$) were evaluated using Tukey's HSD test.

Results: HCW ($P = 0.97$), REA ($P = 0.34$), PYG ($P = 0.51$), KPH ($P = 0.22$), pH ($P = 0.56$), L^* ($P = 0.73$), a^* ($P = 0.90$), YG ($P = 0.38$), marbling score ($P = 0.28$), protein ($P = 0.28$), moisture ($P = 0.25$), and fat ($P = 0.28$) were not altered based upon treatment. Yellowness (b^*) was decreased ($P = 0.05$) in HIGHGAA vs. CON steers. No interaction was detected for WBSF ($P = 0.58$) or cook loss ($P = 0.43$). Treatment influenced WBSF ($P = 0.05$), where HIGHGAA (3.23 kg) had lower WBSF values than both CON (3.60 kg) and LOWGAA (3.56 kg), which were indistinguishable. Postmortem aging similarly reduced ($P = 0.01$) WBSF values at 14- and 28-d postmortem compared with 3 d. Duration of aging increased cook loss ($P = 0.01$), with cook loss being greatest at 28 d postmortem compared with 3 or 14 d.

Conclusion: GAA supplementation in a dose-dependent manner did not impact carcass characteristics and composition of beef strip loin steaks. Throughout the postmortem period, WBSF decreased until day 14, at which time it ceased to decline; however, cook loss peaked at 28 d postmortem. The results of our study indicate that a higher dose of GAA may enhance meat tenderness without affecting other attributes of meat quality. Because this is one of the first studies to evaluate GAA supplementation on beef cattle, future studies could include supplementation at alternative dosage levels with greater experimental units.

Funding Source: Michigan Alliance for Animal Agriculture (M-AAA)

Keywords: guanidinoacetic acid, composition, quality

77 EVALUATING THE IMPACTS OF USING ELECTROSTATIC FIELD ASSISTED THAWING ON FROZEN BEEF QUALITY

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Objectives: Electrostatic field (EF)–assisted thawing is an emerging food thawing technology that is gaining popularity in many Asian countries. We hypothesize that applying an alternating current (AC) EF during thawing can oscillate the positive and negative ions in the ice crystals, causing a weakening of the hydrogen bonds in the ice. It is possible that this oscillating force can break apart the existing ice crystals into smaller, more uniform ice crystals, thus resulting in less overall cellular damage and improved thawed meat yield and quality. Therefore, the objective of this study was to evaluate this hypothesis.

Materials and Methods: Striploins from both sides of USDA Choice carcasses ($n = 12$) were collected and portioned into 4 equal parts ($n = 48$). Portions were vacuum packaged and frozen at −20°C for 14 d and randomly assigned to 1 of 4 EF thawing treatments: 0 kV voltage (control), 2.5 kV voltage (EF-2.5), 5 kV voltage (EF-5), and 10 kV voltage (EF-10). Within each EF treatment, half of the striploin portions were thawed in the inside cooler (0°C) and half in the outside cooler (2°C). Internal temperatures were recorded throughout the thawing process, and the thawing process was considered complete when all striploin portions reached −1°C. After thawing, striploin portions were weighed and purge was collected for microbial and protein analysis, and portions were fabricated into steaks. One steak was immediately cored parallel to muscle fiber direction and immediately frozen in liquid nitrogen cooled isopentane for later histological analysis to assess muscle fiber damage. The rest of the steaks were vacuum packaged and subjected to either 0 or 14 d of aging. After the designated aging period, steaks were overwrapped and placed in a coffin-style retail case for a designated 0- or 7-d retail display. After completion of each designated aging and display period, steaks were utilized for Warner-Bratzler shear force (WBSF), sarcomere length, and myofibrillar protein degradation analysis.

Results: Unfortunately, application of EF to striploins did not reduce purge loss during thawing ($P > 0.05$) as originally hypothesized. On the contrary, there was an increase in purge loss for all EF samples regardless of voltages compared with the control in the outside cooler location ($P < 0.05$). Furthermore, application of EF did not reduce thawing times ($P > 0.05$), with EF-10 actually taking longer to reach the targeted −1°C than the rest of the treatments ($P < 0.05$). All EF treatments significantly reduced purge aerobic plate count ($P < 0.01$) but only in the outside cooler location. It was interesting to note EF-10 had lower WBSF ($P < 0.05$) compared with the control. Although no differences were found for troponin-T degradation, sarcomere length, and purge protein concentrations ($P > 0.05$), EF-10 samples from the outside cooler location tended to have greater muscle fiber spacing compared with the other EF treatments ($P = 0.09$).

Conclusion: Overall, the application of EF during thawing did not reduce purge loss and thawing times, but the EF-10 treatment yielded a more tender product, which could likely be explained by the oscillating ions from the AC voltage elevating muscle structural damage. Although EF treatments did not demonstrate an economic incentive for implementation to assist with meat thawing, future study should evaluate how EF may be used as a chemical-free antimicrobial intervention for the meat industry.

Funding Source: Funded by the Beef Checkoff

Keywords: beef quality, electrostatic field, frozen, thawing

78 THE SUITABILITY OF BEEF × DAIRY SUBPRIMALS AS MODERATE-SIZED ALTERNATIVES FOR THE FOODSERVICE INDUSTRY

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Objectives: The objectives of this project were (1) to evaluate dimensional characteristics and foodservice yield outcomes of subprimals and steaks fabricated from the carcasses of beef × dairy cattle compared with those from native cattle and (2) to determine consumer acceptance of objective tenderness of beef × dairy steaks compared with those from native cattle.

Materials and Methods: One lot of native steers and one lot of beef × dairy (Angus × Holstein) steers were selected from a commercial feedlot in Texas. The left side of 30 carcasses from each lot were selected for the study. Criteria used for cattle selection: USDA Choice quality grade, carcass weight between 406 and 459 kg, and limited dressing defects. Adjusted fat thickness, hot carcass weight, and kidney, pelvic, and heart (KPH) fat percentage were measured for each carcass. Marbling score and ribeye area (REA) were obtained from the plant's instrument grading camera. Selected carcass sides were followed through fabrication, and the following subprimals were obtained: ribeye rolls (IMPS 112A) ($n = 56$), bone-in strip loins (IMPS 175) ($n = 46$), top sirloin butts (IMPS 184B) ($n = 41$), and tenderloins (IMPS 189A) ($n = 60$). Subprimals were transported to a collaborating meat purveyor. Steaks were cut from each subprimal according to specifications consistent with the purveyor's foodservice customers. Steak weight and steak number were recorded from each subprimal. Additionally, steak thickness and diameter were measured for the tenderloins, and steak thickness was measured for the strip loins. Subprimal-to-steak yields were calculated using the weights of the subprimal in steak form and subprimal net weight. One steak from each subprimal was assigned to WBS force, and one steak from each strip loin and ribeye roll as well as 2 steaks from each tenderloin and sirloin were assigned to consumer sensory analysis. The Texas A&M University Institutional Review Board for Use of Humans in Research

approved the procedures used in the consumer sensory panel (Protocol: IRB2021-0988M). Consumer panelists ($n = 118$) were asked to score tenderness liking, flavor liking, juiciness liking, and overall liking on 9-point scales. Data were analyzed using JMP Pro 16.0.0. The Fit Model Function was used to perform an ANOVA test with an alpha level of $P < 0.05$.

Results: Beef × dairy carcasses did not differ ($P > 0.05$) from native carcasses in REA, KPH, or yield grade. Hot carcass weight and marbling score also did not differ, but this would be expected given the criteria for carcass selection. The beef × dairy cattle had lower adjusted fat thickness by an average of 0.27 cm ($P < 0.05$). The carcass types did not differ in carcass-to-subprimal or subprimal-to-steak yields. Steak number was not statistically different in strip loins, sirloins, or ribeyes. Beef × dairy tenderloins produced on average 1.6 fewer steaks than native tenderloins ($P < 0.05$). WBS force measurements were similar between the 2 carcass types. Moreover, consumer ratings of beef × dairy steaks did not differ from native steaks in overall like, juiciness like, tenderness like, or flavor like.

Conclusion: Keeping carcass weight constant, beef × dairy subprimals were not more moderately sized than native subprimals. Beef × dairy cattle could provide a more consistent, high-quality supply of subprimals for the beef industry while adding value to calves produced from the dairy industry.

Funding Source: This project was funded in part by the National Cattlemen's Beef Association.

Keywords: beef × dairy, beef tenderness, consumer panels, subprimal yields

79 NATIONAL BEEF TENDERNESS SURVEY—2022

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Objectives: The objectives of this study were (1) to determine tenderness and other sensory characteristics of US retail and foodservice steaks using Warner-Bratzler Shear (WBS) force and consumer sensory panels and (2) to collect grade, brand, and other label claims from retail packages.

Materials and Methods: Retail products were purchased in 11 cities (Atlanta, GA; Chicago, IL; Denver, CO; Houston, TX; Kansas City, MO; Las Vegas, NV; Los Angeles, CA; New York, NY; Philadelphia, PA; Seattle, WA; and Tampa, FL) between October 2021 through February 2022. The following cuts were purchased: top blade steak; ribeye steak, lip on, boneless; ribeye steak, lip on, bone-in; top loin steak, boneless; top loin steak, bone-in; T-bone steak; porterhouse steak; top sirloin steak, boneless, cap off; tenderloin steak, side muscle off, defatted. Retail steaks were randomly assigned to WBS force evaluation or consumer sensory panel. The following cuts were sampled for foodservice product: Ribeye steak, lip on, boneless; strip loin steak, boneless; top sirloin butt steaks, boneless; and tenderloin steaks, side muscle off, defatted. For WBS force, 1.3 cm cores were sampled parallel to the muscle fibers from the primary muscle of each steak. For consumer panels, cooked steaks were cubed into 1.27 cm × 1.27 cm × steak thickness. Panelists rated steaks for overall liking, flavor liking, juiciness liking, tenderness level, and tenderness liking. Data were analyzed with JMP Pro v. 16.0.0 and Microsoft Excel to determine frequency distribution and analyze percentages of steaks stratified into previously defined tenderness classes. Least-squares means were calculated with steak type as a main effect for steak measurements and retail WBS force analysis.

Results: For both retail and foodservice steaks, tenderloin steaks had the lowest WBS force value, at 13.31 and 25.42 N, respectively. For retail steaks, top sirloins had the highest WBS force value, and top loins had the highest WBS force value at 38.02 N in foodservice steaks. The top blade, bone-in ribeye, Porterhouse, and tenderloin retail cuts had shear force values, in the very tender (<31.4 N) category. Retail top sirloin was the lone cut in the tough category (>45.1 N). In retail consumer sensory evaluation, tenderloin steaks received the highest ($P < 0.05$) rating for overall like, tenderness like, tenderness level, flavor like, and juiciness like. To be comparable with previous years' surveys, if the tenderloin had not been included in the survey, the top blade would have received among the highest panelist ratings. Of retail packages, approximately 66.4% contained a form of branding, and 55.9% had a marketing claim. Top sirloin steaks received the lowest sensory ratings for overall like, tenderness like, tenderness level, flavor like, and juiciness like. Compared with the last 3 surveys, there was an increase in the number of packages with brands or claims on labels. This may indicate the consumer is more interested in the origin of their food. Most retail steaks evaluated were very tender and all decreased in WBS force from the 2010 and 2015 surveys.

Conclusion: The WBS values for retail steaks showed a decrease and foodservice steaks indicated an increase compared with the last survey, representing change for both sectors in tenderness. The United States beef industry may continue to use these data as a benchmark for tenderness of steaks from retail and foodservice establishments.

Funding Source: Funded in part by the Beef Checkoff.

Keywords: beef tenderness, consumer panels, sensory, survey, Warner-Bratzler shear force

80 VARIATION IN MUSCLE FIBER TYPE, PROTEIN DENATURATION, PH, AND QUALITY TRAITS BETWEEN HERITAGE AND COMMERCIAL PIGS

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Objectives: Pork *longissimus* is highly valuable. However, long-term selection for leanness has impacted pork quality and resulted in inconsistent quality. We hypothesized that muscles from heritage pigs would have increased oxidative capacity, improved water-holding capacity (WHC), and lower Warner-Bratzler shear force (WBSF) values compared with commercial pigs. The aim was to determine the impact of genetic line and changes in fiber type distribution on WHC, WBSF, and protein denaturation during cooking.

Materials and Methods: Samples were from 22 carcasses from 2 farms with different genetic lines: Farm A (FmA) uses commercial Landrace × Large White ($n = 12$) and Farm B (FmB) uses heritage Berkshire pigs ($n = 10$). Slaughter occurred at 2 different processors; carcass chilling was blast chilling for FmA, conventional for FmB. The *longissimus lumborum* (LL) was sampled at 3, 24, and 48 h postmortem (pm), and aging occurred for 0 or 14 d. Measurements included muscle fiber type proportion (%) and cross-sectional area (CSA-μm^2), protein denaturation during heating using differential scanning calorimetry (DSC), WHC (purge % and cook loss %), and tenderness using WBSF (N). Data analysis was conducted using restricted maximum likelihood (REML) in GenStat (edition-16).

Results: There was no difference in animal age (21 wk) or carcass weight (FmB 77.6, FmA 81.4 kg; SED = 2.83) between farms ($P > 0.05$ for both). FmB carcasses had higher fat depth than FmA (17, 11 mm respectively; SED = 0.9; $P < 0.001$). Compared with FmB, FmA LL had higher purge (1.83%, 2.85% respectively; SED = 0.33), lower 3 h pH (6.14, 5.90; SED = 0.049), higher 24 h pH (5.71, 5.83; SED = 0.021) ($P < 0.001$ for all), and similar 48 h pH (5.68, 5.66; SED = 0.036; $P > 0.05$). Compared with FmB, FmA LL had similar cook loss after 0 d aging but much higher cook loss after 14 d aging (Table 1). In addition, FmB had lower LL WBSF at 0 d and much lower LL WBSF at 14 d aging, relative to FmA (Table 1). Relative to FmB, FmA carcasses had less type I oxidative fibers (16.0%, 10.1%; SED = 0.51), less type IIa intermediate fibers (22.0%, 14.0%; SED = 0.77), and more type IIb glycolytic fibers (62.0%, 75.9%; SED = 0.74) ($P < 0.001$ for all). Conversely, relative to FmB, FmA LL had higher CSA for all fiber types (type I, 327, 440 μm^2, SED = 15.3; type IIa, 332, 404 μm^2, SED = 13.7; type IIb, 496, 543 μm^2, SED = 9.7; $P < 0.001$ for all). There was an interaction between farm and temperature for DSC, FmB had higher temperatures (°C) for 2 of the 4 protein denaturation peaks compared with FmA (FmB, 55.79, 65.1, 77.1, 80.4; FmA 52.1, 62.4, 70.7, 81.6, respectively, SED = 1.59; $P = 0.012$ for interaction).

Table 1 Effect of aging (Day; 0, 14 d) and source (S; Farm A and Farm B) on quality traits.

	Farm A		Farm B		Interaction – S × Day	
	0 d	14 d	0 d	14 d	SED	*P* value
Cook loss, %	18.57	24.63	15.65	16.79	1.620	0.0170
WBSF, N	30.90	28.61	26.69	21.96	0.983	0.0026

*SED = standard error of difference for interaction

Conclusion: The *longissimus lumborum* from heritage pigs had a higher proportion of oxidative and intermediate fibers and lower proportion of glycolytic fibers. Most likely these differences in fiber type were causative in the higher WHC, lower WBSF, and higher protein denaturation temperatures in heritage pigs, although the blast chilling used for FmA pig carcasses most likely contributed to higher pH at 3 to 24 h pm. These results could be used to improve breeding programs and overall pork quality.

Keywords: fiber type, pork quality, protein denaturation

81 DOES FEEDING HIGH-OLEIC SOYBEANS (TRUSOY) IN A SWINE FINISHING RATION IMPACT MEAT AND CARCASS QUALITY?

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Objectives: To determine if a swine finishing ration that includes a high concentration of oleic fatty acid soybeans will impact carcass composition and meat quality traits.

Materials and Methods: Seventy-two crossbred pigs (Landrace × Yorkshire, Duroc × Landrace × Yorkshire) with initial BW = 78 ± 9 kg were blocked by weight and sex and distributed within 18 pens. Each pen was randomly assigned to 1 of 3 experimental diets: a traditional control soybean-meal base (CTRL), extruded conventional soybean (CONV), and extruded high-oleic acid soybean (TRU). Experimental diets

were offered to animals for 34, 37, 41, 42, 48, or 50 d, until all pigs reached 118 ± 5 kg. Six different slaughter dates were set, harvesting 12 animals/group, to ensure uniformity in final body weights. Hot carcass weight (HCW) and dressing percentage were obtained after slaughter. After a 24 h chill (2°C), loin eye area, subcutaneous fat depth, loin eye color, and marbling score were taken at the 10th/11th rib interface. The carcass right side was then fabricated into primal cuts which were weighed and expressed as percentage of chilled side weight. One 2.5-cm-thick chop was obtained adjacent the 10th for use in a 6-d shelf life test. An additional chop was obtained at the 11th rib, vacuum packaged, aged for 7 d at 2°C, and frozen for later quality analysis. Subcutaneous fat samples were obtained from the first thoracic vertebra, frozen, and saved for subsequent fatty acid analysis. Fresh belly firmness was determined through the belly flop test. Quality analysis data, including retail chop pH, drip loss, cook loss, subjective color, and marbling scores, Minolta L^*, a^*, and b^* values and Warner-Bratzler shear force (WBSF) were obtained. Data were analyzed using the MIXED procedure of SAS where diet, sex, and slaughter date were main effects with interactions, whereas pen and breed were random effects. Repeated measures were used to analyze the shelf-life study. Differences were considered significant at $P \leq 0.05$ with pen as experimental unit.

Results: Interactions between diet and slaughter date were significant for final live weight and HCW, where animals from TRU and CONV were heavier than CTRL. Diet did not impact dressing percentage, loin eye area, fat depth, right carcass weight, and primal cut weight or percentage ($P > 0.05$). In contrast, slaughter group impacted ($P > 0.05$) for carcass composition and quality traits when evaluated as main effect. Diet did not affect pH, drip loss, cook loss, L^*, a^*, b^*, or WBSF but did impact the belly flop test where CTRL had firmer bellies than CONV and TRU. CONV had the highest values for linolenic acid, whereas TRU had the highest concentration of oleic acid and lowest concentration of palmitic and stearic fatty acids. In the shelf-life study, no significant differences were found for diet or its interactions with day of storage and/or slaughter date. However, slaughter date and day of storage impacted L^*, a^*, and b^* when analyzed as main effects ($P \leq 0.05$). L^* increased, whereas a^* and b^* decreased over time in retail display for all the diets.

Conclusion: Extruded high-oleic soybeans increased the percentage of oleic acid in subcutaneous fat while keeping similar carcass and quality traits compared with soybean meal and extruded soybean. Therefore, TruSoy could be considered as a dietary alternative to modify the fatty acid profile in pork when fed during the finishing period.

Funding Source: Minnesota Soybean Research and Promotion Council

Keywords: oleic acid, pork quality, soybean, TruSoy

82 IMPACT OF EXTENDED FEEDING DURATION ON INSTRUMENTAL COLOR ANALYSIS OF LOCALLY GROWN BEEF

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Objectives: The objective of this study was to evaluate the effect of increased finishing weights to determine color differences in locally grown beef.

Materials and Methods: Angus crossbred steers ($n = 48$) at an average weight of 340.9 kg were divided among 2 treatments: short-fed (SF) = 522.7 kg average final weight and long-fed (LF) = 613.6 kg average final weight to simulate a beef direct marketing operation in Arkansas. Cattle were split into 2 pens ($n = 12$ calves/treatment in each pen) and each pen had access to 4 automated feeders, which were filled with a finishing diet as needed to offer ad libitum intake. Feed intake was monitored using RFID tags with automated feeders. Body weights were recorded at 28 d intervals throughout the finishing process to determine harvest dates and measure cattle performance. Finished steers were transported to a commercial processing facility. A strip loin was collected from the right side of each carcass approximately 48 h following harvest. Strip loins were vacuum packaged and wet aged in the absence of light for 21 d, then cut into two 2.54 cm steaks. Following fabrication, steaks were subjected to a simulated retail display for 7 d in a multideck case under continuous 3,500 K LED lights. Instrumental color analysis was conducted every 12 h utilizing a Hunter Lab EZ Spectrophotometer according to the AMSA Guidelines for Meat Color Measurement. Data were analyzed using SAS PROC MIXED (v. 9.4) with repeated measures. A completely randomized design was used with the fixed effect of group and day and random effect as time of day. The Satterthwaite adjustment for denominator degrees of freedom was used. Statistical differences were determined with $\alpha < 0.05$.

Results: A significant group × day interaction resulted for LF steaks exhibiting greater L^* values throughout the display period ($P < 0.001$). Inversely, SF steaks exhibited greater a^* values throughout the display period ($P < 0.001$). This is due to greater amounts of marbling in LF steaks reflecting more light and less marbling present in SF steaks creating a redder appearance. A redder presentation was exhibited from SF steaks throughout the duration of display. SF steak b^* values at day 0 indicated more discoloration ($P \leq 0.001$) continuing through to day 7, at which SF steaks were 2.14 points greater than LF steaks. Similarly, SF steaks exhibited greater chroma values for the duration of display ($P \leq 0.001$). There was a difference in hue at day 0 and 7 ($P < 0.001$, $P < 0.001$), respectively, with SF steaks having the greater hue on day 0 and lower hue on day 7 indicating SF

steaks had more discoloration in the beginning but were surpassed by the LF steaks at the end of display. This is due to the inverse relationship of L^*, a^*, and hue, indicating that LF steaks presented less red compared with SF steaks and therefore discolored at a faster rate.

Conclusion: The current study indicates that extended duration of feeding locally grown Arkansas beef results in significant differences of instrumental color; however, both finishing weights produced steaks with appropriate color for retail display. However, if there are potential processing bottlenecks from reduced processing capacity, short and long-fed cattle will be acceptable for color through local marketing diversification.

Funding Source: This research was funded by the Arkansas Beef Council.

Keywords: beef, color, locally raised, retail display

83 EVALUATION OF LUBABEGRON FED TO CONVENTIONAL HEIFERS AND ITS EFFECTS ON BEEF PALATABILITY

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Objectives: The objective of this study was to evaluate the effects on palatability and dimensional changes to the *longissimus lumborum* (LL) of heifers fed lubabegron supplementation.

Materials and Methods: USDA Choice striploins ($N = 106$) collected from conventional heifer cattle fed lubabegron for 0 or 56 d were fabricated into 2.54 cm steaks and wet aged for 7, 14, 21, 28, or 35 d postmortem. All steaks were analyzed for dimensionality and slice shear force (SSF), and a subset stratified by treatment and aging period were utilized for trained sensory analysis and desmin degradation. Steaks were placed on a gridded background and photographed prior to packaging. Each digital image was processed to analyze steak area (measured around the LL muscle), steak length (measured across the LL muscle from the medial end to the lateral end of the steak), and steak widths (measured at 25%, 50%, 75%, and 87.5% of the length of the LL muscle from the anterior end) were obtained from each steak to gain an understanding of dimensional changes. Sensory analysis was conducted on steaks aged 14 and 28 d to evaluate beef flavor ID, browned, roasted, metallic, fat-like, sour, oxidized, liver-like, overall tenderness, and overall juiciness on a 100 mm continuous, unstructured line scale. Desmin degradation was evaluated using SDS-PAGE gels for samples aged 7, 28, and 35 d. An analysis of variance was interpreted with $\alpha = 0.05$ for SSF, steak dimensionality, sensory analysis, and desmin degradation.

Results: Steaks from treated cattle had a greater SSF value ($P \leq 0.001$) at 7, 14, and 21 d indicating increased toughness, in comparison with control steaks. At 28 and 35 d, no difference existed between the treatment and control ($P \geq 0.05$). Steaks from control and treated cattle were not different for any attribute ($P \geq 0.11$) in trained sensory analysis. Additionally, steaks between aging timepoints ($P \geq 0.07$) were not different. Steaks for dimensionality were numbered 1 (medial end) through 11 (lateral end). Generally, steaks from treated cattle exhibited numerically greater surface area and widths at all lengths when compared with the steaks from control cattle. Both intact and degraded bands were greater at 35 d postmortem and the least at 7 d postmortem. Lubabegron supplementation was not different for intact or degraded desmin ($P \geq 0.07$)

Conclusion: Steaks from heifers treated with lubabegron had higher SSF values at early aging timepoints, but no differences were detected by a trained sensory panel. The overall dimensionality of the steaks favors the supplementation of lubabegron. Lubabegron supplementation had no effect on desmin degradation.

Funding Source: Elanco Animal Health

Keywords: beef quality, dimensionality, lubabegron, sensory, tenderness

84 SENSORY ATTRIBUTES, INSTRUMENTAL COLOR, PROXIMATE COMPOSITION AND COLLAGEN CONTENT OF BEEF PATTIES FROM BOS INDICUS AND BOS INDICUS–BOS TAURUS CROSSBRED CATTLE

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Objectives: *Bos indicus* breeds are commonly raised in tropical and subtropical countries because they are adapted to warm and humid environments. Over the last decades, efforts have been made to introduce *Bos taurus* genetics into tropical herds not only to improve growth performance but also fat content and sensory attributes. In this study, we evaluated the effects of 3 different genetic groups of cattle including Nellore (Nell), ½ Nellore ½ Angus (NellAn), and ½ Senepol ¼ Nellore ¼ Angus (SeNellAn) on sensory attributes, objective color, proximate values, and collagen content of beef patties.

Materials and Methods: Eighteen ($n = 6$ per group) Nellore (Nell), ½ Nellore ½ Angus (NellAn), and ½ Senepol ¼ Nellore ¼ Angus (SeNellAn) steers, averaging 24 mo, from the Nellore (Nell), ½ Nellore ½ Angus (NellAn), and ½ Senepol ¼ Nellore ¼ Angus (SeNellAn), pasture finished groups were used. Steers were slaughtered at a commercial plant, carcasses were refrigerated, and 24 h postmortem, the *M. semimembranosus* and *adductor* were excised and shipped to the Veterinary and Animal Science School of Federal University of Bahia (UFBA), Brazil. Patties were formulated by using approximately 85% of ground beef and 15% of commercial ground pork fat procured from a local butcher. Spices included salt (1.5%), sugar (0.2%), garlic paste (0.3%), and ground black pepper (0.2%). Patties analyzed for proximate and collagen content were kept frozen until the analyses could be made. For color and sensory evaluation, fresh samples were used. Instrumental color (L^*, a^*, b^*, and Chroma values) of patties was assessed by using a CR-410 Minolta chromameter after 30 min of blooming. Proximate values and collagen content of patties were determined by near-infrared spectroscopy (NIRS) in a FoodScan apparatus. A consumer taste panel ($n = 70$ panelists) was conducted using a 9-point hedonic scale to score the main sensory attributes. Data were analyzed by SAS as a completely randomized design, and means were considered significantly different when ANOVA was $P \leq 0.05$.

Results: No breed effects were observed on protein ($P = 0.90$), fat ($P = 0.15$), ash ($P = 0.89$), and collagen content ($P = 0.52$). Moisture values were higher in patties from Nell and SeNellAn ($P = 0.002$) when compared with patties from NellAn. Minimal effects were observed on instrumental color, where patties from SeNellAn were lighter than patties from other breed groups ($P = 0.002$). No breed effects were observed on aroma ($P = 0.71$), flavor ($P = 0.36$), and overall acceptance ($P = 0.11$). SeNellAn patties were more tender than Nell patties ($P = 0.005$). Beef patties from crossbreds were juicier ($P = 0.006$) than those from Nell ($P \leq 0.005$).

Conclusion: In similar dietary management conditions, the inclusion of *Bos taurus* in *Bos indicus* genetics minimally affects proximate and instrumental color values. The addition of Senepol may improve some sensory attributes. However, this improvement does not increase overall acceptance of beef patties.

Keywords: beef, *Bos indicus*, *Bos taurus*, Senepol

85 SENSORY ATTRIBUTES, PHYSICOCHEMICAL CHARACTERISTICS, AND FATTY ACID PROFILE OF CARNE DE SOL FABRICATED FROM STEERS OF DIFFERENT GENETIC GROUPS

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Objectives: Carne de sol is a further processed dried meat product widely consumed in arid and semiarid regions of Brazil, especially in Northern states. The aim of this study was to evaluate the effects of 3 genetic groups of cattle, Nellore (Nell), ½ Nellore ½ Angus (NellAn), and ½ Senepol ¼ Nellore ¼ Angus (SeNellAn), on pH, WHC, WBSF, proximate values, collagen content, water activity, instrumental color, fatty acid composition, and nutraceutical indices, including catalytic enzyme activities of carne de sol fabricated from round muscles of steers.

Materials and Methods: *Semimembranosus* and *adductor femoris* muscles were obtained from 18 steers. Genetic groups included Nellore (Nell, $n = 6$), ½ Nellore ½ Angus (NellAn, $n = 6$), and ½ Senepol ¼ Nellore ¼ Angus (SeNellAn, $n = 6$) steers fed a similar grass-based diet. Beef cuts were transferred under refrigeration to the Federal University of Bahia (UFBA). Carne de sol was manufactured at the UFBA and analyzed for pH, WHC, water activity (a_w), CIE L^*, a^*, b^*, and Chroma values (410 Minolta chromameter), WBSF, proximate and collagen content, sensory attributes of the cooked product (consumer panel $n = 70$, aroma, flavor, tenderness, juiciness, and overall acceptance), and fatty acid content. Fatty acids were estimated by gas chromatography and proximate and collagen content by using near-infrared spectroscopy. Data were analyzed by SAS as a completely randomized design and means were considered significantly at $P \leq 0.05$.

Results: Carne de sol manufactured from Nell had higher pH when compared with SeNellAn. Nell had higher a_w when compared with NellAn. Regarding color, samples produced from SeNellAn were lighter than samples from Nell and NellAn (Nell = 31.2^b, NellAn = 31.3^b, and SeNellAn = 34.0^a). SeNellAn had higher concentrations of C22:5 n-3 (Nell = 12.09^b, NellAn = 13.04^b, SeNellAn = 15.76^a), total n-3 (Nell = 38.69^b, NellAn = 34.82^b, SeNellAn = 45.52^a) and higher PUFA:SFA when compared with other breeds. SeNellAn also had a higher concentration of C20:5 n-3 (Nell = 6.80^b, NellAn = 7.66^{ab}, SeNellAn = 8.69^a) when compared with Nell. When compared with NellAn, SeNellAn had higher concentrations of C18:2 n-6 (Nell = 65.23^{ab}, NellAn = 56.94^b, SeNellAn = 71.13^a), PUFA (Nell = 130.5^{ab}, NellAn = 116.4^b, SeNellAn = 143.9^a), n-6 (Nell = 91.85^{ab}, NellAn = 81.27^b, SeNellAn = 92.63^a), and UFA:SFA. SeNellAn and Nell had higher MUFA:SFA when compared with NellAn. Nell had higher n6:n3 when compared with other breeds. Catalytic enzyme Δ9-C16 desaturase activity was higher for SeNellAn (Nell = 9.50^{ab}, NellAn = 9.35^b, SeNellAn = 10.49^a) when compared with NellAn, whereas the Δ9-C18 desaturase activity was higher in Nell and SeNellAn when compared to NellAn (Nell = 62.69^a, NellAn = 56.97^b, SeNellAn = 62.00^a). The elongase activity was higher

in NellAn when compared with Nell (Nell = 67.01[b], NellAn = 68.83[a], SeNellAn = 68.29[ab]). Regarding nutraceutical activities, TI was significantly lower in carne de sol from SeNellAn when compared with carne de sol from other groups (Nell = 1.34[ab], NellAn = 1.45[a], SeNellAn = 1.21[b]).

Conclusion: Major breed effects were observed on fatty acid profile of carne de sol. From a nutritional standpoint, carne de sol from SeNellAn seemed to present a more favorable fatty acid profile when compared with other breeds.

Keywords: angus, carne de sol, dried meat, Nellore, Senepol

86 EFFECTS OF CHLORINE AND LACTIC ACID TREATMENTS ON QUALITY OF RAW AND COOKED CHICKEN

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Objectives: Food spoilage is a multifactorial process in which microbial spoilage plays a crucial role. In a companion study, we applied 50 ppm chlorine (C) and 2% lactic acid (LA) to study antimicrobial effects on fresh chicken breasts. The objective of this study was to investigate the effects of C and LA on several quality indicators for raw (R) and deep-fried (D) legs and wings from the same carcasses, including pH, color, water activity, texture, moisture content (MC), and water holding capacity (WHC).

Materials and Methods: Untreated chicken carcasses ($N = 54$) were obtained from a small abattoir, transported on ice to the university, and evenly allocated to the C, LA, or drinking water (W) rinse treatment using a completely random design. After separating the breasts for the microbial study, the legs and wings of each carcass were separated, labeled, vacuum-packed, and frozen for later evaluation. One leg and wing from each chicken were used for the R group, and the other used for the D group. The wings were deep-fried at 175°C for 6 min, and legs were deep-fried at 175°C for 10 min. Color, pH, water activity, WHC, and MC were tested using routine methods. Texture of skin was measured in triplicate by driving a probe at a specific rate into samples to quantify hardness.

Results: For the leg data group, the LA samples had lower pH for R (5.67) and D (6.17) than those from W and C (6.16, 6.20 R; 6.41, 6.41 D) treatments ($P < 0.05$). There were no significant treatment differences in water activity and color. Deep-frying did reduce ($P < 0.05$) L value (R = 77.7, D = 61.0) and increase b value (R = 14.2, D = 28.8) for color. For MC, both C and LA groups were numerically lower than the W group in both R (W 59%, C 45%, LA 44%) and D (W 37%, C 30%, LA 32%) treatments. For WHC, there were no significant differences in the R group. In the D group, LA was numerically higher than W and C treatment for WHC ($P > 0.05$) (W 0.24, C 0.19, LA 0.28). There was no difference ($P > 0.05$) in texture in all treatments which averaged 601 g for R and 648 g for D.

In the wing data group, the LA samples also had lower pH for R (5.75) and D (6.07) than W and C (6.38, 6.31 R; 6.52, 6.50 D) treatments ($P < 0.05$). No significant differences in water activity or color due to treatment were found. Deep-frying did ($P < 0.05$) lower L values (R = 77.4, D = 56.6) and increase b values (R = 13.8, D = 24.8) for color. For MC, LA had a higher content in both R (W 45%, C 45%, LA 51%) and D (W 22%, C 20%, LA 31%) groups, but not significantly. For WHC, there were no significant differences between treatment or for R (W 0.15, C 0.21, LA 0.20) and D (W 0.30, C 0.25, LA 0.29) ($P > 0.05$). For texture, there was no difference between treatments which averaged 620 g for R and 678 g for D ($P > 0.05$).

Conclusion: In conclusion, the C and LA treatments did not significantly alter the quality measurements other than a reduction in pH for the LA and observed changes in L and b values for color which were affected by cooking. These findings can help reassure processors to apply decontamination treatments. Future sensory panels can be performed to further investigate the palatability effects of treatments on chicken exposed to decontamination solutions.

Funding Source: Department of Food Science

Keywords: antimicrobial intervention, chicken, deep fried

87 VOLATILE AROMA COMPOUNDS OF USDA SELECT STEAKS USING FIVE GRILL TEMPERATURES

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Objectives: Because of the importance of Maillard reaction product contributions to sensory and aroma, the ability to generate these compounds reliably would be very advantageous. Our objective was to create grill temperatures ranging from 149°C to 260°C to cook USDA Select top loin steaks and measure volatile production. We hypothesized that increasing grill surface temperatures will result in linear or quadratic increases in volatile aroma compounds.

Materials and Methods: Thirty USDA Select boneless top loins were vacuum-packaged and aged for 14 d (4°C). The loins were divided into 10 steaks with 2 steaks from each loin assigned 1 of 5 grill temperatures: 149°C, 177°C, 204°C, 232°C, or 260°C. Steaks were turned at an internal temperature of 35°C and removed at an internal temperature of 71°C. Cubes from each sample were frozen in liquid nitrogen and stored at −80°C for GC/MS volatile aroma analysis. Data were arranged in a completely randomized

design with grill surface temperature as a fixed effect and 30 replications. Linear and quadratic treatment effects as well as least-squares means and SEM were determined.

Results: For the alcohol volatiles, 1-butanol increased and 1-heptanol decreased linearly as grill temperature increased ($P < 0.05$). The aldehydes 2-decenal, 2-undecanal, 3-dodecen-1-al, decanal, and undecanal all increased linearly ($P < 0.017$) while pentanal concentrations decreased linearly as the grill temperature increased ($P = 0.029$). Acetaldehyde and tetradecanal concentrations decreased to 232°C then increased to 260°C in a quadratic manner ($P < 0.05$) as grill temperature increased. In the ketone volatile aroma compounds, 2-decanone and 2-octanone increased ($P < 0.009$) and 2,3-butanedione and 3-methyl-2-butanone decreased ($P < 0.03$) linearly as the grill temperature increased. Additionally, 2-methyl-3-octanone, 2,3-octanedione, and 4-octanone increased quadratically ($P < 0.05$) as the grill temperature increased with 2,3-octanedione peaking at 204. As would be expected, the pyrazine compounds (Table 1) increased ($P < 0.03$) with increasing grill temperature.

Conclusion: Increasing the grill surface temperature when cooking USDA Select beef strip loin steaks increases volatile aroma compounds important to the acceptance of beef. The increase in grill temperature positively influences the volatile aroma compounds unique to flavor in lean beef.

Funding Source: This research was funded by the Beef Checkoff.

Keywords: beef, grill temperature, volatile

88 EFFECTS OF LUBABEGRON FED TO HOLSTEIN STEERS DURING THE FINISHING PERIOD ON BEEF QUALITY

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Objectives: Lubabegron has been used in cattle to reduce gas emissions, but limited research has been done to evaluate the effect on beef quality; thus, in this study, beef quality attributes of the *Longissimus lumborum* (LL) were assessed in Holstein steers fed lubabegron.

Materials and Methods: Strip loins ($n = 212$) across all USDA quality grades were collected from Holstein steers fed lubabegron supplementation for 0 d (control), 28 d, 56 d, and 84 d. Then striploins were fabricated into 2.54 cm steaks and aged for 7, 14, 21, 28, or 35 d. All steaks were analyzed for slice shear force (SSF) and dimensionality with a subset assigned to desmin degradation. At the time of fabrication, steaks were imaged for dimensionality prior to packaging. Then, using digital imaging software, steak area (distance around LL), steak length (from the medial to lateral end of LL), and steak width (25%, 50%, 75%, and 87.5% of the length of LL muscle from the anterior end) were measured. Desmin degradation was evaluated using SDS-PAGE gels for samples aged 7, 28, and 35 d. An analysis of variance was interpreted with $\alpha = 0.05$ for SSF, steak dimensionality, and desmin degradation.

Results: Regardless of length of time cattle were fed lubabegron, steaks from treated cattle were tougher ($P < 0.01$) than steaks from control cattle, as measured by SSF after 7 or 14 d aging postmortem. After 21 d aging, steaks from control cattle and cattle fed lubabegron for 28 d SSF values were not different, but steaks from cattle fed lubabegron longer (56 d or 84 d) were tougher. At 28 and 35 d of aging, SSF values were not different among steaks from control or any treated cattle. Generally, steaks from cattle fed lubabegron for any amount of time exhibited greater surface area and greater widths at every measurement (25%, 50%, 75%, and 87.5%). Degraded desmin was different ($P < 0.01$) for 35 d postmortem age compared to ratios from samples aged 7 d postmortem ($P > 0.01$), with 21 d postmortem being intermediate and not differing from either. The feeding duration of lubabegron had no differences ($P \geq 0.34$) for degraded desmin.

Conclusion: Steaks from Holstein steers treated with lubabegron for any length of time had higher SSF values at early aging time points, but no differences were detected after 28 d. The overall dimensionality of the steaks favors the supplementation of lubabegron. Desmin degradation was not affected by lubabegron supplementation.

Funding Source: Elanco Animal Health

Keywords: lubabegron, tenderness, slice shear force, dimensionality, protein degradation

89 ROLE OF PLANT DIVERSITY DURING GRAZING ON GOAT MEAT QUALITY

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Objectives: The objective was to determine goat meat quality from goats that grazed pastures of differing levels of plant diversity.

Materials and Methods: Two fields (F1 and F2) located approximately 500 m apart were selected. Within each field, 2 diet treatments, either high-diversity (HD) or low-diversity (LD) forage was seeded in 2 sections within each field. The HD sections were seeded with a cool season cover crop mixture containing 7 different plants. The LD sections were seeded with a sorghum x sudangrass hybrid. The LD sections

were sprayed with a broadleaf control herbicide to control annual broadleaf weeds. Each treatment was sub-divided into 20-m x 30-m plots. Twenty-four Boer x Savannah yearling goats were randomly allocated by sex into 4 groups (6 goats/treatment/replicate; IACUC 1-2020). Goats were put into one 20-m x 30-m plot in each treatment replicate with free access to fresh water and allowed to graze until they utilized approximately 75% of the vegetation, then moved to the next 20-m x 30-m plot. A total of 8 plots were grazed for an average of 7 d for a total of 56 d. Forage species intake was estimated through clipping collections taken before and after each plot was grazed. Goats were transported to North Dakota State University and slaughtered under USDA inspection. Carcasses were weighed and cooled for 48 h. Temperature and pH measurements were taken at 45 min and 24 h in the *biceps femoris*. Loin muscle area, body wall thickness, kidney and pelvic (KP) fat percentage, subcutaneous fat cover, and flank lean color scores were recorded. Samples for proximate analysis were collected from the right leg. The left leg was removed and weighed, and four 2.5-cm-thick chops were removed in crosscut sections starting with the sirloin face. Chops were used for Warner-Bratzler shear force and drip loss in accordance with AMSA guidelines. Chops for retail display were placed on Styrofoam trays with polyvinylchloride overwrap, placed in an open cooler at 4°C for 11 d, and scanned with a Minolta colorimeter for L^*, a^*, and b^* daily. Data were analyzed using goat as the experimental unit. Carcass data were analyzed with main effects of diet and field and the diet x field interaction. Retail display included repeated measures.

Results: Body weight gain and muscle fat content were greater ($P < 0.04$) in HD goats compared with LD goats grazed on F2. F1 body wall thickness (0.90 ± 0.02 cm) was less than F2 (1.30 ± 0.02 cm; $P = 0.001$). The KP was greater in LD goats ($1.38 \pm 0.10\%$) compared with HD goats ($1.08 \pm 0.10\%$; $P = 0.02$). HD goat meat had greater (6.56 ± 0.37 kg) shear force than LD goat meat (5.43 ± 0.37 kg; $P = 0.03$). F1 goat meat (0.18 ± 0.01 g) had greater water loss than F2 goat meat (0.10 ± 0.01 g; $P = 0.01$). Overall, L^* values were lighter in F1 goat meat (45.0 ± 0.3) than F2 goat meat (43.5 ± 0.3; $P < 0.001$).

Conclusion: Plant diversity and field location impacted goat meat quality and composition. The LD diet increased leg muscle tenderness, and the F2 field decreased muscle fat. The LD goats did not gain weight so they may have been in a nutrient deficit, thus actively utilizing fat and muscle for energy maintenance. Field location influenced body wall thickness, which may have influenced temperature decline during carcass cooling, thus impacting drip loss and L^* values. Field differences may be explained by forage composition as F2 had greater amounts of radish forage.

Keywords: forage, goat, quality

90 EFFECTS OF WET AGING ON FREE AMINO ACID AND SHORT-CHAIN PEPTIDE CONTENT IN COOKED BEEF

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Objectives: The development of water-soluble flavor compounds (WSFC) such as free amino acids and short-chain peptides contributes to cooked beef flavor. The current study, as part of an ongoing investigation into wet-aging impacts on beef flavor, was designed to evaluate the effects of wet aging on the content of amino acids and short-chain peptides in cooked beef *longissimus lumborum* muscle.

Materials and Methods: Twenty USDA Select boneless beef loins (NAMP #180) were dorsally divided into 4 equal portions that were randomly assigned to either 0, 7, 14, or 21 d of aging. Each portion was cut into two 2.5-cm thick steaks (descriptive and consumer panels) and one 1.3-cm thick steak (chemical analysis) from the anterior to the posterior end. Steaks were vacuum-packaged individually, stored at 2°C in the dark, and moved to −20°C after respective aging. Steaks that were used for chemical analysis were trimmed of external fat, connective tissues, and accessory muscles, leaving only the *longissimus lumborum* muscle. The muscle was cubed, frozen in liquid nitrogen, and pulverized into finely divided powder. One hundred milligrams of raw powder was weighed and heated at 75°C for 10 min until the meat temperature reached 72°C. Water-soluble flavor compounds were extracted in a solution of perchloric acid, acetonitrile, water, and potassium carbonate with the addition of norvaline as an internal standard. The extract was filtered through 0.2-μm nylon and 3-kDa membranes. The amino acids in the filtrate were derivatized with propyl chloroformate and determined by gas chromatography-mass spectrometry. The short-chain peptides were derivatized by a Thermo Scientific™ Pierce™ Quantitative Colorimetric Peptide Assay kit #23275 and measured at 480 nm. Data were analyzed in a generalized linear mixed model of SAS 9.4 (SAS Institute, Cary, NC) with aging time as a fixed effect and loin as a random effect.

Results: The short-chain peptide concentration was 2.81, 4.41, 4.60, and 6.57 mg/g, increasing from day 0 to day 7 ($P = 0.037$) and then from day 14 to 21 ($P = 0.011$). Thirty-one amino acids were quantified in the water-soluble fraction of the cooked beef *longissimus lumborum* muscle. The predominant amino acids were ALA, VAL, HIS, and LYS,

ranging from 1.81 to 2.19 mmol/kg, whereas the least predominant ones were HLY, CYS, SAR, and ASN, ranging from 0.02 to 0.07 mmol/kg. GLU was increased by 0.37 mmol/kg from day 0 to 21 ($P \leq 0.001$), 5 times greater than its flavor threshold. Methionine, ASP, TRP, and PHE, which are important precursors for Maillard reactions, also increased from day 0 to 21, by 0.42 ($P \leq 0.002$), 0.08 ($P < 0.001$), 0.06 ($P \leq 0.006$), and 0.43 mmol/kg ($P < 0.001$), respectively. However, HIS and β-ALA decreased from day 0 to 7 ($P \leq 0.009$), then increased from day 7 to 21 ($P < 0.001$). Other amino acids increased from day 0 to 14 ($P \leq 0.049$), such as TYR, THR, and GPR.

Conclusion: Short-chain peptides that contribute to bitterness in cooked beef were greater as wet-aging duration increased, as our lab previously reported for raw steaks. However, some free amino acids that may impart a desirable taste in cooked beef were less concentrated than previously reported for raw beef. Results indicate that the extended aging period was important for increased concentrations of desirable flavor compounds and precursors that are important to beef flavor.

Funding Source: This work was supported by the USDA National Institute of Food and Agriculture, AFRI project #1024314.

Keywords: beef, wet aging, amino acid, short-chain peptides, water-soluble flavor compound

91 NATIONAL BEEF QUALITY AUDIT–2022: TRANSPORTATION, MOBILITY, LIVE CATTLE, HARVEST-FLOOR ASSESSMENTS, AND CARCASS CHARACTERISTICS OF MARKET COWS AND BULLS

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Objectives: The study objective was to assess current transportation conditions, mobility status, live animal visual defects, and carcass and offal characteristics of market cows and bulls, and to obtain USDA grade information and other carcass characteristics from market cows and bulls.

Materials and Methods: Before data collection, 13 collaborating universities conducted a correlation meeting to assure standardized data collection for the National Beef Quality Audit (NBQA) 2022. Areas of evaluation included transportation and mobility, live animal evaluation, hides, brands, bruises, injection-sites, and offal and carcass assessments. One-third of the cattle and carcasses being processed in a full production day were assessed at 20 facilities across the United States. Data were analyzed using JMP Pro, Version 16.0.0 (SAS Institute Inc., Cary, NC) and Microsoft Excel 2018 (Microsoft Corporation, Redmond, VA) to calculate the frequencies, distributions, means, and standard deviations.

Results: Trailers ($n = 113$), live animals ($n = 3,124$), hide-on carcasses ($n = 6,662$), hide-off hot carcasses ($n = 5,746$), offal items ($n = 6,358$), and chilled carcasses ($n = 5,417$) were surveyed. Cattle were hauled a mean distance of 490.6 km for 6.3 h and had 2.3 m^2 of space allotted per head. When assessed for mobility, 77.0% of all cattle were sound, a slight decrease from (81.3%) NBQA-2016. The mean body condition score (BCS) for beef cows and bulls was 3.8 and 2.6, respectively. The mean BCS for dairy cows and bulls was 2.3 and 2.6, respectively. The current audit displayed the highest percentage (79.5%) of cows and bulls that were "too light" muscled (muscle scores of 1 or 2) when compared to the 2007 and 2016 audits (66.7% and 66.3%, respectively). Of cattle surveyed, 45.1% had no visible live animal defects, and 10.6% had horns. Unbranded hides were observed in 88.3% of cattle. Fewer than half (37.8%) of cattle had no visible mud contamination. Carcass bruising was observed on 66.7% of cow carcasses and 46.4% of bull carcasses, similar to percentages observed in NBQA-2016. Nearly all cattle were free of knots (98.2%) or injection-site lesions (97.1%). Harvest-floor assessments found that 45.0% of livers, 22.2% of viscera, 19.3% of kidneys, 46.6% of lungs, 19.9% of hearts, 11.2% of heads, and 6.4% of tongues were condemned. The leading cause of condemnation for offal items was contamination, aside from livers, which were primarily condemned for abscesses. There was an 8% increase in cows carrying a fetus. Mean USDA quality attributes were lean maturity C[19], skeletal maturity

D[80], overall maturity D[51], and marbling score Slight[87]. The mean USDA yield grade attributes for carcasses surveyed were as follows: AFT 0.4 cm, HCW 318.9 kg, LMA 64.5 cm^2, and KPH 1.8%, resulting in a mean USDA yield grade of 2.6. The presence of dark cutting was observed in 5.2% of market cows and bulls ribbed for grading. All plants that completed the food safety questionnaire reported findings of birdshot/buckshot in carcasses of market cows and bulls.

Conclusion: The NBQA-2022 serves as a benchmark of the current state of the US beef industry and is compared to previous audits as a method of managing industry progress. Findings from NBQA-2022 highlight areas of industry advancement as well as areas that will require improvement using further research and producer education in the market cow and bull sector.

Funding Source: This project was funded, in part, by the Beef Checkoff.

Keywords: audit, bulls, carcass, market cows, quality defects

92 A SYSTEMS APPROACH TO DERIVING CARCASS VALUE FROM HOLSTEIN X SIMANGUS CATTLE IN AN ACCELERATED FINISHING MODEL

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Objectives: Crossbreeding dairy cows with beef sires has increased in the US dairy industry. This beef x dairy mating results in dairy-beef which has altered the US fed beef supply. The predominant mating has been Holstein x Angus; thus, our objective was to research the effects of Holstein x SimAngus (HolSim) breeding on carcass characteristics and fresh meat quality. We hypothesized that carcasses from HolSim mating will result in improved carcass composition and yield production while maintaining carcass quality compared to Holstein carcasses.

Materials and Methods: Starting on day 1, Holstein steers ($n = 9$) and HolSim steers ($n = 12$) were fed once daily at 0830, until an end weight of 635 kg was reached. Holstein steers averaged 421 d and HolSim steers averaged 432 d on feed. Steers were humanely slaughtered under USDA inspection, immediately following slaughter, hot carcass weight (HCW) was recorded. Forty-eight hours following slaughter, carcass length, body width, backfat thickness, and area of the *longissimus dorsi* (LD) was recorded. Strip loins were collected from each carcass and aged for 14 d. After aging, Warner-Bratzler shear force (WBSF) and slice shear force (SSF) were determined. Remaining steaks were placed under retail display for 7 d. Objective color (L^*, a^*, and b^*) was measured after 0, 1, 3, 5, and 7 d in retail display using a HunterLab MiniScan Spectrocolorimeter. Myoglobin concentrations, deoxymyoglobin (Dmb), oxymyoglobin (Omb), and metmyoglobin (Mmb) were calculated using readings from the HunterLab MiniScan on days 0, 1, 3, 5, and 7 in retail.

Results: HolSim steers had higher HCW and dressing percentages compared to Holstein steers ($P < 0.0001$). HolSim carcasses had shorter carcass lengths and body widths compared to Holstein carcasses ($P = 0.0005$). Holstein carcasses had less backfat compared to HolSim carcasses ($P = 0.0034$). LD area was larger in HolSim carcasses ($P < 0.0001$). No differences were observed for WBSF or SSF ($P > 0.05$). Strip steaks from HolSim steers had lower Dmb and higher Omb values on day 0 of retail ($P < 0.05$). Strip steaks from HolSim steers had higher a^* and saturation index values on day 7 in retail ($P < 0.05$). Strip steaks from HolSim steers had lower Mmb values and higher Omb values on day 7 in retail ($P < 0.05$).

Conclusion: Carcass and fresh meat data suggest that HolSim steers had improved yield production compared to Holstein steers without a loss in quality when steers were fed to a weight-constant end-point.

Keywords: BeefxDairy, carcass merit, meat color

93 EFFECT OF POSTMORTEM AGING ON WATER-HOLDING CAPACITY AND REABSORPTION CAPABILITY OF BEEF LONGISSIMUS LUMBORUM MUSCLE

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Objectives: Water-holding capacity (WHC) is the ability of meat to retain moisture and resist water loss from protein denaturation or physical damage. WHC is one of the most important quality characteristics of meat products along with tenderness, as it relates to juiciness and other palatability attributes. Postmortem aging is a widely adopted postharvest practice in the meat industry to improve tenderness. While the mechanism by which aging improves tenderness is well-understood, the relationship between WHC and postmortem aging is not fully established. Furthermore, little information is available regarding the reabsorption ability of fresh muscle with aging. The purpose of this study was to investigate the effect of aging on the WHC and reabsorption capability of beef loins.

Materials and Methods: Strip loins (*M. longissimus lumborum*; $n = 60$) were collected from the both carcass sides from 30 market-weight beef cattle (USDA Top Choice grade) at 2 d postmortem. The loins were divided into 4 groups ($n = 15$), individually vacuum-packaged, and randomly assigned to different postmortem aging times (2, 7, 14, or 21 d) at 1°C ± 0.5°C. After each assigned aging time,

the beef samples (approximately 20 g) taken from intact muscle underwent compression drip loss and centrifugal drip loss to determine WHC. A tetragonal sample (3 x 3 x 2.54 cm, width x length x height) was taken from the central portion of the muscle section for further freeze-drying. The meat samples were lyophilized for the water reabsorption capability and subsequent repeated WHC measurements. Chemical assays including pH and protein solubility were conducted. The statistical analysis was performed by mixed model using SAS software (SAS 9.4, Cary, NC). Least-squares means for all traits were separated (F-test, $P < 0.05$) by using least significant differences.

Results: Drip loss decreased with aging ($P < 0.05$). Compression drip loss and centrifugal drip loss of fresh meat were the highest at 2 d ($P < 0.05$), and there was no difference between 7 d, 14 d, and 21 d ($P > 0.05$). Compression drip loss and centrifugal drip loss of rehydrated beef samples decreased with aging time ($P < 0.05$). For the water reabsorption capability of the lyophilized sample, the water recovery rate increased according to the aging time ($P < 0.05$). The pH increased with increasing postmortem aging time ($P < 0.05$). Postmortem aging had a significant impact on protein solubility, where the total and myofibrillar protein increased as postmortem aging increased ($P < 0.05$), whereas sarcoplasmic protein decreased after 2 d of postmortem aging ($P < 0.05$).

Conclusion: The results of this study showed that postmortem aging could improve the WHC of meat. It was also found that the reabsorption capability of fresh muscle increases with the aging duration, which may be partially attributed to the increase in WHC with aging. Increases in protein solubility due to endogenous proteolytic enzyme degradation are likely attributed to the improvement of WHC and reabsorption capability of aged muscle. Further trials investigating the underlying mechanisms by which postmortem aging would improve reabsorption capability of muscles will be warranted.

Funding Source: USDA Hatch Grant

Keywords: beef, postmortem aging, reabsorption capability, water-holding capacity

Meat and Poultry Quality and Composition—Measurement and Prediction

94 THE EFFECT OF INCORPORATING SUSPENDED FRESH® BEEF TRIMMINGS ON GROUND BEEF RETAIL SHELF LIFE

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Objectives: Suspended Fresh® (SF) is a trademarked process that can extend the storage shelf life of fresh meat products by holding them slightly above freezing temperature to slow down the growth of spoilage microorganisms. Although whole muscle cuts are subjected to SF, trim from these products are typically discarded because the impact of including these on shelf life of ground beef is unknown. Therefore, the objective of this study was to evaluate the impact of 15% inclusion of SF flap meat trimmings on ground beef shelf life.

Materials and Methods: Flap meat (*obliquus internus abdominis*) from a commercial processor was held in SF storage (-2.7 ± 0.2°C) for 60 d. The flap meat was further trimmed to industry standards and the trimmings were sprayed with 5% lactic acid for 15 s. These trimmings were incorporated into ground chuck at a 15% inclusion, and a non-inclusion ground chuck served as the control. The inclusion and control grinds ($n = 6$) were formed into patties (227g) and bricks (ca. 5 cm thick), placed on trays, and overwrapped with PVC film. Packaged products were held in a retail display case (3°C) under continuous fluorescent lighting for 5 d. During retail display, samples were evaluated for off odors, instrumental color, and visual color panels to assess discoloration. Also, samples were analyzed for aerobic plate counts (APC) on the initial and final day of retail display. Data were analyzed in R, with a significance level of $\alpha = 0.05$.

Results: The treatment × day interaction was not significant ($P > 0.05$). Moreover, there were no significant differences ($P > 0.05$) between the control and inclusion treatments throughout the retail display time for odor, discoloration scores, L^* (lightness), and a^* (redness), but there were differences ($P < 0.05$) between each day for odor, L^*, a^*, b^* (yellowness), and discoloration scores. The APC of the control and inclusion ground beef samples were similar ($P > 0.05$), irrespective of presentation type. Initial microbial loads for the control bricks and patties were 6.1 and 6.2 log CFU/g, respectively, and 6.1 and 6.0 log CFU/g, respectively, for the inclusion product. On the last retail display day, microbial loads for the control bricks and patties were 7.9 and 8.2 log CFU/g, respectively, and 8.0 and 8.1 log CFU/g, respectively for the inclusion product.

Conclusion: The use of SF flap meat trim did not result in a difference in the shelf life of the ground beef as indicated by the lack of differences in color, odor scores, and APC. Further studies could evaluate the effect of different levels of inclusion of SF trimmings on ground beef shelf life.

Keywords: color, flap meat, microbial load, Suspended Fresh

95 EVALUATION OF CURRENT USDA BEEF YIELD EQUATION FOR PREDICTING SUBPRIMAL YIELD AND THE USE OF CUTOUT DATA TO PREDICT LEAN, BONE, AND FAT PERCENTAGES IN BEEF CARCASS

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Objectives: Beef cattle population have gone through substantial changes in frame size and composition since the original cutability study used to model the current USDA yield grade (YG) equation was conducted; these modifications have made a considerable impact on the ability of the equation to forecast yield. The 4 predictors used in the current YG are hot carcass weight (HCW), ribeye area (REA), backfat (BF), and kidney pelvic and heart fat (KPH). The objective of this study was to assess the accuracy of the current USDA beef yield equation for predicting subprimal yield (SY) and to identify potential carcass regions that can serve as possible indicators of total lean, fat, and bone in the beef carcass. Identifying the most explanatory regions of the carcass for compositional differences may serve as guidance for developing new technologies and/or equation in meaningful traits on the carcass.

Materials and Methods: Results of 2 independent cutability studies were combined to create a database with individual YG and cutability data ($N = 214$).To calculate YG, KPH was standardized to 2.5%, since a direct measurement could not be obtained. Individual carcass cutability data were obtained through a cutability test consisting of beef sides fabricated to a final subprimal fat specification ranging between 0.6 and 1.2 cm. Yield data included the weights of trimmed subprimals, fat, lean trimmings, and bone which weighed back to 98% to 102% of the hot side weight (HSW). Regression analysis was performed to assess the relationship between USDA YG and SY. Various multiple linear regression (MLR) techniques were performed to identify potential carcass regions that could serve as indicators of total lean, fat, and bone in beef carcass.

Results: The current USDA YG equation explained 33% of the variation in SY. The inclusion of REA as a predictor in MLR, utilizing HCW and BF as independent variables, increased the variability explained by the model by 3%. The weight of 5 subprimals (bottom round, chuckroll, inside skirt, inside round, and clod heart), expressed as a percentage of the HSW, explained 78% of the variation in SY. Furthermore, when subprimal weight was used as a predictor, 43% of the variation in SY was explained by 4 predictors (navel, eye of round, tri-tip). The weights of 4 different fat deposits (striploin fat, bottom butt fat, bottom round fat, and flank shell fat), expressed as a percentage of the HSW, explained 67% of the variation in total fat percentage (TFP). Moreover, when the weight of fat deposits was used as predictors, 65% of the variation in TFP was explained by 3 predictors (Striploin fat, bottom butt fat, and bottom round fat). The weight of 3 bones (foreshank bone, neckbone, brisket bone), expressed as a percentage of HSW, explained 94% of the variation of bone percentage. Lastly, when the weight of bone was used as a predictor, 71% of the variation in bone percentage was explained by 3 predictors (aitch bone, neckbone, and foreshank bone).

Conclusion: In conclusion, the current USDA YG equation explained a low percentage of variation in SY. Models utilizing different carcass regions could be built to more accurately estimate SY. The chuck, plate, and round could provide predictors of lean in the carcass. The loin, sirloin, and loinedge could provide predictors of fat in the carcass. The neckbone and foreshank can provide bone predictors in the carcass.

Keywords: beef, bone yield, fat yield, subprimal yield, yield grade

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96 EVALUATION OF LINEAR MEASUREMENTS, USDA YIELD GRADE, AND SPECIFIC GRAVITY TO PREDICT COMPOSITION OF THE ROUND IN HETEROGENEOUS BEEF CATTLE

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Objectives: As the downward trend in the cow cycle produces fewer slaughter cattle on the market and as feeders continue to fatten cattle to greater slaughter weights, accurate measurement of carcass composition may be as important in 2023 as ever. Although many have speculated on its lack of accuracy, USDA yield grade is currently the only standardized method in the industry to predict carcass composition. Technologies that measure density of carcass tissues may prove to be effective alternatives to predicting carcass composition. The present study aimed to predict composition of the round using a combination of live animal measurements, carcass measurements, and specific gravity.

Materials and Methods: Cattle ($n = 17$) of varying biological types were transported to the Washington State University Meat Laboratory. Immediately before harvest, hip height, width, and length as well as live weight were captured for each animal. Cattle were harvested, and hot carcass weights were obtained. After chilling a minimum of 48 h postmortem, carcass length, round circumference, and traits

associated with USDA yield grade were obtained. The round from the left side of each carcass was separated from the loin/flank, weighed in air, and weighed in water. After a 12-h drip period, rounds were re-weighed in air and separated into bone and soft tissue (lean, fat, and connective tissue). Separable bone weight was used to calculate percentage bone in the round. Soft tissue was ground through a 9.53-mm plate once and a 3.18-mm plate twice, being mixed for 120 s between each grinding. Approximately 1 kg of soft tissue was subsampled from random locations, frozen in liquid nitrogen, homogenized into a fine powder, and stored at −20°C until further analysis. Percentage fat of the soft tissue was determined using a modified Folch chloroform-methanol method and used to calculate percentage fat in the round. The difference in percentage fat and bone from the whole was used to calculate percentage lean. Live traits, carcass traits, USDA yield grade and associated traits, and specific gravity were used in linear models to predict percentage lean, fat, and bone of the round and soft tissue. Models were considered significant at $P \leq 0.05$, and trends were considered at $0.05 < P \leq 0.10$.

Results: Live cattle measurements (hip height, hip width, hip length, and live weight) did not ($P = 0.55$) predict lean percentage in the round. However, live measurements were predictive ($P < 0.01$, $R^2 = 0.62$) of percentage bone in the round. Carcass measurements (round circumference, carcass length, and hot side weight) did not ($P = 0.44$) predict lean percentage in the round. USDA yield grade ($P < 0.01$, $R^2 = 0.44$) and its separate factors ($P = 0.04$, $R^2 = 0.40$) were predictive of lean percentage. Specific gravity of the round was not predictive ($P = 0.40$) of lean percentage, but when bone was removed, specific gravity was predictive ($P = 0.03$, $R^2 = 0.23$) of percentage fat in the soft tissue.

Conclusion: A major limitation of this study was that weights of bone and soft tissue were obtained with relatively low precision (to the nearest 0.23 kg). Even so, these results demonstrated that density measurements in a binary tissue system may be predictive of composition. As alternatives to the USDA yield grade are evaluated, technologies or mechanisms that utilize density measurement warrant exploration.

Keywords: beef, bone, carcass composition, specific gravity, USDA yield grade

97 THE IMPACT OF DIFFERENT PRODUCTION BACKGROUNDS ON THE FATTY ACID COMPOSITION OF HERITAGE AND COMMERCIAL-BRED TURKEYS

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Objectives: Alternative production backgrounds appeal to environmentally conscious consumers. This translates to small producers identifying ways to differentiate their products to appeal to niche markets and to incorporate production claims on the retail label. The objective of this study was to determine the fatty acid composition of slow-growing heritage turkeys, fast-growing free-range commercial turkeys, and fast-growing conventionally produced commercial turkeys.

Materials and Methods: Whole heritage-bred (HB), free-range commercial (FR), and commercially bred (CM) turkeys ($n = 20$ each) were obtained from retailers and a commercial processing facility and frozen at −40°C. The diet history of each production practice was unknown. Prior to fabrication, turkeys were thawed for 96 h in a 2°C–4°C walk-in cooler. Carcasses within treatments were fabricated in random order with CM turkeys processed 1 wk before HB and FR turkeys. Breasts with skin and thighs with skin from the right side of each carcass were frozen in liquid nitrogen and pulverized in a food processor to form a powder, freeze-dried, put into whirl pack bags, and frozen at −80°C until fatty acid analysis. The procedure by Sukhija and Palmquist (1988) was used for fatty acid profile determination. Data were analyzed as 3 × 2 factorial with the main effects of the treatments HB, FR, and CM ($n = 20$) with the breast and thigh parts as their interaction.

Results: There was no interaction between treatment and part for any of the fatty acids evaluated. While there was no difference ($P > 0.05$) for total saturated (SFA), polyunsaturated fatty acids (PUFA), or ω6:ω3 ratio within turkey type, FR turkeys had lower ($P < 0.05$) total monounsaturated fatty acids (MUFA) by more than 13% compared to HB and CM. The mean ω6:ω3 ratio for HB, FR, and CM was 12.8:1, 12.9:1, and 11.7:1, respectively, which is higher than the recommended 4:1 ratio. Total SFA and MUFA were higher ($P < 0.05$) in the thigh than in breast meat. Total PUFA and ω6 and ω3 fatty acids were higher ($P < 0.05$) in the breast than in thigh meat; however, there was no difference ($P > 0.05$) in the ω6:ω3 ratios. The mean ω6:ω3 ratio for turkey breast and thigh meat was 11.9:1 and 13.1:1, respectively. The highest ($P < 0.05$) amount of α–linolenic acid was found in CM with 1.37% of extractable fatty acid content and was similar ($P > 0.05$) to FR with 1.09% of extractable fatty acid content. Turkey breast meat had a higher ($P < 0.05$) amount of α–linolenic acid with 1.376 of extractable fatty acid content compared to thigh meat with 0.89% of extractable fatty acid content.

Conclusion: Using free-range or conventional production practices for turkeys resulted in meat with similar SFA, PUFA, and ω6:ω3 ratios. This study provides further information on the effect of nutritional quality within each of these different breeds.

Keywords: breast, fatty acid, nutritional quality, thigh, turkey

98 CARCASS PERFORMANCE OF DAIRY BEEF CROSS CALVES WITH ENHANCED FEEDING DURING PRE-WEANING

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Objectives: The objective of this study was to determine the effects that intensive pre-weaning management strategies have on carcass merit and value.

Materials and Methods: Calves ($N = 166$) were sourced from a local dairy in the state of Georgia and randomly assigned to one of 2 treatments by birth order. Treatments included calves fed 1.02 kg of dry matter (DM) milk replacer (27% protein: 10% fat) over 3 daily feedings (MILK; $n = 79$) or fed 0.45 kg DM milk replacer at 2 daily feedings (CON; $n = 80$). All calves were fed treatments for approximately 45 d during the pre-weaning period in addition to free choice starter. On day 45, calves were subjected to step-down weaning by reducing milk consumption by 50% until day 55, when abrupt weaning occurred. Calves were transported to Riverbend Farm (Athens, GA) post-weaning for backgrounding before being transferred to Chatel Farms (Reidsville, GA) on study day 182 for finishing. Calves ($N = 144$) were blocked into feedlot pens by weight and fed a uniform grower and finishing diet for approximately 318 d. Following the finishing period, calves were transported to a commercial abattoir (FPL Foods, Augusta, GA) for harvest. Post-harvest, carcasses were stored in a 2°C cooler for 48 h before the right side was ribbed between the 12th and 13th ribs, and an experienced grader assigned USDA yield and quality grades based on USDA standards. A 10-cm loin section was collected from the right side of carcass. Samples were fabricated into 3 steaks starting from the anterior end. Steak 1, 1.5-cm thick, was discarded. Steak 2, 1.5-cm thick, had the epimysium trimmed and was vacuum packaged and placed in frozen storage (-20 ± 2°C) for proximate analysis. Steak 3, 2.5-cm thick, was vacuum-packaged, aged for 21 d, and frozen for slice shear force analysis.

Results: There were no treatment effects for marbling score and yield grade ($P > 0.276$). Carcasses from the MILK treatment had greater hot carcass weight and adjusted 12th rib back fat than the CON carcasses ($P < 0.027$). Ribeye area tended to be greater ($P = 0.060$) in MILK carcasses than CON carcasses. There were no treatment effects on slice shear analysis and moisture retention measures ($P > 0.131$).

Conclusion: Preliminary data show differences in hot carcass weight and adjusted 12th rib backfat, but no differences in quality grades. This shows that intensive inputs and management practices during the pre-weaning period do not increase value of beef on dairy carcasses due to no added premiums on the grid.

Keywords: beef, carcass, dairy, management, quality

99 COMPARISON OF ACIDIFIED PERACETIC ACID AND PROMOATTMXL EFFECTS IN COLOR PROPERTIES ON PORK PICNICS

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Objectives: The study objective was to determine the values of color for pork picnics after submersion in 2 antimicrobials over the course of 21 d.

Materials and Methods: Pork picnics from suppliers were randomly assigned to each treatment group; a total of 2 replications were conducted throughout this study. The picnics were submerged for 6–8 s using a gondola and allowing a minimum of 20 s time to drip. The picnics were kept in a lug for 24 h to simulate trim layering as in combo storage at meat facilities. After 24 h, each treatment was coarse or fine grounded and portioned into 1 lb brick pork picnics that were treated with different antimicrobials (Water, Acidified Peracetic Acid and PromoatTMXL) over the course of 21 d (10 d, 14 d, 18 d, and 21 d). The day of the grinding and on each day of storage, the bricks were broken in half and allowed to bloom for 20 min, followed by a freezing treatment. Additionally, a set of bricks was stored for 21 whole days under freezing; these were allowed to slack out, thaw, and bloom. Instrumental color measurement was taken using the HunterLab (L^*, a^*, b^*) through a film. SAS statistical software was used to analyze the data, a LS mean analysis was performed with Tukey adjustment to identify the difference between means, and significance was evaluated at 0.05 probability level.

Results: For storage day 0 to day 21, L^* values were higher on day 10 and day 14 compared to a^*, b^*, and chroma values, which were higher on day 18 ($P < 0.0001$). Hue values did not show any statistical difference ($P > 0.05$). Between treatments, no difference was shown for L^*, b^*, or hue and chroma values ($P > 0.05$). However, the a^* parameter had the lowest values in acidified peracetic acid and water ($P = 0.0042$). No interaction between treatment and day was shown.

Samples of 21 d refrigerated and frozen ones presented higher values on a^*, b^*, and chroma ($P < 0.05$). No statistical difference was found for L^* and hue ($P > 0.05$).

Conclusion: Based on the data collected, slight changes were determined as storage time increased and in between treatments. No statistical difference was found between treatments regarding color, for which the use of said antimicrobials should be determined based on the microbial effect on the products.

Keywords: antimicrobial, ground pork, refrigeration, storage

100 NATIONAL BEEF QUALITY AUDIT 2022: CARCASS CHARACTERISTICS SURVEYED BY INSTRUMENT GRADING

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Objectives: The project objective was to analyze instrument grading information from beef processing establishments to determine monthly, seasonal, and audit-to-audit comparisons in various carcass value-determining traits.

Materials and Methods: Instrument grading data ($n = 4{,}418{,}768$ carcasses) were requested from 6 major packing companies distributed across the United States. One week's worth of data was acquired per month from June 2021 to June 2022. Instrument grading data collected in this study included kill data, grade data, breed types, sex, marbling scores, maturity scores, defects, preliminary yield grade (PYG), fat thickness (FT), loin muscle area (LMA), hot carcass weight (HCW), percentage kidney, pelvic, and heart fat (%KPH), calculated USDA YG, and USDA QG. During grading, the beef processing facilities followed guidelines defined by Quality Assessment Division (QAD) 515 Beef Carcass Instrument Grading Procedures by the USDA. For statistical analyses, data were inputted into a Microsoft Excel Spreadsheet. JMP Pro Version 16.0.0 and Microsoft Excel were used to analyze all data. Fit Y by X functions were used for analysis of variance, and student's *t*-test were conducted to extract least-squares means comparisons. Correlations were determined using the multivariate function.

Results: Instrument grading data resulted in the following mean values: marbling score (Modest16), USDA YG (3.3), FT (1.55 cm), LMA (91.6 cm^2), and HCW (400.6 kg). Percentage of USDA YG were YG 1 (7.9%), YG 2 (31.7%), YG 3 (40.0%), YG 4 (17.1%), and YG 5 (3.3%). Distributions of USDA QG were Prime (8.2%), Choice (74.7%), Select (15.8%), and other (1.4%). The other grade category includes Standard, Commercial, Utility, dark cutter, blood splash, hard bone, and calloused ribeye. Month to month, there was little variation of total percentages of each carcass classification which included native steer and heifer and dairy steer and heifer. Native heifers had the greatest FT at 1.68 cm over the course of the year. HCW peaked in native steers during December at 408.09 kg and January at 408.53 kg. LMA was the highest in December at 93.97 cm^2 in native cattle and dropped to 91.51 cm^2 toward June. Dairy heifers possessed the highest mean marbling score of Modest55. Both native steers (Modest14) and heifers (Modest47) reached their peak marbling scores in April. Carcasses classified as dark cutters within the instrument grading data were highest during the month of July at 1.41%, and lowest in March at 0.40%. When comparing instrument grading data to USDA in-plant grade data, the percentages of Select between the 2 are within 0.6%, and Prime is within 0.7%. There was a slight difference between in-plant and instrument grading in the percentages of Choice (69.2% and 74.7%, respectively). Of the 5 USDA YG classifications, comparisons between data sets were within 3.3% for each yield grade.

Conclusion: NBQA-2022 produced higher average marbling scores and an increase in percentage of USDA Prime and Choice carcasses when compared to 2016 NBQA data. Mean values for USDA YG, HCW, LMA, and FT also increased from 2016, thereby reflecting an increase in overall size, muscling, and fat deposition in fed cattle. The results of this study provide a current overview of the carcass characteristics associated with beef grading within the beef industry in the United States.

Funding Source: This project was funded, in part, by the Beef Checkoff.

Keywords: beef quality, carcass, instrument grading, quality grade, yield grade

101 EFFECTS OF THE DIETARY CONCENTRATE LEVEL ON PALATABILITY TRAITS OF SPANISH WETHERS AND DOELINGS

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Objectives: The objective of the study was to determine the effects of dietary concentrate level on palatability traits of Spanish wethers and doelings.

Materials and Methods: At approximately 4 mo of age, 56 (31 wethers and 25 doelings) goats were weaned and randomly assigned to one of the 5 feeding programs. The concentrate diet treatments included 20% (20C), 40% (40C), 50% (50C), 60% (60C), and 70% (70C) concentrate. Other than concentrate percentage, all other feed ingredients were the same to minimize subsequent variation in diets. Diets were fed free choice for ad libitum consumption. Goats were harvested following typical commercial procedures at approximately 8 mo ($n = 12$) and 10 mo ($n = 44$) of age. Fabrication into the major wholesale cuts (IMPS 11 series) occurred 48 h postmortem (only left sides of carcasses were evaluated). From each loin, 6 boneless chops were sliced 1.9 cm thick and assigned to the consumer taste panel ($n = 60$) for likeness of tenderness, juiciness, flavor, and overall likeness. Additionally, 4 chops from the rib section were sliced 1.9 cm thick and assigned to the trained sensory panel ($n = 6$) for tenderness, juiciness, flavor intensity, and off-flavors following AMSA guidelines. From the sirloin portion of the leg, one chop was sliced 2.54 cm thick and assigned to objective tenderness measures using shear force ($n = 60$). Each chop was cooked to a final target internal temperature of 68°C. Data were analyzed using GLIMMIX procedure in SAS. Sex, diet treatment, and their interactions were analyzed as main effects.

Results: Regardless of demographics, consumers did not perceive a difference in tenderness, juiciness, flavor, or overall likeness between treatments. Trained panelists also found no significant differences in tenderness, juiciness, or flavor. However, trained panelists did report goats fed the 20C diet resulted in the most ($P < 0.05$) off flavors. Moreover, there was a significant difference ($P < 0.05$) in objective tenderness measures, with female goats fed the 70C diet being tougher than females fed the 20C, females fed 60C diet, and all males. Furthermore, females fed the 20C diet and males fed the 60C were the most tender ($P < 0.05$). In conclusion, while objective tenderness methods showed variation between treatments, consumer and trained panelists were not able to detect these differences.

Conclusion: Thus, there were no consistent trends for palatability traits of chops from goats fed varying concentrate diets.

Keywords: goat, meat quality, palatability

102 COLOR STABILITY AND LIPID OXIDATION IN LONGISSIMUS LUMBORUM MUSCLE FROM RAM LAMBS ARTIFICIALLY RAISED ON MILK REPLACER AS A PRE-WEANING STRATEGY

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Objectives: Pre-weaning management of lambs, such as rearing on milk replacer, can influence animal growth and production traits. Scientific information on meat quality of lambs raised on milk replacer is limited. Therefore, the objective of the study was to evaluate the effect of pre-weaning management on the color stability of *longissimus lumborum* (LL) muscle from ram lambs during refrigerated storage.

Materials and Methods: Polypay ram lambs were raised conventionally with ewes (CR; $n = 5$) or artificially on milk replacer (MR; $n = 5$) for a 60-d pre-weaning period. After 60 d, the lambs were finished on a high forage diet (50:50 forage: concentrate) containing 50% orchard grass pellet as the forage source as well as 76% cracked corn and 24% pre-mixed protein pellet as the concentrate source. The lambs were fed ad libitum the high forage diet until they reached the target slaughter weight of 59 kg. The lambs were harvested, and LL muscles from both sides of the carcasses (24 h postmortem aging) were fabricated into 2.5-cm thick chops. The chops were placed on polystyrene trays, overwrapped with oxygen permeable polyvinyl chloride film, and randomly assigned to refrigerated storage (2°C) in the darkness for either 0, 3, or 6 d. At the end of storage periods, instrumental color, color stability (R630/580), pH, lipid oxidation, and metmyoglobin reducing activity were evaluated after removing the chops from the packages. Instrumental color and biochemical properties were analyzed using a split-plot design, with the pre-weaning management as a whole-plot and storage time as a sub-plot. The LL muscles from each lamb carcass served as the experimental unit, whereas the sub-plot experimental units consisted of chops

fabricated from each lamb carcass and assigned for 0, 3, or 6 d of refrigerated storage. Data were analyzed using PROC GLIMMIX of SAS. Least square means were separated using the PDIFF option with a Tukey-Kramer adjustment, and the differences were considered statistically different at the $P < 0.05$ level.

Results: Pre-weaning management had no influence ($P > 0.05$) on surface redness (a^* value), yellowness (b^* value), color stability (R630/580), pH, or metmyoglobin reducing activity of LL chops. However, a pre-weaning x storage day interaction was found for lightness (L^* value). Color stability (R630/580) and metmyoglobin reducing activity decreased ($P < 0.05$) during aerobic storage in CR and MR chops. Additionally, lipid oxidation increased ($P < 0.05$) in CR and MR chops during storage.

Conclusion: Artificially raising lambs on milk replacer for 60-d pre-weaning period had no impact on fresh meat color stability. Surface redness, color stability, and lipid oxidation were similar in chops from lambs raised conventionally and on milk replacer. The results suggest that milk replacer may be exploited as a successful artificial rearing strategy in lamb production without compromising fresh meat color.

Keywords: artificial rearing, color stability, lamb color, milk replacer

103 AN ASSESSMENT OF CARCASS HOT FAT TRIMMING TO IMPROVE CARCASS CHILLING AND CARCASS QUALITY

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Objectives: Beef chilling practices continue to be challenged by today's incremental increase in carcass size and backfat thickness. Reducing bulk, specifically thick layers of insulating fat, prior to chilling through the use of hot fat trimming (HFT) could improve the ability to chill carcasses and improve quality. The objective of this study was to determine the effect of 2 levels of HFT on chilling rate, tenderness, marbling score, lean color, and the demand for energy during the chilling process.

Materials and Methods: Paired sides of beef carcasses ($N = 420$; $n = 105$ sides per treatment × 2 replications) varying in weight and backfat thickness were selected on the harvest floor at a commercial processing facility. Alternating left and right sides of the same carcass were assigned to HFT, either minorly trimmed (MT; rep 1) or aggressively trimmed (AT; rep 2), with the paired side left untouched (negative control [CON]). MT specifications included 10 mm of fat remaining over the inside round and 6 mm of fat remaining over the outside round, loin edge, loin, rib, chuck, and brisket. AT specifications included 0 mm of fat over the inside round, outside round, and chuck with 6 mm of fat remaining over the loin edge, loin, rib, and brisket. The following measurements were obtained during collection: hot side weight, trimmed side weight, carcass temperature decline, instrumental color, quality and yield grade factors, as well as an 8 cm section from the anterior end of the strip loin. Temperature probes were inserted to monitor temperature in the deep tissue round, loin, chuck, and surface. Loin sections were aged to 14 d and fabricated into 2.54 cm steak for slice shear force (SSF) and Warner-Bratzler shear force (WBSF) determination with the remaining portion (face steak; approximately 100 g) reserved for sarcomere length analysis. This study was a nested design where carcass side served as the experimental unit nested in carcass, with a significance level set at $\alpha = 0.05$ for all statistical analysis.

Results: Both MT and AT sides chilled more rapidly than CON counterparts at all measured locations ($P < 0.05$). Exponential decay models showed among the greatest difference ($P < 0.05$) realized in the chuck and surface. These areas reached 4°C in 1 h 29 min and 1 h 22 min faster in MT sides and 45 and 30 min faster in AT sides, respectively. Round temperatures of MT and AT reached 4°C more rapidly (14 min and 55 min, respectively) than paired CON counterparts. In the loin, MT and CON temperature declines were not different ($P = 0.10$); however, AT sides demonstrated a 14 min advantage ($P < 0.01$). These temperature advantages translated to 0.0113 and 0.0117 savings in tons of refrigeration (TR) over CON in MT and AT sides, respectively. Tenderness was not affected by HFT, as shown by no difference in SSF and WBSF values and sarcomere lengths for CON and either MT ($P \geq 0.31$) or AT ($P \geq 0.58$) sides. No differences found in marbling score between CON and MT or AT ($P \geq 0.16$), or instrumental lean color of CON and AT ($P = 0.16$).

Conclusion: In the current study, HFT uniquely had an advantage in temperature decline without affecting tenderness. Additionally, HFT results in lower energy usage and could lead to reduced refrigeration costs over untrimmed sides.

Funding Source: This project was funded by the National Cattlemen's Beef Association (NCBA) Beef Checkoff, with in-kind support from Cargill Protein.

Keywords: beef quality, chilling, energy expenditure, hot fat trimming, tenderness

104 THE ACCURACY OF USDA YIELD GRADE AND BEEF CARCASS COMPONENTS AS PREDICTORS OF RED MEAT YIELD

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Objectives: Recent research has demonstrated a discrepancy of USDA yield grade (YG) and red meat yield (RMY) and, specifically, the lack of relationship between ribeye area (REA) and carcass muscularity. The current YG equation only utilizes 4 predictors obtained from a cross-sectional area of the carcass between the 12th and 13th rib. Including additional independent variables from different carcass regions may increase the ability to forecast RMY and carcass value. This work was intended to evaluate the accuracy of YG relative to RMY and to identify the predictive capacity of carcass components to explain variations in composition.

Materials and Methods: To evaluate the accuracy of the YG equation, individual carcass data ($N = 93$), as well as cutout data, were captured in a commercial processing facility. Individual carcass cutout data were obtained through a yield test consisting of beef sides fabricated to common product specification. Yield data included weights of trimmed subprimals, bone, fat, and lean trimmings adjusted to 90% lean, all expressed as a percentage of the carcass weight. Adjusted trim was combined with subprimal yield to generate total RMY. Regression analysis was conducted to evaluate the current YG equation predictive ability on RMY, as well as to assess the relationship between YG and RMY on cutout value. Using "all possible combinations" multiple linear regression, individual carcass components were used as predictors to identify carcass regions that could be used as potential indicators of muscularity and fat.

Results: Yield grade explained 34% of the variation in RMY and 37% of the variation in cutout value. Including REA as an independent variable increased the model's predictive ability by 3%, but no relationship existed between REA and RMY ($P = 0.12$). Conversely, RMY explained 89% of the variation in cutout value, suggesting RMY is a better indicator of carcass value than YG. Utilizing 4 subprimal weights (inside round, clod heart, chuck roll, and outside skirt) expressed as a percentage of the hot carcass weight as predictors, 88% of the variation in RMY was explained. Using 4 subprimal weights as predictors (navel, ball tip, eye of round, and rib short rib), 66% of the variation in RMY was explained. As predictors, 5 fat depot weights (hot fat trimmed, loin tail fat, flank shell fat, chuck fat, and bottom butt fat; expressed as a percentage of the hot carcass weight) accounted for 94% of the variation in adjusted total fat. Utilizing 4 fat depot weights (hot fat trimmed, top butt fat, bottom butt fat, and flank shell fat) as predictors, 86% of the variation in adjusted total fat was explained. Individual carcass components that explain variation in muscularity and fat are located in multiple carcass regions, implying the importance of including predictors from different carcass regions other than a single cross-sectional area between 12th and 13th rib.

Conclusion: This study confirmed that USDA YG had a low predicting ability on RMY and cutout value. Alternative carcass components could be used to generate superior models to predict RMY and cutout value. The chuck, plate, and round proved to be excellent indicators of muscularity in the carcass, whereas the loin, sirloin, and loin edge were excellent indicators of fat in the carcass.

Keywords: beef, prediction, red meat yield, USDA yield grade

105 EFFECT OF BLOOM TIME ON PRELIMINARY YIELD GRADE, RIBEYE COLOR, RIBEYE AREA, MARBLING SCORE, AND CALCULATED YIELD GRADE FOR THE VBG-SMARTCAM AND THE VBG-7L GRADING INSTRUMENTS

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Objectives: This study evaluated the changes of preliminary yield grade, ribeye color, ribeye area, marbling score, and calculated yield grade for the VBG-SmartCam and VBG-7L during the following time intervals (minutes): 0, 5, 10, 15, 20, 30, 60, 90, 120.

Materials and Methods: The camera was operated through 3 stages of 30 sides ($n = 90$) on stationary rails to help maintain carcass identification through all data collection points. Data were analyzed PROC VARCOMP of SAS to evaluate the repeatability of camera assessments and to assess the proportion variance attributable to variation among carcasses, bloom time, and error. Additionally, PROC GLIMMIX of SAS with a fixed effect of evaluation time and a random effect of carcass ID to determine whether camera assessments differed among bloom times.

Results: Variance component analysis showed that SmartCam marbling score repeatability was >0.99 with carcass ID, bloom time, and error accounting for 97.9%, 0.4%, and 1.6% of the total variance, respectively. The mixed model showed that marbling score decreased over time: 584 (Modest 84) at 0 min, 575 at 15 min, 569 at 30 min, and 556 at 120 min ($P < 0.0001$). SmartCam ribeye lean color assessment showed the variable RibeyeColor_r, the red channel on the Red-Green-Blue color scale, increased a total 18.4 units from ribbing (77.7 at 0 min) to the last time observed (96.1 at 120 min) ($P < 0.0001$ for each comparison; except 90–120 min; $P = 0.511$). SmartCam RibeyeColor_r repeatability was >0.99 with carcass ID, bloom time, and error accounting for 66%, 32%, and 2% of the total variance, respectively. Bloom time did not affect

SmartCam yield grade, ribeye area, or preliminary yield grade. Variance component analysis showed that VBG-7L marbling score repeatability was >0.99 with carcass ID, bloom time, and error accounting for 67.6%, 31.3%, and 1.1% of the total variance, respectively. The mixed model showed that marbling score decreased over time: 536 (Modest 36) at 0 min, 529 at 15 min, 524 at 30 min, and 516 at 120 min ($P < 0.0001$). VBG-7L ribeye lean color assessment showed the variable RibeyeColor_r, the red channel on the RGB color scale, increased a total 14.3 units from ribbing (102.7 at 0 min) to the last time observed (117 at 120 min) ($P < 0.0001$ for each comparison). VBG-7L Ribeyecolor_r repeatability was >0.99 with carcass ID, bloom time, and error accounting for 68%, 31%, and 1% of the total variance, respectively. Bloom time did not affect VBG-7L calculated yield grade, ribeye area, or preliminary yield grade.

Conclusion: It is optimistic to see similar trends for both grading instruments. Follow-up studies would need to be conducted to further observe carcass data accuracy and repeatability within plants. The application of instrument grading observing the highest marbling score at ribbing indicates that potential changes needed to be made in current grading systems for packers to optimize beef carcass quality grade potential.

Funding Source: Texas Tech University

Keywords: beef grading, bloom time, instrument grading, technology

106 EVALUATING THE ACCURACY OF USING RAPID EVAPORATIVE IONIZATION MASS SPECTROMETRY (REIMS) TO DETERMINE BEEF MATURITY AND QUALITY GRADE

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Objectives: Rapid evaporative ionization mass spectrometry (REIMS) has shown potential in the meat and food industries to identify food fraud, classify samples, and potentially predict quality attributes. In this study, the repeatability and prediction accuracy of REIMS for identifying the physiological maturity and quality grade of beef strip loins ($N = 802$), was explored.

Materials and Methods: Beef carcasses were selected inside a single processing facility in Nebraska (day 2 postmortem) representing 2 carcass types: old (O; $n = 448$) maturity beef and young (Y; $n = 423$) maturity beef. Old-maturity beef carcasses determined to be over 30 mo of age (through dentition and skeletal maturity) were marked separately from young-maturity beef carcasses. Within skeletal maturity groups, carcasses were selected to represent 5 marbling scores: Slightly Abundant or greater (SLAB+) (O; $n = 89$) (Y; $n = 85$), Moderate (MD) (O; $n = 90$) (Y; $n = 84$), Modest (MT) (O; $n = 91$) (Y; $n = 84$), Small (SM) (O; $n = 88$) (Y; $n = 85$), and Slight (SL) (O; $n = 90$) (Y; $n = 85$). Metabolomic profiling of raw beef strip loin steak samples was performed using REIMS technology. The REIMS samples were thawed in a refrigerator at 0°C–-4°C for 16 to 24 h. Prior to analysis, thawed samples were kept in a cooler with ice for 25 to 30 min to ensure a consistent temperature across all samples at the time of analysis. A Synapt G2 Si Q-ToF (TOF), running in a negative sensory mode, with a REIMS ionization source and an iKnife sampling device (Waters Corporation, Milford, MA) was used to analyze each sample. A minimum of two 2-cm "burns" per sample were collected using the iKnife, with each "burn" lasting approximately one second. The "burns" for each sample were made on the cut surface, crossing both the lean and intramuscular fat naturally present in the sample. Abstract Model Builder (AMX) [Beta] version was the software used to preprocess the data, and R studio was used to analyze the results.

Results: The combination of dimensional reductions (feature selection [FS], principal component analysis [PCA], and a combination model [PCA-FS]) and 10 machine learning algorithms generated the best model to accurately predict age and quality grades in beef strip steak samples. XGBoost was the most successful and was used to generate the final prediction accuracies of the test data. The XGBoost machine learning algorithm was able to predict maturity (young maturity beef vs. old maturity beef) at an accuracy of 67.5%. Similarly, XGBoost was able to predict the quality grade (Prime, Choice, and Select) of beef samples at an accuracy of 63.8%.

Conclusion: In conclusion, the prediction accuracy of REIMS to differentiate Y from O beef steak samples and to differentiate quality grade in beef steak samples is very promising for the industry, as it provides real-time data with minimal sample preparation. Follow-up studies should include analysis of heat soluble versus insoluble collagen of old and young beef steaks.

Funding Source: Texas Tech University

Keywords: beef, young, old, maturity, quality grade, REIMS

107 PRINCIPAL COMPONENT ANALYSIS OF MEASURES OF MEAT QUALITY RELATED WITH INCIDENCE OF BOVINE RESPIRATORY DISEASE (BRD)

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Objectives: The objective of this study was to evaluate whether cattle experiencing a varied number of treatments for bovine respiratory disease (BRD) is related to variation in post-harvest beef quality.

Materials and Methods: Cattle ($n = 72$) were selected for this study based on number of metaphylactic treatments received in response to BRD (0, 1, or 2 treatments; $n = 24$ per treatment). On day 246 in the feedlot, cattle were shipped and processed at a commercial abattoir. At 48 h postmortem, striploins from steers were collected and further sectioned into quarters where they were randomly assigned to aging treatments (7, 14, 21, 28 d). Following assigned aging treatments, 3 steaks were cut from quarters aged 7, 21, and 28 d. Quarters aged 14 d had 5 steaks, with the additional 2 steaks assigned to retail display. Retail display steaks were packaged in overwrap and displayed in coffin-style cases to be evaluated every 12 h for redness and % discoloration by trained panelists for 6 d. Oxymyoglobin (OMb) and metmyoglobin (MMb) were determined by Hunter MiniScan for 0 and 6 d of retail display. Slice shear force (SSF) was evaluated on steaks representing every carcass and aging point. A principal component analysis (PCA) was performed using R statistical software. Meat quality attributes for color stability (redness, % discoloration, MMb, and OMb at 0 and 6 d of display) and SSF values at 7, 14, 21, and 28 d, as well as marbling scores of carcasses, were included in the model.

Results: Results of the PCA explained 100% of the variation, with 86.3% of the variation explained by PC1 and 13.7% explained by PC2. PC1 separated cattle treated 1 and 2 times from those never treated. Cattle treated 2 times were associated with darker red steaks, and an increased percentage of discoloration at 0 and 6 d of display. Cattle treated twice were also associated with increased percentage MMb at day 6 of display. Further, samples from cattle treated twice showed increased SSF values at 14 d of age, suggesting less tender samples from those animals at that time point. Cattle who were never treated for BRD were more closely associated with increased marbling scores. An increase in MMb percentage at day 0, as well as SSF values at 7 and 21 d, were also associated with 0 treatments, but these attributes loaded less heavily on the component. Cattle treated 1 time for BRD showed the fewest relationships with meat quality attributes measured; however, these samples were associated with increased percentages of OMb at day 0, as well as increased SSF values at day 28.

Conclusion: These data suggest that the number of treatments received for BRD may be related to meat color. Moreover, these data further suggest that increased BRD treatment may have a detrimental effect on the color stability of beef. Additionally, this model does not reveal a clear relationship between SSF values and number of BRD treatment.

Keywords: bovine respiratory disease, retail display, slice shear force

108 IMPACT OF AN ALTERNATIVE FABRICATION METHOD ON THE INITIAL TEMPERATURE AND PH DECLINE OF THE TOP ROUND FROM HEAVY WEIGHT BEEF CARCASSES

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Objectives: The average size of beef carcasses in the United States has increased linearly over time. The deep portion of the beef top round has been observed to have a slower chilling rate and faster pH decline especially in heavy weight carcasses. This study examines the impact of an alternative round fabrication method on top round temperature and pH decline.

Materials and Methods: Heavy-weight carcasses (HCW > 453.6 kg) were used in the study ($n = 11$). The femur bone on one side of each carcass was exposed partially by peeling down the knuckle sub-primal (TRT) prior to chilling. The knuckle on the adjacent side remained intact (CON). Each side was then evenly placed into the hot carcass cooler (0°C) for 48 h before further fabrication. Temperature loggers were placed in both the deep (DP) and superficial (SP) locations of the top round (TP) on each side immediately post-treatment fabrication. Temperature probes at SP were 2.54 cm below the surface of the TP. Probes for DP were inserted at the midline sagittal center of TP until in contact with the femur bone. Temperature ($n = 10$, one sample was lost due to equipment failure) and pH for SP and DP were recorded for 48 h to examine the change in decline rate during the initial chilling process. The pH was measured every hour for the first 12 h and every 6 h until hour 48. The carcasses were ribbed after 48 h, and ultimate pH was taken at the 12th–13th rib interface. Data were analyzed in R (4.2.2) with muscle location (SP/DP) and fabrication methods (TRT/CON) as fixed effects and animal as a random effect.

Results: Overall DP TRT had a 2°C lower average temperature compared to DP CON at the different observed time points. Significant interaction for location x fabrication methods was observed in temperature decline at hour 6 ($P = 0.029$), 12 ($P = 0.021$), and 36 ($P = 0.031$), and a trend was observed at hours 24 ($P = 0.066$), 30 ($P = 0.069$), and 48 ($P = 0.058$). No significant treatment effect was observed for SP at hours 6 ($P = 0.429$), 12 ($P = 0.644$), 24 ($P = 0.525$), 30 ($P = 0.279$), 36 ($P = 0.342$), and 48 ($P = 0.385$).

The muscle sampling location had a significant effect on pH decline throughout the 48 h, while no fabrication effect was observed. The DP had a significantly lower pH than SP starting from hour 0 ($P < 0.001$). At 42 h, a significant location effect was still present ($P = 0.004$) with DP having an average pH of 5.60 while SP averaged 5.69. This is expected since DP is known to have more rapid pH decline than SP from prior research. However, location ($P = 0.209$) effect was not significant at hour 48, and DP and SP reached a final pH of 5.55 and 5.58 respectively. For carcass ultimate pH at the 12th–13th rib interface, sides regardless of fabrication methods all reached an average pH of 5.54; no significant treatment effect was observed ($P = 0.806$).

Conclusion: The preliminary results suggest that pH decline and ultimate pH was not impacted by the alternative fabrication method. Peeling the knuckle resulted in accelerated temperature decline of the deep portion of beef top rounds. This could indicate potential mediation of temperature induced protein denaturation at DP location. Future research focusing on eating quality should be conducted to investigate whether top round fabricated with peeled knuckle resulted in increased palatability.

Funding Source: The Beef Checkoff

Keywords: beef, carcass size, fabrication method, pH, temperature

109 NATIONAL BEEF QUALITY AUDIT-2022: IN-PLANT SURVEY OF FACTORS RELATED TO QUALITY OF FED STEER AND HEIFER CARCASSES

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Objectives: The objective for this portion of the National Beef Quality Audit (NBQA)-2022 was to obtain USDA beef grading information and other carcass characteristics from US fed steers and heifers.

Materials and Methods: Collection of in-plant cooler data occurred between July 2021 and November 2022 at 35 different beef packing plants through a collaboration of 13 different universities. In-plant audits provided observations from multiple points throughout the year. Universities collected data from 10% of all carcasses processed during one full day of operation for a total of 9,746 carcasses. Carcass ID, carcass weight, ribeye area (REA), sex class, and breed classification (native, Bos indicus, and dairy). Bos indicus possessed a dorsal thoracic hump measuring greater than 10.2 cm, and dairy cattle had muscling and conformation that was angular and thin overall. All remaining cattle were classified as native. REA was measured using a dot grid, blotting paper, or the plant's beef camera. Lean and skeletal maturity was determined by the USDA Grader. Furthermore, preliminary yield grade (PYG), kidney, pelvic, and heart (KPH) fat, marbling score, degree of dark cutting, and presence of blood splash or callouses were recorded. Data were sent to Texas A&M University for analysis. Microsoft Excel and JMP Pro 16.0.0 software were used to analyze data. Fit Y by X functions were used for analysis of variance, and a student's t-test was used to conduct least squares means comparisons. Distributions, frequencies, means, standard deviations, minimums, and maximums were calculated in JMP using the distribution function. Correlations were determined using the multivariate functions.

Results: Distributions of sex class among sampled carcasses were steer (65.0%) and heifer (35.0%), while distributions of breed type were native (87.7%), dairy (11.3%), and Bos indicus (0.9%). The mean marbling score for this study was Small98. With the increase in mean marbling score, the mean quality grade (QG) increased to Choice16. The overall maturity of carcass was A66, the highest maturity mean since 2000. The overall USDA QG distribution of carcasses sampled were 7.5% Prime, 69.2% Choice, 16.4% Select, and 6.8% other. Other USDA QG represents carcasses graded as Standard, Commercial, Utility, dark cutter, blood splash, or calloused ribeye. From NBQA-2016, the percentage of Prime (+3.7%), Choice (+1.9%), and other (+0.2%) all increased, whereas the rate of Select carcasses decreased drastically (−6.8%). Dark cutting and blood splash were

observed at 1.7% and 0.5%, respectively, showing a decrease in percentage of dark cutting carcasses from the NBQA-2016 but an increase in blood splash. Distributions of USDA YG were YG 1 (7.7%), YG 2 (29.5%), YG 3 (40.1%), YG 4 (17.0%), and YG 5 (5.6%). Following the trend from previous years, the mean YG increased to 3.3.

Conclusion: The NBQA-2022 is the first of its kind to report a mean marbling score in the Modest range, meaning there was an increase of carcasses grading Prime and Choice. However, much like previous years, there was an increase in the YG of carcasses as characteristics like HCW, AFT, and REA all increased. As carcasses progressed from YG 1 to YG 5, there were improvements in marbling scores and QG, except there was no statistical difference between YG 4 and YG 5.

Funding Source: This project was funded, in part, by the Beef Checkoff.

Keywords: beef quality, carcass, quality grade, yield grade

110 PROFILING SENSORY AND MICROBIAL CHARACTERISTICS ASSOCIATED WITH THE SHELF-LIFE OF BULK PACKAGED, PREVIOUSLY FROZEN, ENHANCED USDA CHOICE BEEF SIRLOIN STEAKS

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Objectives: Steak enhancement is a common practice within the meat industry to increase palatability; however, minimal research has been conducted analyzing the effects of post-processing aging on injected steaks. This study evaluated sensory and microbial attributes to profile characteristics associated with the shelf-life of bulk packaged, previously frozen, enhanced USDA Choice beef sirloin steaks.

Materials and Methods: Frozen, bulk packaged, injected USDA Choice beef sirloin steaks (*Gluteus medius*) were received by Texas Tech University and were maintained at −20°C until assessment. Individual steaks (170 g) were thawed and placed into refrigeration (4°C) for the trial. Original saddle-bag bulk packages ("bag group" $n = 24$) were separated and individual steaks (8 steaks/bag) were randomly assigned to a refrigerated storage period (0, 7, 14, 21, 28, or 35 d). At the conclusion of each storage period, individual packages were opened, and purge loss, instrumental color values (L^*, a^*, b^*), and odor attributes (oxidized, putrid, sour, and total off-odor) were measured. Then, steaks were cooked in a combi oven to a peak temperature of 71°C, and trained sensory panelists quantified tenderness, juiciness, beef flavor id, browned, roasted, fat-like, buttery, umami, metallic, bitter, liver, sour, soapy, and oxidized on a continuous 100-point scale. Purge was used for microbial analysis to calculate enumerative estimation of aerobic bacteria. Analysis of variance was conducted to determine the effect of extended thawed refrigeration in relation to all response variables, with bag group included as a random effect. Finally, a multivariate discriminant function analysis (DFA) was utilized to create a composite variable of all attributes measured to designate an overall shelf-life determination.

Results: With extended thawed refrigeration, a sharp decline in quality was observed. There was an interaction ($P < 0.01$) between days aged and all response variables including subjective odor, purge loss, sensory attributes apart from juiciness, microbial counts, and instrumental color values. For odor attributes, oxidized and off-note intensity values substantially increased after the initial time point (0 d), with sour notes becoming more prevalent after 14 d and putrid scores increasing after 21 d ($P < 0.01$), removing freshness from the odor profile completely. Steaks released the most exudate during thawing (0 d), but further aging resulted in no statistical differences between days 7 and 35. As refrigeration time increased, beef flavor identity and browned decreased especially between 28 and 35 d ($P < 0.01$), and umami notes declined consistently throughout. Off-flavors such as bitter increased after day 7, metallic after 14 d, sour and soapy between 28 and 35 d, and liver and oxidized increased consistently with each treatment ($P < 0.01$). Microbial counts increased after 7 and 21 d. L^* color values increased after 0 d, and a^* increased after between 7 and 14 d. When all characteristics were analyzed using a DFA, a total freshness threshold arose and indicated a shift in quality between day 7 and 14.

Conclusion: Extended refrigeration beyond 7 d after thawing resulted in a decline of cumulative quality attributes and decreased palatability.

Keywords: beef, multivariate, palatability, shelf-life

111 EFFECT OF REFRIGERATION STORAGE ON THE QUALITY OF CHICKEN TENDERLOINS DURING TRANSPORT FROM A PROCESSING FACILITY TO A FOOD SERVICE DISTRIBUTION SYSTEM

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Objectives: This study was designed to assess quality parameters, including spoilage changes occurring in chicken tenderloins during distribution from a processing facility to a distribution center and during handling in a food service distribution system.

Materials and Methods: To ensure coverage, time of day effect, and monitor microbial deterioration during storage, a minimum of 10 samples were assessed at 0, 7, 14, and 21 d, with 3 repetitions conducted. Color measurements were taken using the HunterLab instrument. L^*, a^*, and b^* values were recorded and taken at 0, 7, 14 and 21 d of storage at refrigerated conditions (4°C). As a subjective analysis, color and odor panels were conducted at 0, 7, 14 and 21 d of storage at refrigerated conditions (4°C) by 7 trained panelists. Panelists were trained according to the American Meat Science Association (AMSA) guidelines used as a reference for meat color evaluation. Each panelist graded specific attributes such as brightness, lean, and discoloration with an unstructured line scale from 0 to 100. The literature on odor is limited, and some information is restricted by the perception consumers may have after smelling, which affects their meat consumption. However, the baselines for this panel were stipulated before training, and panelists were asked to identify the intensity of 4 odor traits: rancid, metallic, raw meat, and sour.

Results: A total of 120 samples were analyzed for color and odor; a one-way ANOVA was performed, comparing scores at each time point for each attribute, followed by a pairwise multiple comparison *t*-tests, adjusted by Bonferroni's correction when calculating the *P* values using R (Version 4.1.3) statistical software. The subjective analysis for color showed a significance across time ($P < 0.001$) of 38 and 31 in day 21, except for the attribute of brightness, which scored 19, meaning that, visually, for consumers the vividness of the color remains over time. In odor, there was a statistical difference ($P < 0.001$) of 33, 48, 18 and 15 in all the attributes evaluated. The attributes of rancid and raw meat were scored in a category of moderate in day 21. This can potentially indicate that the off odors rancid and raw meat can intensify and score a higher level after day 21. The L^*, a^*, and b^* values showed a statistical difference across time ($P < 0.05$) in the chicken tenderloins. Moreover, the L^* value presented a decrease in the final stage (day 21) meaning a discoloration of the samples.

Conclusion: Poultry processing facilities can improve maintaining food quality through the processing chain and identify best practices to avoid spoilage and extend the quality of the product when prolonged distribution time is needed.

Keywords: chicken tenderloins, color analysis, food quality, odor analysis

111.1 EVALUATION OF VEAL CARCASS COMPOSITION BY BIO-IMPEDANCE: A POTENTIAL APPROACH FOR YIELD GRADING

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Objectives: Measuring the composition of veal carcasses is important to evaluate growth efficiency and for genetic selection to optimize animal production traits. Carcass composition assessments are also essential and play a key role in determining market value. In this context, lean yield and fat estimations in carcass grading systems are valuable for the meat industry to allow sorting of carcasses for different market specifications and to establish equitable payment systems for producers. Currently in Canada, the grain-fed veal carcass grading system relies on a visual conformation assessment without measuring carcass composition. The implementation of new technologies, such as bio-impedance technology (BIA), to assess veal carcass composition is increasingly desired to enhance both consistency and accuracy of yield assessments. The aim of the present study was to evaluate the feasibility of BIA to estimate the lean and fat content of hot and cold grain-fed veal carcasses and the potential implementation for yield grading assessments.

Materials and Methods: A total of 273 left carcass sides (134 males and 139 females) were selected in a federally inspected veal commercial slaughterhouse. The BIA (Quantum IV–Bioelectrical Composition Analyser, RJL Systems) measurements (resistance, reactance, and electrode distance) were taken on hot and cold carcass sides at the time of slaughter, before entering the cooler, and at 24 h postmortem. Then, left veal carcass sides were scanned with a Lunar iDXA unit to estimate the total lean and fat content.

Results: Veal carcass weights and backfat thickness were within the range of the North American commercial veal carcasses with averages of 86.9 kg (±3.9 kg) and 3.9 mm (±3.2 mm), respectively. Hot and cold carcass sides showed high variability of resistance and reactance values ranging from 128.6 Ω to 267.5 Ω and from 30.7 Ω to 83.9 Ω, respectively. As expected, female and male carcasses showed differences ($P < 0.0001$) in lean (54.9% vs. 60.1%, respectively) and fat (23.4% vs. 16.4%, respectively) tissue composition. Overall, male carcasses were leaner than female ones. Lean and fat prediction accuracies (R^2) improved when sex was factored into the equations (Table 1). Likewise, the accuracies observed were slightly higher in cold carcasses ($R^2 = 0.76$–0.83) than those on hot carcasses ($R^2 = 0.45$–0.74) across the lean and fat content predictions (Table 1). Particularly, the highest prediction accuracies were observed for the lean ($R^2 = 0.82$) and fat ($R^2 = 0.83$) of cold carcasses. Overall, the error of lean percentage prediction was lower than the fat percentage (Table 1). Interestingly, the carcass temperature collected in the neck region on the cold carcass slightly improved the fat prediction equation accuracy, decreasing the coefficient of variance error (CVe%) from 9.36% to 8.92%, whereas carcass moisture data did not improve the accuracy of both lean and fat prediction equations (data not shown).

Table 1. Lean and fat content (%) of the hot and cold veal carcass sides predicted with Bio-Impedance measurements (BIA) with and without factor sex in the prediction equation.

				Factor sex included			Factor sex excluded		
	n	Units	Mean	R^2	RMSE	CVe (%)[2]	R^2	RMSE	CVe (%)
Lean									
Hot carcass	273	%	57.45	0.71	1.87	3.26	0.45	2.59	4.52
Cold carcass[1]	273	%	57.45	0.82	1.47	2.56	0.76	1.71	2.98
Fat									
Hot carcass	273	%	19.96	0.74	2.30	11.53	0.48	3.27	16.35
Cold carcass	273	%	19.96	0.83	1.87	9.36	0.76	2.20	11.02

[1]Excluding the internal carcass temperature in the predicted equation

[2]Coefficient of variance error

Conclusion: The results of the present study suggest that lean and fat percentages of veal carcasses can be objectively and accurately predicted by applying the BIA technology. Further implementation of this technology would be valuable for development of a grading method based on the lean or fat content of grain veal carcasses.

Funding Source: The authors gratefully acknowledge funding support from the Ministry of Agriculture, Fisheries and Food, Les Producteurs de bovins du Québec-Maison de l'UPA and the in-kind contribution of animals, facilities, and people received from Agriculture and Agri-Food Canada (AAFC), Lacombe (Alberta) and Sherbrook (Quebec) Research and Development Centers, Canada. Special thanks are extended to CBGA graders for the plant carcass data collection. The authors express their gratitude to the AAFC-Lacombe abattoir and technical staff for the collection and compilation of the research data.

Keywords: bio-impedance technology, carcass composition, veal

Meat and Poultry Safety

112 SALMONELLA ENTERICA, ESCHERICHIA COLI O157:H7, AND LISTERIA MONOCYTOGENES INACTIVATION IN NON-INTACT BEEF STEAKS DURING LOW-TEMPERATURE SOUS VIDE COOKING

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Objectives: Sous vide, which is cooking of vacuum-packaged products in water at low temperatures and longer times, is popular in food service and home kitchens. After sous vide cooking, meat may be served immediately after searing or rapidly chilled in an ice bath and refrigerated for later use. This method provides uniform cooking and ease of handling and improves the production system organization in restaurants along with improving eating quality. Generally, sous vide cooking is considered safe; however, there is a temptation to use lower temperature and longer time combinations than used with dry cookery to achieve different quality attributes. In our previous study, we assessed the time–temperature combinations for intact beef steaks. Parameters for blade-tenderized steaks should also be determined, as inactivation of internalized pathogens may require longer cooking times.

Materials and Methods: Eye of round steaks (2.54 cm thick, 100 ± 3 g) were cut and individually inoculated with 5 strains of *Salmonella enterica*, 3 strains of *Listeria monocytogenes*, and 3 strains of *Escherichia coli* O157:H7 on the surface. A jaccard was used to tenderize the steaks individually. After pathogen attachment (30 min) and vacuum packaging, steaks were cooked at 52.5°C, 57.5°C, 60°C, and 62.5°C for up to 450 min, 90 min, 56 min, and 35 min, respectively. Samples were taken out for enumeration every 45 min, 15 min, 8 min, and 5 min, respectively, and sliced thinly with a sterile blade to account for internal pathogens. *Salmonella*, *Listeria,* and *E. coli* O157:H7 were enumerated using xylose lysine tergitol agar, modified oxford agar, and cefixime tellurite sorbitol MacConkey agar, respectively. These experiments were independently replicated 6 times. Data were analyzed using a mixed linear model with cooking temperature and time as fixed effects and replicates as random effects. The data are being analyzed to generate non-linear predictive models for pathogen inactivation, which will be the optimal way to predict time to 5 and 6.5 log reduction.

Results: Four cooking temperatures take different times ($P < 0.001$) for *Salmonella*, *Listeria*, and *E. coli* O157:H7 lethality. Time–temperature combinations for 5-log and 6.5-log reductions in non-intact beef steaks are mentioned in Table 1. Of the 3 pathogens, *Salmonella* is the least resilient, requiring the shortest time to both 5- and 6.5-log reductions at all temperatures.

Table 1. Cooking time (min) to achieve a minimum 5- and 6.5-Log reduction during sous vide cooking.

Cooking temperature	5 Log Reduction			6.5 Log Reduction		
	Salmonella enterica	*Listeria monocytogenes*	*E. coli* O157:H7	*Salmonella enterica*	*Listeria monocytogenes*	*E. coli* O157:H7
52.5°C	90	315	180	135	360	315
57.5°C	30	60	45	45	75	60
60°C	24	32	24	24	40	32
62.5°C	20	30	20	25	35	30

Conclusion: Data generated in this study provide guideline time–temperature combinations for non-intact beef steaks to support sous vide cooking in food service and home kitchens. *Salmonella enterica* and *E. coli* O157:H7 take less time to be inactivated than *Listeria monocytogenes*. Considering the risk associated with beef products, *E. coli* O157:H7 could be used as a pathogen lethality indicator in sous vide cooking as it survives better in high moisture conditions, especially at lower temperatures.

Funding Source: Research was funded by the Florida Beef Council.

Keywords: needle tenderization, non-linear modeling, sous vide

114 RAPID QUANTITATIVE METHOD DEVELOPMENT AND VERIFICATION FOR ENUMERATION OF SALMONELLA IN PORK LYMPH NODES USING BAX® SYSTEM REAL TIME ASSAY

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Objectives: The purpose of this study was to develop and verify a rapid RT-PCR enumeration method for *Salmonella* in pork lymph nodes (LN) utilizing BAX® System SalQuant® as well as to assess the performance of the methodology in comparison with 3M™ EB Petrifilm™ + XLD replica plate existing methodology.

Materials and Methods: For the method development, *Salmonella* negative small (<3 g) and medium (≥3 g and ≤25 g) pork LN were trimmed, weighed, surface sterilized, pulverized, and spiked with 1.00 to 5.00 Log CFU/LN using *Salmonella* Typhimurium ($n = 32$). Samples were homogenized with 20 mL (small LN) and 80 mL (medium LN) of BAX MP and then incubated at 42°C and tested at 6, 8, and 24 h using the BAX® System RT PCR Assay for *Salmonella*. Cycle threshold (CT) values associated with each pathogen concentration and LN size were recorded and utilized to evaluate their relationship with the inoculated levels. For method verification, additional pork LN ($n = 26$) were processed as described before and enumerated by (1) BAX® System SalQuant® and (2) most probable number (MPN) using BAX® System RT PCR Assay for *Salmonella*. The relationship between both methodologies was assessed using linear regression analysis. For the method comparison, market hog LN ($n = 3{,}564$) were collected from 6 commercial pork abattoirs located in 3 different regions in the United States (east, central, and west) during 3 seasons (winter, spring, and fall). Mesenteric, subiliac, superficial inguinal, pre-scapular, tracheobronchial, and axillary LN from 33 different animals were collected each time. Samples were processed as mentioned before and enumerated by (1) BAX® System SalQuant® and (2) 3M™ EB Petrifilm™ + XLD replica plate method. Kappa measurement of agreement and *t*-test for paired samples were conducted to compare both methodologies. All significant differences were evaluated under an $\alpha = 0.05$.

Results: Linear-fit equations during method development were estimated with recovery times of 6 h and a limit of quantification of 10 CFU/LN ($R^2 = 0.90$ and Log RMSE = 0.479). Slopes and intercepts for method verification using BAX® System SalQuant® were not significantly different ($P > 0.05$) when compared with MPN. No statistical difference ($P = 0.289$) was found between BAX® System SalQuant® and 3M™ EB Petrifilm™ + XLD replica plate for the method comparison. The kappa coefficient was 0.384, which indicates a fair agreement between both enumeration methodologies.

Conclusion: The results support the capability of BAX® System SalQuant® to enumerate *Salmonella* in small and medium pork LN. This development and validation provides evidence for the availability of a rapid and feasible quantification methodology for pathogen load estimation in meat products with advantages over published methodologies with lower limits of quantification (10 CFU/LN).

Keywords: pathogen control, pork lymph nodes, *Salmonella* quantification

115 CULTURED SUGAR-BASED, BUFFERED VINEGAR ALTERNATIVE PRODUCTS INHIBIT THE OUTGROWTH OF LISTERIA MONOCYTOGENES IN OVEN-ROASTED TURKEY

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Objectives: Clean-label antimicrobials continue to be sought-after ingredients in the ready-to-eat (RTE) deli meat industry. The Canadian Food Inspection Agency (CFIA) has promulgated rules that buffered vinegar products need to be labeled with the associated buffering system beginning November 2023. In this study, cultured sugar-based ingredients (Verdad® Powder N30 [CS-1] and Verdad® N16 [CS-2]) and a novel cultured sugar ingredient (Verdad® N38 [NCS]) were evaluated for control of *Listeria monocytogenes* outgrowth in RTE turkey.

Materials and Methods: Ground and formed oven-roasted turkey breast samples were produced without antimicrobial (negative control [NC]) or with antimicrobials: 0.75% CS-1 + 2.00% CS-2 (T1), 1.10% CS-1 + 2.35% CS-2 (T2), and 1.90% NCS (T3). Product was sliced in 25 g samples, inoculated with a 5-strain *L. monocytogenes* cocktail or left uninoculated (background microflora analysis), vacuum packaged, and stored at 4.4°C (40°F). Upon sampling, uninoculated slices were evaluated for pH change and/or outgrowth of background flora, and the inoculated product was sampled for *L. monocytogenes* counts. The product was transferred to a sterile stomacher bag to which a 1:2 dilution of buffered peptone water (BPW) was added. The sample was stomached (200 rpm; 30 s), serially diluted, and spread plated onto Modified Oxford agar (MOX; 35°C incubation for 48 h) to enumerate *Listeria* and de Man, Rogosa, and Sharpe agar (MRS; 30°C incubation for 48 h) to enumerate background lactic acid bacteria. Time to 1-log and 2-log outgrowth (TTG1 and TTG2, respectively) and statistical differences in population among treatments at each pull date was evaluated.

Results: Turkey samples were analyzed for *L. monocytogenes* outgrowth for 77 d. All the treatments had a similar starting *L. monocytogenes* population of ca. 2.90 log CFU/g. The negative control sample observed a TTG1 of ca. 7 d and a TTG2 of ca. 12 d. *Listeria* population did not show a significant difference ($P > 0.05$) among treatments T1, T2, and T3, which all exhibited no outgrowth throughout the shelf life. Lactic acid bacteria outgrowth was not observed in all treatments, nor was a change in product pH outside normal fluctuation. Therefore, control of *L. monocytogenes* was achieved by antimicrobial addition and not the outgrowth of indigenous microflora or changes in product pH.

Table 1. Population (log CFU/g) of *Listeria monocytogenes* in the negative control (NC) or treated (T1-T3) samples of turkey over 77 days.

Treatments	Days to 1-log outgrowth (loa CFU/g)	Days to 2-log outgrowth (log CFU/g)
NC: Negative control	7	12
Tl: 0.75% CS-1 + 2.00% CS-2	>77	>77
T2: 1.10% CS-1 +2.35% CS-2	>77	>77
T3: 1.90% NCS	>77	>77

Conclusion: The application of cultured sugar antimicrobials can extend the shelf life of RTE meat products. In this particular project, a shelf life of 77 d was achieved, outperforming negative control by 70 d.

Funding Source: Corbion

Keywords: food safety, *Listeria monocytogenes*, microbial outgrowth, shelf life, turkey

116 SHELF-LIFE ENHANCEMENT OF GROUND POULTRY USING COMBINATION OF NATURAL ANTIOXIDANT AND VINEGAR

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Objectives: Increase in concerns regarding the use of synthetic preservatives has incited greater interest in natural preservatives for the extension of shelf-life of ground chicken. Rosemary extract (RE) is a clean-label antioxidant/antimicrobial in meat systems; however, a limited documentation is available on the use of RE in combination with natural vinegar based acetic acid salts (IsoAge DV100) in improving the shelf-life of ground chicken. The aim of the current research was to validate the inhibition of spoilage microorganisms in ground chicken supplemented with RE alone or in combination with IsoAge DV100.

Materials and Methods: Different treatments of ground chicken thighs (97% poultry basis and 3% with non-meat ingredients balanced with water as per CFR 319.140) were prepared. To help distribute the rosemary, 1.5% water was added across all of the treatments. Treatments included control (no preservative) and RE at a concentration of 20, 40, 60, 80, and 100 ppm alone or in combination with 0.75% IsoAge DV100. Treated samples were packed and stored under aerobic atmosphere at 4°C for up to 25 d. At each sampling time point, i.e., day 0, 2, 4, 6, 8, 10, 12, 21, and 25, two samples/

Table 1. Time (days) to end of shelf life (6 log CFU/g) at 4°C.

	Days to 6 logs CFU/g	
Treatment	Aerobic Plate Count	Enterobacteriaceae
Control	6.46 ± 0.079^{A}	8.17 ± 0.006^{D}
20 ppm RE*	6.28 ± 0.026^{A}	8.05 ± 0.063^{D}
40 ppm RE	5.93 ± 0.093^{A}	7.71 ± 0.148^{D}
60 ppm RE	6.56 ± 0.039^{A}	8.33 ± 0.079^{D}
80 ppm RE	6.90 ± 0.196^{AB}	8.09 ± 0.064^{D}
100 ppm RE	5.85 ± 0.509^{A}	7.92 ± 0.148^{D}
0.75% IsoAge DV100	9.52 ± 1.05^{BC}	18.26 ± 0.711^{E}
20 ppm RE + 0.75% IsoAge DV100	11.66 ± 0.075^{CDE}	18.43 ± 0.291^{E}
40 ppm RE + 0.75% IsoAge DV100	12.76 ± 0.902^{DE}	17.51 ± 3.057^{E}
60 ppm RE + 0.75% IsoAge DV100	14.16 ± 0.224^{E}	18.51 ± 0.298^{E}
80 ppm RE + 0.75% IsoAge DV100	12.07 ± 0.550^{CDE}	18.71 ± 0.112^{E}
100 ppm RE + 0.75% IsoAge DV100	11.40 ± 0.461^{CD}	19.01 ± 0.305^{E}

Data represented as mean ± standard deviation (days). Different letters in the same column depict significant differences between treatments ($P \leq 0.05$).

*RE: Rosemary Extract

treatment were removed from the 4°C refrigerator, homogenized, and plated onto Plate Count and Violet Red Bile (VRB) agar for enumeration of aerobic plate count (APC) and Enterobacteriaceae (EB), respectively. Spoilage threshold and maximum population density at end of stationary phase was considered as 6 and 8 log CFU/g, respectively. Data generated were used for primary modelling using modified Gompertz equation to calculate maximum growth rate (μmax; log/day) and days to reach spoilage threshold for each treatment. Differences among the treatments were determined using one-way ANOVA. Statistical analysis and model building was performed in JMP Pro version 15.1.0 (SAS Institute Inc., Cary, NC), with significance set at $P \leq 0.05$.

Results: Overall, RE (60 ppm or greater) in combination with 0.75% IsoAge DV100 was effective in controlling the growth of APC and EB in ground chicken. Specifically for APC and EB, the combination treatment (RE 60 ppm or greater + 0.75% IsoAge DV100) significantly ($P \leq 0.05$) enhanced the shelf-life of ground chicken by 8 and 11 d as compared to the control (no preservative), which reached spoilage threshold (6 logs CFU/g) by 6 and 8 d, respectively.

Conclusion: Results of this study corroborate the ability of natural antioxidant in combination with IsoAge DV100 in enhancing the shelf-life of ground chicken by 100%.

Keywords: ground chicken, rosemary extract, spoilage control, vinegar

117 IDENTIFICATION OF ACTIONABLE SENTINELS FOR SALMONELLA CONTAMINATION OF BEEF LYMPH NODES AND DETERMINING THE IMPACT OF ENVIRONMENTAL CONTAMINATION LEVELS

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Objectives: The study objective was to determine whether finishing pen surface soil material samples (SMS), cecal content swabs (CCS), or ileocecal lymph nodes (ICLN) can be used as sentinels for high-levels of *Salmonella* in beef cattle peripheral lymph nodes (PLN).

Materials and Methods: Four 10-gram SMS were obtained from each of 100 finishing cattle pens distributed equally across 10 commercial feedyards. Culture methods were used to detect and quantify *Salmonella* in SMS. Quantified SMSs were assigned a *Salmonella* Index (SalI) equal to their log CFU/g value. SMS that were *Salmonella* prevalent but below the limits of quantification (2.30 log CFU/g) were assigned a SalI of 1.00. *Salmonella* prevalence negative SMS were assigned a SalI of 0.00. Eight pens with 100% SMS *Salmonella* prevalence and SMS SalI ≥ 1.00 and 8 pens with SMS SalI = 0.00 were sampled at harvest in a commercial beef processing plant. From each of these 16 pens, CCS, ICLN, superficial cervical LN, popliteal LN, and subiliac LN were obtained from between 20 and 25 randomly sampled carcasses. *Salmonella* were enumerated and detected using BAX System SalQuant and BAX Real-time PCR *Salmonella* assays, respectively. Quantified samples were assigned a SalI equal to their log CFU value. Cecal content sponges and LN samples that were *Salmonella* prevalent but below the limits of quantification (1.76 log CFU/cecal content sample; 1.00 log CFU/LN sample) were assigned SalIs of 0.88 and 0.50, respectively. *Salmonella* negative samples were assigned a SalI of 0.00. For each pen, the mean of superficial cervical LN, popliteal LN, and subiliac LN SalI was the mean PLN SalI. Pens with mean PLN SalI ≥ 1.00 were classified as contaminated with high levels of *Salmonella*. SMS, CCS, and ICLN were each evaluated as possible sentinels for PLN. Pens with mean sentinel SalI ≥ 1.00 and mean PLN SalI ≥ 1.00 were considered true positives. Pens with mean sentinel SalI ≥ 1.00 and mean PLN SalI < 1.00 were considered false positives.

Table 1. *Salmonella* levels and classifications in peripheral lymph nodes (PLNs), pen surface soilmaterial samples (SMSs), cecal content swabs, and Ileocecal lymph nodes (LNs).

	Mean *Salmonella* index				*Salmonella* level classification			
Pen ID	PLNs	Pen surface SMSs	Cecal content swabs	Ileocecal LNs	PLNs	Pen surface SMSs	Cecal content swabs	Ileocecal LNs
97	3.63	1.40	1.97	2.65	High	High	High	High
63	3.01	1.00	1.04	1.10	High	High	High	High
56	2.11	1.88	1.55	0.58	High	High	High	Low
51	1.19	1.00	0.81	1.03	High	High	Low	High
94	0.32	1.00	0.07	0.02	Low	High	Low	Low
55	0.25	1.00	1.29	0.83	Low	High	High	Low
88	0.19	0.00	0.26	0.46	Low	Low	Low	Low
89	0.15	0.00	0.65	0.70	Low	Low	Low	Low
54	0.10	0.00	0.64	3.34	Low	Low	Low	High
41	0.05	1.00	1.28	1.03	Low	High	High	High
93	0.01	0.00	0.31	0.27	Low	Low	Low	Low
71	0.01	0.00	0.13	0.25	Low	Low	Low	Low
2	0.00	0.00	0.08	0.15	Low	Low	Low	Low
16	0.00	0.00	0.48	0.31	Low	Low	Low	Low
17	0.00	1.00	0.32	0.43	Low	High	Low	Low
37	0.00	0.00	1.19	1.32	Low	Low	High	High

Pens with mean sentinel SalI < 1.00 and mean PLN SalI ≥ 1.00 were considered false negatives. Pens with mean sentinel SalI < 1.00 and mean PLN SalI < 1.00 were considered true negatives.

Results: High *Salmonella* levels (mean SalI ≥ 1.00) were identified in PLN from 4 pens (Table 1). SMS from 8 pens had high *Salmonella* levels including all pens with high PLN *Salmonella* levels (Table 1). CCS from 6 pens had high *Salmonella* levels including 3 of 4 pens with high PLN *Salmonella* levels. ICLN from 6 pens had high *Salmonella* levels including 3 of 4 pens with high PLN *Salmonella* levels (Table 1). Evaluation of SMS, CCS, and ICLN as *Salmonella* sentinels for PLN found specificities were 67%, 75%, and 75% for SMS, CCS, and ICLN, respectively. SMS, CCS, and ICLN had false negative rates of 0%, 25%, and 25%, respectively. False positive rates were 33%, 25%, and 25% for SMS, CCS, and ICLN, respectively.

Conclusion: These results suggest that SMS, CCS, and ICLN each could be used to identify pens of cattle with high levels of *Salmonella* in PLN. However, SMS was the only method with no false negative results. Additional research across diverse production environments is needed to confirm these results.

Funding Source: Beef Checkoff, Foundation for Meat and Poultry Research and Education, and Agricultural Research Service National Program 108—Food Safety.

Keywords: beef, cattle, lymph nodes, quantification, Salmonella

118 EFFICACY OF POTASSIUM BASED ORGANIC ACID SALTS ON FRANKFURTERS AGAINST LISTERIA MONOCYTOGENES

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Objectives: Given the market trend and increasing regulation of sodium reduction, potassium-based solutions are preferred antimicrobials. The objective of the study was to assess organic acid blends prepared from "Generally Recognized as Safe" potassium-based ingredients such as propionates, lactates, and acetates for antilisterial effects on frankfurters stored at 4°C for 120 d.

Materials and Methods: A total of 2000 hot dogs of different treatment formulations (0.25%–1.25% potassium acetate/diacetate blend, 0.65%–0.85% potassium/diacetate propionate blend, and 4.8% potassium lactate/sodium acetate) and control (no antimicrobials) were surface inoculated in pairs with 5-strain cocktail of *L. monocytogenes*. Inoculation level of ca. 3 log CFU/g of *L. monocytogenes* was achieved on day 0 for all the treatments. Following bacterial attachment, the hot dogs were vacuum packaged and stored at 4°C and sampled up to 120 d in duplicates. At each sampling, hot dogs were homogenized using a stomacher and plated onto Modified Oxford medium for enumeration. Failure of antilisterial capacity was assessed at 2 log CFU/g outgrowth, and treatment performance from 2 replicates was compared using one-way ANOVA. Statistical analysis was

Table 1. Recovery of *Listeria monocytogenes* (log CFU/g) from surface-inoculated frankfurters stored at 4 °C.

	Treatments					
Day	Control	0.65% Potassium Acetate/Diacetate	0.65% Potassium Propionate/Diacetate	1.25% Potassium Acetate/Diacetate	0.85% Potassium Propionate/Diacetate	4.8% Potassium lactate/ Sodium diacetate
0	3.0 ± 0.05^{A}	2.9 ± 0.22^{A}	2.9 ± 0.03^{A}	2.9 ± 0.20^{A}	2.9 ± 0.02^{A}	3.0 ± 0.03^{A}
7	3.1 ± 0.04^{A}	2.8 ± 0.18^{A}	2.7 ± 0.02^{A}	2.7 ± 0.15^{A}	2.7 ± 0.25^{A}	2.9 ± 0.02^{A}
14	4.3 ± 0.08^{A}	2.8 ± 0.08^{B}	2.6 ± 0.11^{B}	2.6 ± 0.02^{B}	2.8 ± 0.09^{B}	2.9 ± 0.11^{B}
21	6.2 ± 0.2^{A}	2.7 ± 0.01^{B}	2.7 ± 0.14^{B}	2.7 ± 0.11^{B}	2.8 ± 0.06^{B}	3.0 ± 0.14^{B}
28	7.5 ± 0.04^{A}	2.8 ± 0.01^{B}	2.8 ± 0.04^{B}	2.8 ± 0.06^{B}	2.8 ± 0.15^{B}	2.8 ± 0.04^{B}
35	8.3 ± 0.06^{A}	2.6 ± 0.02^{B}	2.8 ± 0.21^{B}	2.8 ± 0.25^{B}	2.7 ± 0.04^{B}	2.7 ± 0.21^{B}
49		2.7 ± 0.39^{B}	2.3 ± 0.16^{B}	2.9 ± 0.27^{B}	2.7 ± 0.01^{B}	4.4 ± 0.16^{C}
63		2.8 ± 0.03^{B}	2.8 ± 0.06^{B}	2.8 ± 0.04^{B}	3.1 ± 0.04^{B}	4.2 ± 0.06^{C}
77		2.7 ± 0.14^{B}	2.4 ± 0.04^{B}	3.0 ± 0.21^{B}	3.1 ± 0.08^{B}	3.4 ± 0.07^{B}
91		3.2 ± 0.03^{B}	2.9 ± 0.03^{B}	3.3 ± 0.25^{B}	3.2 ± 0.70^{B}	2.8 ± 0.02^{B}
105		2.7 ± 0.03^{B}	2.6 ± 0.14^{B}	2.8 ± 0.25^{B}	3.1 ± 0.08^{B}	2.5 ± 0.06^{B}
120		3.0 ± 0.32^{B}	2.7 ± 0.15^{B}	3.0 ± 0.11^{B}	3.2 ± 0.62^{B}	2.6 ± 0.26^{B}

Data depicted are the mean ± standard deviation. Values indicated by different letters across the row are significantly different ($P < 0.05$).

carried out using JMP Pro version 15.1.0 (SAS Institute Inc., NC), with significance set at $P < 0.05$.

Results: The control treatment exhibited fastest outgrowth (>2 log CFU/g) of *L. monocytogenes* by 21 d of storage at 4°C. As compared to control and lactate-based blend, both higher and lower concentrations of potassium acetate/diacetate and potassium propionate/diacetate blends significantly ($P < 0.008$) controlled *L. monocytogenes* outgrowth (<2 log CFU/g) for 120 d of storage at 4°C. Table 1 represents the growth of *L. monocytogenes* on the control and treatments over time on frankfurters stored at 4°C.

Conclusion: Potassium acetates/diacetate and potassium propionate/diacetate blends can be used as highly effective and cost-efficient alternatives to classic lactate-based *Listeria* interventions.

Keywords: frankfurters, *Listeria monocytogenes*, organic acid, pathogen control, preservatives

119 DOSE-RESPONSE ASSESSMENT OF SODIUM NITRITE CONCENTRATION ON LISTERIA MONOCYTOGENES IN CURED HAM

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Objectives: Sodium nitrite is used for its preservative effect against *Clostridium* spp., and could additionally inhibit *L. monocytogenes* outgrowth, thereby enhancing the food safety of processed meats. Due to varying usage regulations (brine injected products could vary between 120 and 200 ppm) across regions and food products, capturing the dose response is essential to help evaluate the antilisterial effect of varying levels of sodium nitrite obtained. The objective of this study was to evaluate the antimicrobial efficacy of sodium nitrite ($NaNO_2$) via a dose response in a model cooked ham system.

Materials and Methods: Deli-style hams were manufactured with pork ham muscles and 35% brine extensions resulting in 0–300 ppm nitrite content. Base brine formulation included 1.9% salt (NaCl), 1.85% sugar, 0.3% sodium phosphate, and 0.04% sodium erythorbate on total formula basis. Hams were sliced, ground, and inoculated using a blender. Inoculation level of ca. 3 log CFU/g with a 5-strain cocktail of *L. monocytogenes* (serotype 1/2a, 1/2b, 4a, and 4b) was achieved on day 0 for all the treatments. Following inoculation samples were vacuum packaged and stored at 4°C. Sampling (duplicates) were removed from storage, homogenized, and plated onto modified Oxford Media for enumeration. Failure of antilisterial performance threshold and maximum population density at end of stationary phase was considered at 2 and 8 log CFU/g, respectively. Data generated were used for primary modelling using modified Gompertz equation to calculate maximum growth rate (μmax; log/day), lag time (days) and days to reach failure threshold. Differences among the treatments were determined using one-way ANOVA. Statistical analysis and model building was carried out using JMP (SAS Institute Inc., NC), with significance set at $P < 0.05$.

Results: Time to reach >2 logs CFU/g of population of *L. monocytogenes (*presented in Table 1) were calculated from the model using growth rate and lag time. It was observed that with increasing dose of sodium nitrite in the formulation, there was an increase in the lag time and days to reach antilisterial threshold and decrease in the exponential growth rate. However, significant difference ($P < 0.05$) in increase in days to reach 2 log outgrowth was only observed between the highest dosage (300 ppm) and the

Table 1. Time to reach failure of antilisterial performance at 4 °C.

Sodium Nitrite Concentrations	Days to reach > 2 log CFU/g
No Nitrite Control	11.73 ± 0.73^{A}
20 ppm $NaNO_2$	11.77 ± 0.04 ^{A}
40 ppm $NaNO_2$	11.95 ± 0.15 ^{A}
60 ppm $NaNO_2$	11.83 ± 0.50 ^{A}
80 ppm $NaNO_2$	12.22 ± 0.20 ^{A}
100 ppm $NaNO_2$	11.75 ± 0.13 ^{A}
120 ppm $NaNO_2$	11.76 ± 0.18 ^{A}
140 ppm $NaNO_2$	11.85 ± 0.68 ^{A}
160 ppm $NaNO_2$	12.33 ± 0.03^{A,B}
180 ppm $NaNO_2$	12.43 ± 0.53 ^{A,B}
200 ppm $NaNO_2$	12.56 ± 0.22 ^{A,B}
300 ppm $NaNO_2$	14.11 ± 0.03 ^{B}

Data depicted are the mean ± standard deviation. Values indicated by different letters are significantly different ($p \leq 0.05$).

dosages between 20 and 140 ppm. All the treatments reached 8 log CFU/g by 28 d.

Conclusion: Sodium nitrite as a curing agent in ham plays an important role in *L. monocytogenes* protection. Data generated in this study can aid in decisions for secondary process necessitation such as adjusting dosage of natural curing agents (Accel™) in meat products.

Keywords: dose response, ham, *Listeria monocytogenes*, pathogen control, preservatives

120 ACCELERATING RISK ASSESSMENT OF LISTERIA MONOCYTOGENES AND UNDERSTANDING IMPACT OF PH IN LONG SHELF LIFE MEAT PRODUCTS USING PREDICTIVE MICROBIOLOGY PRINCIPLES

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Objectives: Market demand for meat products with long shelf life puts a key challenge toward development of food safety systems safeguarding against of *Listeria monocytogenes* (LM) outgrowth. *Listeria* control is enabled through reducing outgrowth and longer lag times for these conditions. Meat products can be formulated across various pH, with a goal of extending shelf life at ambient temperature. While this contributes to increased shelf life, it also elicits the development of accelerated methodology to evaluate risk at such pH. The objective of this study was to optimize and develop an accelerated method for determining the risk assessment using specific parameters from LM growth curves at different pH values.

Materials and Methods: Six LM strains isolated from meat and dairy sources were examined for growth and lag time in Bioscreen C at 20°C. Brain heart infusion broth at pH values between 4.5 and 7.5 in 0.2 increments were measured in duplicate. Optical density was measured every 30 min for approximately 6 d to generate growth curves. Data were fitted with the Modified Gompertz equation to generate growth rates and lag times for each pH value. Lag time was defined as λ using the equation $y_{(t)} = y_{(0)} + A \cdot \exp[-\exp[\mu_{max}/A \cdot (\lambda - t) + 1]]$. Differences in growth rate and lag time across pH were evaluated with ANOVA and Tukey's pairwise comparisons.

Results: A linear ($R^2 = 0.9276$) increase ($P < 0.001$) in growth rate was observed by increasing the pH (Increase in growth rate of 2.27 1/24 h per unit pH increase). Lag time was more affected at pH 4.5 to 5.0, as lag times ranged from 18.48 to 45.12 h. For pH 5.1 till 7.5, only a limited change in lag time was observed, as lag times ranged from 6.72 to 12.24 h.

Conclusion: Considering higher pH treatments had minimal change in measured lag time, while growth rate continued to display differences, these results show that growth rate gives better insight in pH effect than lag time when using OD-based methodologies.

Keywords: food safety, *Listeria*, method development, modeling, pathogen

121 CARCASS VASCULAR RINSE BLEND ENHANCED WITH DIFFERENT ANTIMICROBIALS REDUCES SALMONELLA IN INOCULATED PRE-RIGOR GROUND BEEF

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Objectives: The study objective was to investigate the ability to improve the antimicrobial efficacy of a vascular rinse blend solution by the addition of different antimicrobial chemicals against *Salmonella* when incorporated into pre-rigor ground beef prior to being vacuum packaged.

Materials and Methods: *Salmonella* Enteritidis, Typhimurium, Infantis, and Kentucky stock cultures were equally pooled and used to inoculate pre-rigor ground beef. Prior to carcass splitting, pre-rigor triceps brachii (TB) muscles were excised, coarse ground, and inoculated with

the *Salmonella* cocktail adjusted to 0.5 McFarland density (~1.5 x 10^8 cfu/mL) within 1 h postmortem. After incubation (1 h, 4°C), the ground beef was divided and 5 Rinse and Chill (RC; 98.5% water, glucose, polyphosphates, maltose) based blend treatments (TRT) were prepared. Two treatments contained only RC (40 ppm, RC-40; 1000 ppm, RC-1000; added on a meat weight basis, delivered as a solution). The remaining 3 treatments contained RC-1000 along with cetylpyridinium chloride (300 ppm CPC), acidified sodium chlorite (300 ppm ASC), or CPC (150 ppm) + ASC (150 ppm). After inoculation, samples were fine ground, portioned, vacuum packaged, and stored at 4°C. *Salmonella* enumeration was performed at 0, 1, 3, 7, 14, 21, and 28 d post inoculation. The pH of the samples was also recorded. Four beef cattle were harvested, and the excised TB served as the experimental unit. A 5 x 7 factorial design (TRT x Day) was used to statistically analyze the data, and the harvest period served as a covariate in the analysis.

Results: The average pH at the time of grinding the beef was 6.13 (0 d), and after 24 h, the average was 5.84. On the inoculation day, no differences ($P > 0.05$) were observed in *Salmonella* counts (log cfu/g) among the TRT (range of 5.93 to 6.01 log cfu/g). RC-40 and CPC had lower ($P < 0.05$) *Salmonella* counts (5.82 log cfu/g) on days 21 and 28. ASC resulted in a reduction ($P < 0.05$) in *Salmonella* on each day post inoculation to a final count of 3.89 log cfu/g (28 d). CPC + ASC reduced ($P < 0.05$) the *Salmonella* on 3, 7, and 28 d post inoculation. However, the final reduction (28 d, 5.31 log cfu/g) was less than ASC. *Salmonella* loads were not affected ($P > 0.05$) by RC-1000.

Conclusion: Antimicrobial treatments containing acidified sodium chlorite added to the rinse blend (RC-1000) when incorporated into pre-rigor ground beef appear to be more effective than cetylpyridinium chloride at *Salmonella* reduction. These results demonstrate potential applicability of antimicrobial supplementation in vascular rinse solutions as a means to reduce *Salmonella* prevalence.

Keywords: acidified sodium chlorite, cetylpyridinium chloride, pre-rigor beef, *Salmonella*, vascular rinsing

122 MOLD INHIBITION IN PET TREATS USING CLEAN-LABEL PRESERVATION SOLUTIONS

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Objectives: Due to an increased consumer preference for a clean-label and non-synthetic pet diet, there has been an elevated demand on the use of clean-label ingredients in pet foods. Therefore, the purpose of this study was to investigate the efficacy of natural antimicrobials: cultured sugar–natural flavor (CS-NF) and cultured sugar (CS) against mold outgrowth in chicken jerky pet treats in ambient conditions.

Materials and Methods: Treatments were incorporated into chicken jerky pet treats during manufacturing as follows: (i) no preservative as negative control, (ii) commercial sample product, (iii) 1.5% CS-NF, and (iv) 1.4% CS. Mold isolates *Eurotium herbariorum*, *Penicillium roqueforti*, and *Aspergillus oryzae* were streaked on Potato Dextrose agar (PDA), followed by incubation until luxurious mycelial growth was achieved. A 10 mL suspension of tris-phosphate buffer was added to the agar plate to dislodge mycelium growth using a sterile loop. The final concentration of spores used to inoculate pet treats was 2 $\log_{10}$ CFU/g. The prepared mold cocktail suspension was spot inoculated onto 3 pet treats/treatment and stored at a relative humidity (RH) of approximately 84% in an air-tight container with a saturated potassium chloride solution and incubated at 21°C. Pet treats were monitored for visible mold growth on a daily basis and a percentage increase in shelf-life was determined in comparison to the commercial sample product. Treatment performance was compared using one-way ANOVA ($P < 0.05$).

Results: Mold outgrowth was observed in the inoculated negative control by day 58 (standard deviation [SD] = 14.7), whereas on average the inoculated commercial sample product showed visible mold by day 67 (SD = 24.8). All treatments extended mold-free shelf-life compared to controls. Inoculated 1.5% CS-NF average days to mold were 95 (SD = 3.6), followed by inoculated 1.4% CS samples with 93 (SD = 4.6). No significant difference ($P = 0.11$) was observed; however, CS-NF and CS treatments were able to increase shelf-life by 28 and 26 d, respectively, compared to commercial sample product.

Conclusion: This study highlights that CS-NF and CS solutions are effective clean-label mold control solutions for jerky pet treats. Treatments CS-NF and CS resulted in a shelf-life extension of 42% and 39%, respectively.

Keywords: clean-label preservation solution, mold inhibition, pet treats

123 EVALUATION OF CLEAN-LABEL ANTIMICROBIALS AGAINST SPOILAGE MICROORGANISMS ISOLATED FROM HIGH MOISTURE PET FOODS

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Objectives: As the customer focus shifts to a natural fresh diet for pets, the use of clean-label ingredients in pet foods is becoming increasingly popular. Therefore, the aim of this

	Average Growth Rate (h^{-1})			
Strain	1.65% BV/smoke	2.5% Fermentate	1.5% CS-NF	Blank
L. cellobiosus	5.45	4.61	0	6.32
L. sakei	0	2.87	0	7.13
E. faecium	0.87	4.23	0	10.88
E. faecalis	0	4.01	1.33	9.24
L. curvatus	0	0	0	14.17

study was to assess the efficacy of clean-label antimicrobials against commonly abundant spoilage microorganisms isolated from refrigerated high-moisture pet foods using an in-vitro accelerated test set up.

Materials and Methods: Clean-label antimicrobials; 1.65% buffered vinegar/smoke (BV/smoke), 2.5% fermentate, 1.5% cultured sugar-natural flavor (CS-NF), and blank (no preservative) were incorporated into De Man, Rogosa, and Sharpe agar and adjusted to pH 6.0. Lactic acid bacteria (*Lactobacillus cellobiosus*, *Lactobacillus sakei*, *Enterococcus faecalis, Enterococcus faecium,* and *Lactobacillus curvatus*) were isolated from 2 chicken-based pet foods. Each treatment was aliquoted into 100-well honeycomb followed by the addition of culture inoculum of each target microorganism. The plates were then placed in the Bioscreen-C at 37°C, and optical density was measured at 600 nm to generate growth curves. The maximum growth rates (μmax; h-1) were determined using the growth curves for each treatment and a no preservative reference.

Results: 1.65% BV/smoke and 2.5% fermentate decreased μmax of *L. cellobiosus* by 1.71 and 6.32 h^{-1} respectively, whereas 1.5% CS-NF completely inhibited growth compared to blank (Table 1). 1.65% BV/smoke and 1.5% CS-NF completely inhibited growth of *L. sakei*, whereas 2.5% fermentate decreased growth by 4.26 h^{-1}. The μmax of *E. faecalis* was reduced by 5.23 and 7.91 h^{-1} in 1.5% CS-NF and 2.5% fermentate, respectively, compared to blank (μmax 9.24 h^{-1}) whereas no growth was observed in 1.65% BV/smoke.1.5% CS-NF completely inhibited growth against *E. faecium*, while 1.65% BV/smoke and 2.5% fermentate exhibited 6.65 and 10.01 h^{-1} reduction in the μmax compared to blank (μmax 10.88 h^{-1}). Growth was completely inhibited in *L. curvatus* by all treatments.

Conclusion: All treatments showed efficacy against the target microorganisms compared to blank, with 1.5% CS-NF completely inhibiting growth of *L. cellobiosus, L. sakei*, *L. curvatus*, and *E. faceium*. This shows the potential of these clean-label antimicrobial interventions to prevent spoilage of high-moisture pet foods.

Keywords: clean-label antimicrobial, high-moisture pet foods, spoilage microorganisms

124 QUANTITATIVE AND QUALITATIVE SALMONELLA BIOMAPPING OF COMMERCIAL PORK HARVEST FACILITIES

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Objectives: *Salmonella* is one of the leading causes of bacterial foodborne illness worldwide. Animals often serve as a reservoir for these potentially pathogenic microorganisms, resulting in a high risk of cross contamination during harvest. Antimicrobials are often utilized to mitigate this risk; however, validating the in-line efficacy of these interventions can be challenging. Therefore, the objective of this study was to utilize a combination of quantitative and qualitive *Salmonella* data to generate a microbial map of the harvest process at multiple commercial processing facilities. It is hypothesized that an overall reduction in *Salmonella* will be observed from beginning to end of harvest, with variability observed relative to process flow and antimicrobial application.

Materials and Methods: Carcass swabs were collected from 3 commercial market hog facilities (A, B, C) at 9 locations throughout harvest: (1) at exsanguination, (2) at the gambrel table, (3) after shavers, (4) after bunging, (5) after opening, (6) after evisceration, (7) after split, (8) pre-wash cabinet, and (9) post-wash cabinet. Each of these facilities was sampled 5 times a day for a 5-d period, each set following a single carcass through harvest swabbing the ham, loin, and jowl. After collection, samples were stored at 4°C and shipped overnight to an ISO 17025 accredited corporate laboratory where they were analyzed for quantitative *Salmonella* using the Gene-Up Quant *Salmonella* Kit (limit of detection [LOD] 10) and qualitative *Salmonella* using Gene-Up SLM2 Kit following an overnight enrichment (LOD1). Quantitative *Salmonella* data was reported as colony forming units (CFU)/cm^2. The data from each location was compared as a random complete block design using ANOVA with means separated by Tukey's HSD ($p \leq 0.05$). *Salmonella* prevalence was analyzed using a contingency analysis with chi-square tests for significance ($p \leq 0.05$).

Results: In total, 147 of the 669 (21.97%) carcass swabs tested positive for *Salmonella.* As hypothesized, sample location had a significant impact on *Salmonella* prevalence, with 46.9% of all positive samples being collected at exsanguination ($p < 0.0001$). Additionally, prevalence varied between facilities ranging from 14.67% at facility A to 27.35% at facility C ($p = 0.0035$). Of the 600 swabs that yielded valid quantitative results, 593 were reported to be below the LOD and adjusted to 10 CFU/cm^2 for statistical analysis. Both facility and location had a significant effect on the quantity of *Salmonella*. Aside from exsanguination, in which there was no statistical difference, the greatest amount of *Salmonella* was observed at the gambrel table

(11.28 CFU/cm^2; $p = 0.0008$). Additionally, when comparing across processing facilities, *Salmonella* levels were greater at facility B compared to facility A (10.00 ± 0.14 and 10.50 ± 0.14 CFU/cm^2, respectively; $p = 0.019$).

Conclusion: The low levels of *Salmonella* detected suggest that current sanitary dress procedures are successful at mitigating some bacterial cross contamination during harvest. However, the prevalence data suggest that some populations of *Salmonella* are able to survive and remain on/in the carcasses as they proceed toward fabrication, requiring further investigation into the growth and survival kinetics of *Salmonella* during fabrication and further processing.

Funding Source: This work was financially supported in part by the Vilas Trust and the Wisconsin Alumni Research Foundation.

Keywords: biomapping, pork, qualitative, quantitative, *Salmonella*

125 THE IMPACT OF HUMIDITY AND FAT CONTENT ON SALMONELLA LETHALITY ON THE SURFACE OF IMPINGEMENT-COOKED MEAT AND POULTRY PRODUCTS

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Objectives: Small dimension meat and poultry products cooked in high-temperature and short-time processes (e.g., impingement ovens) pose a food safety concern due to the uncertainty of achieving lethality on the product surfaces. The USDA, FSIS cooking guideline (Appendix A) acknowledges this concern by requiring such processes to meet relative humidity critical parameters in order to achieve proper *Salmonella* lethality on the product surfaces. Current research suggests a product's fat content may provide a protective effect with increasing levels, and the processing humidity during a cooking process can impact the lethality of *Salmonella* on product surfaces; however, more investigation is needed to better understand the impact. The objective of this study was to quantify the effect of processing humidity using the oven's wet bulb temperature and the product's fat content on *Salmonella* lethality on the surface of impingement-cooked meat and poultry products.

Materials and Methods: Ground beef patties (10% and 30% fat), ground pork patties (30% and 50% fat), and chicken breast strips were surface inoculated with an 8-strain *Salmonella* cocktail to yield ≥8.5 log CFU/g. They were cooked in a pilot-scale, 2-zone, steam-injected impingement oven following 17 different processing conditions with varying wet-bulb temperatures (ambient, 62.8°C, 73.9°C, or 82.2°C) strategically chosen to fill gaps that exist in literature. Duplicate samples from 3 replications were obtained before the products entered the oven and at 3 time points during the cooking process chosen to capture reductions of approximately 2.5, 5, and 7 log CFU/g of *Salmonella*. Samples were immediately put in liquid nitrogen, surfaces sliced (~2–4 mm), serial diluted in 0.1% BPW, and plated on differential media. Oven and product temperature data were also collected. Significance of the *Salmonella* reduction for product fat content and processing condition within a species were determined by ANOVA.

Results: Results showed increasing the fat content from 10% to 30% in ground beef patties and 30% to 50% in ground pork patties led to numerically greater reductions of *Salmonella* on the product surfaces but was not significant ($P > 0.05$). During cooking, those higher fat products reached a higher surface temperature than the lower fat products and could explain why greater lethality was achieved in the higher-fat products. In addition, the lethality of *Salmonella* on product surfaces was numerically greater in processing conditions with higher wet-bulb temperatures; however, the results were not significant ($P > 0.05$). This likely created an environment with a wet-bulb temperature high enough to allow the product surfaces to remain hydrated while experiencing lethal time-temperature conditions for *Salmonella*, meeting the Hydrated Surface Lethality (HSL) criteria. On the other hand, processing conditions with lower wet-bulb temperatures likely caused the product surface and any *Salmonella* on the surface to dehydrate, which increased the pathogen's heat tolerance and resulted in less lethality.

Conclusion: The results of this study demonstrate how decreasing a product's fat content or the oven's humidity can pose a food safety concern due to less lethality of *Salmonella* achieved on the product's surface during thermal processing. The findings provide useful information to USDA, FSIS, and the meat industry to ensure sufficient surface lethality for products cooked in high-temperature and short-time processes.

Funding Source: Foundation for Meat and Poultry Research and Education

Keywords: Appendix A, hydrated surface lethality, impingement oven, *Salmonella*, thermal inactivation

126 EVALUATION OF SMOKE SYSTEM AS CLEAN-LABEL SOLUTION FOR ENHANCING MEAT SHELF LIFE

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Objectives: Smoke Technology offers multiple benefits such as flavor, color, preservation impact as well as positive product characteristics. Market trends require clean-label solutions such as smoke for meat shelf-life extension. The objective of the study was to determine growth curves and minimum inhibitory concentrations (MIC) of spoilage micro-organisms *in vitro* against various smoke fractions.

Materials and Methods: Varying concentrations 0.5%, 1%, 1.5%, 3%, and 4% of smoke products (Smoke Clear, Cloud S5, Cloud SC100, Red Arrow Smoke EZ) and blank (no smoke fractions/broth) were prepared in De Man, Rogosa and Sharpe (MRS) and brain infusion heart broth. Samples at pH 6.0 were aliquoted into 100-well honeycomb plates with inoculums of *Lactobacillus sakei* and *Leuconostoc mesenteroides* (~6 log CFU/g). The plates were placed in the Bioscreen-C at 37°C to generate growth curves. Growth curves were fitted using the Modified Gompertz equation, and the maximum growth rates (μmax; d^{-1}) were determined. Generated μmax values were used to determine the MIC. The MIC was defined as the lowest concentration at which no growth occurred. Data were analyzed using one-way ANNOVA ($P < 0.05$).

Results: All smoke products tested exhibited a similar inhibition pattern except Cloud SC100 (Table 1). Cloud SC100 exhibited no growth for both *Lactobacillus sakei* and *Leuconostoc mesenteroides* at 0.5%. In contrast, all the other smoke products with low carbonyls and phenols showed a comparable, but not full, inhibition at 0.5% and 1% for *L. sakei* and *L. mesenteroides,* respectively. At 0.5%, they exhibited a significantly ($P < 0.05$) reduced growth rate of *L. sakei* (μmax 2.70-3.87 d^{-1}) compared to control (5.30 d^{-1}) while at 1% they exhibited significantly ($P < 0.05$) reduced growth rate of *L. mesenteroides* (μmax 1.59 to 2.05 d^{-1}) compared to control (5.98 d^{-1}). At 1% and 1.5%, smoke solutions were able to completely inhibit *L. sakei* and *L. mesenteroides*, respectively. Overall, higher efficacy of Cloud SC100 could be attributed to its higher content of antimicrobial compounds.

Table 1. Determination of minimum inhibitory concentration for smoke products at pH 6

Smoke Products	pH	Titratable Acidity	Minimum Inhibitory Concentration	
			Leuconostoc mesenteroides	*Lactobacillus sakei*
Smoke Clear	2.1-2.5	6.0-7.2%	1.5%	1%
Cloud S5	5.0-5.4	1.0-1.5%	1.5%	1%
Cloud SC100	2.5-5.9	0.15-0.75%	0.5%	0.5%
Red Arrow	3.5-5.0	1.0-2.0%	1.5%	1%

Values represent the concentrations of smoke at which it showed complete inhibition.

Conclusion: The study highlights the antimicrobial efficacy of smoke systems against shelf-life related meat microorganisms and provides industry with a natural multi-functional ingredient.

Keywords: predictive modeling, preservatives, smoke, spoilage control

127 IN-PLANT STUDY TO ASSESS THE EFFICACY OF CITRILOW AS AN ANTIMICROBIAL INTERVENTION IN BEEF SUB-PRIMALS

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Objectives: The objective of this project was to conduct an in-plant study to determine the antimicrobial efficacy of Citrilow + ozonated water as an intervention on microbial indicators sampled from beef sub-primals.

Materials and Methods: Sub-primals were subjected to a spray treatment of Citrilow applied through a 360° spray cabinet. Citrilow was applied at an ambient temperature and pH range of 0.5 to 2.0. Following the Citrilow treatment, ozonated water was sprayed onto the cuts at 50°F with a concentration off 1.5 to 2.3 ppm and an ORP (Oxygen Reduction Potential) between 700 and 900 mV with a pressure ≥20 psi. Samples were randomly collected before and after treatment as follows: A total of 30 samples (15 before and 15 after) were collected from each of the following subprimals: Briskets, Shoulder Clods, Chuck Rolls, Top Butts, Knuckles, and Loin Tails. Sample collection was performed using EZ-Reach™ swabs pre-hydrated with 25 ml of buffered peptone water (BPW) to collect a 100 cm^2 area. Swab samples were immediately chilled and transported to the ICFIE Food Microbiology Laboratory at Texas Tech University for microbial analysis. Samples were stomached at 230 rpm for one minute and serially diluted as needed using 9 mL BPW tubes. The homogenates were sampled to determine total Aerobic Counts (AC), Enterobacteriaceae Counts (EB), and generic *Escherichia coli* Counts (EC) using the TEMPO® system. A total of 4 repetitions were conducted throughout the whole study with a grand total of 120 samples (60 before and 60 after) per sub-primal. A *t*-test statistical analysis was performed using the R software to determine differences between before and after treatment samples based on a *p*-value of 0.05 for the study. Enterobacteriaceae and *Escherichia coli* counts were transformed to LogCFU/sample for statistical analysis and visualization purposes as counts were considerably low when analyzed on a LogCFU/cm^2 basis (detection limit = 0.25 CFU/cm^2).-value of 0.05 for the study.

Results: Aerobic Counts for the 6 sub-primals Briskets, Chuck Rolls, Knuckles, Loin Tails, Shoulder Clods, and

Top Butts were significantly reduced ($P < 0.05$) on average by 0.76, 1.19, 0.55, 0.49, 0.68, and 0.42 LogCFU/cm^2 after Citrilow spray intervention, respectively. Enterobacteriaceae counts for the 6 sub-primals: Briskets, Chuck Rolls, Knuckles, Loin Tails, Shoulder Clods, and Top Butts were significantly reduced ($P < 0.05$) on average by 0.60, 1.11, 0.39, 0.51, 0.56, and 0.56 LogCFU/sample after Citrilow spray, respectively. Lastly, *Escherichia coli* counts were significantly reduced ($P < 0.05$) on 4 out of the 6 different sub-primals including Briskets, Knuckles, Loin Tails, and Top Butt on average by 0.67, 0.50, 0.25, and 0.37 LogCFU/sample after Citrilow spray intervention, respectively. Counts were not significantly reduced ($P > 0.05$) for Chuck Rolls and Shoulder Clods.

Conclusion: The Citrilow antimicrobial intervention scheme proved to be promising as an alternative intervention for the reduction of indicator levels in sub-primals. These findings suggests that Citrilow may play a competitive role as an organic acid intervention on reducing bacterial loads on sub-primals, thus contributing to food safety.

Keywords: antimicrobial intervention, beef, Citrilow, microbial indicators, sub-primals

128 BIO-MAPPING FOR PATHOGENS AND MICROBIAL INDICATORS IN A COMMERCIAL BEEF PROCESSING FACILITY

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Objectives: The objective of this study was to determine the prevalence of Shiga toxin *Escherichia coli* (STEC) (O157:H7, O26, O45, O103, O111, O121, and O145) and *Salmonella* throughout multiple processing stages of a commercial beef abattoir.

Materials and Methods: This study was conducted during a 6-wk period in July and August, with 2 sampling days per week, resulting in a total of 12 sampling days. In the lairage area, boot swabs were used to collect pen surface samples from 5 uncleaned pens. Pens were walked in a Z-shaped pattern across the entire length of the pen. Hide-on, pre-evisceration, post-evisceration, and cold carcass microbial swabs of a 100 cm^{2}area were sampled over the foreshank, brisket, and inside round. Hide-on samples consisted of 10 swabs on each sample day of the foreshank, brisket, and inside round, with the foreshank and brisket swabs being combined. For pre-evisceration, post-evisceration, and cold carcass samples, 5 carcasses were swabbed each sampling day per sampling point per anatomical location ($n = 540$). Trim samples were collected via swabbing an area of 100 cm^2 in 5 different combos per sampling day. Five lymph nodes from 3 different locations (mesenteric, superficial inguinal, subiliac) were collected on each sampling day. Lairage and hide-on samples were screened for *Salmonella*, STEC O157:H7, and non-O157 serogroups, whereas lymph nodes were screened only for *Salmonella*. Samples were enumerated using the Tempo® System for Aerobic Counts (AC), Enterobacteriaceae (EB) and Escherichia coli (EC). Lymph nodes, hide samples, and lairage area samples were analyzed with the BAX System Real-Time Assay for STEC and *Salmonella*. Pathogen prevalence was analyzed using a chi-square test of independence ($\alpha = 0.05$). The Kruskal-Wallis test was used to assess differences between groups, and a multiple comparison Wilcoxon's test with the Bonferroni-Holm adjustment was used for mean separation.

Results: Lairage pen samples yielded 100% prevalence for *Salmonella*, whereas non-O157 STEC serogroups and STEC O157:H7 were detected in 95% and 33.3% of samples, respectively. Hide-on foreshank-brisket samples were positive for non-O157 STEC serogroups in 76.6% of samples and *Salmonella* in 63.3% of samples, whereas STEC O157:H7 was detected in only 3.3% of samples. Samples of hide-on inside round had the highest prevalence of non-O157 STEC serogroups (83.3%), followed by *Salmonella* (45%) and STEC O157:H7 (5%). Microbial indicator counts were highest for post-evisceration samples, intermediate for pre-evisceration samples, and lowest for cold carcass samples. AC counts were reduced from 3.3 to 3.4 log post-evisceration to 1.3 to 1.4 log for cold carcass samples. Likewise, post-evisceration counts for EB (1.5 to 1.7 log) and EC (1.2 to 1.5 log) were reduced to <Limit of Quantification (LOQ) for cold carcass samples. Trim samples had higher counts (AC = 1.96 log; EB = 1.28 log; EC = 1.12 log) for all 3 microbial indicators when compared to cold carcass samples. *Salmonella* was detected in only one lymph node of each type; no locational effect was found.

Conclusion: Hide-on pathogen prevalence was lower than lairage pen pathogen prevalence. Furthermore, AC, EB, and EC counts were reduced by 0.96, 0.36, and 0.28 log from post-evisceration samples to trim samples.

Funding Source: International Center for Food Industry Excellence

Keywords: food safety, pathogen, *Salmonella*, STEC

129 THERMAL INACTIVATION KINETICS OF SHIGA-TOXIN PRODUCING ESCHERICHIA COLI (STEC), SALMONELLA, AND NON-PATHOGENIC E. COLI IN RAW GROUND PORK

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Objectives: Shigatoxigenic *Escherichia coli* (STEC) have historically been associated with the consumption of contaminated beef products. However, recent epidemiological evidence suggests pork products may contribute to human STEC infections. This study aimed to determine the thermal inactivation kinetics of STEC O157:H7 and compare the heat resistance to *Salmonella* and non-pathogenic *E. coli* in raw ground pork.

Materials and Methods: *Salmonella,* nalidixic acid-resistant STEC O157:H7, and nalidixic acid-resistant *E. coli* strains were inoculated into fresh ground pork (ca. 5% fat) to a final concentration of 7–8 log CFU/g. Five-gram inoculated pouches (2 replications) of each treatment temperature (55°C, 60°C, 65°C, and 68°C) were submerged in a circulating water bath for predetermined times (0, 10, 20, 30, 40, 50 min for 55°C; 0, 1, 1.5, 2, 3, 4 min for 60°C; 0, 5, 10, 15, 20, 25 s for 65°C; 0, 3, 6, 9,12, 15 s for 68°C). Cells were recovered on MacConkey agar with 50 ppm nalidixic acid for *E. coli*. XLD for *Salmonella*. Survival data were fitted using log-linear, log-linear with shoulder, and Weibull models using GInaFiT version 1.7. Based on the adjusted R^2 and root mean square error (RMSE), the log-linear with shoulder and Weibull models fitted better to the survival curves.

Results: Contaminated pork should be heated at 55°C, 60°C, 65°C, and 68°C for at least 64.5, 7, 0.7, and 0.5 min, respectively, to achieve a 5-log reduction of O157:H7. The thermal resistance (5D) of O157:H7 was significantly higher ($P < 0.05$) than *Salmonella* at 55°C and 60°C but similar at 65°C and 68°C. The 5D of *E coli* was similar ($P > 0.05$) to O157:H7 at 55°C but lower ($P < 0.05$) at 65°C, 60°C, and 68°C. However, 5D of *E. coli* was similar ($P > 0.05$) to *Salmonella* at 55°C, 60°C, and 65°C but lower ($P < 0.05$) at 68°C. Therefore, the strain of generic *E. coli* used in this study is not suitable as a potential surrogate for STEC O157:H7 in ground pork. The z-values calculated from the D-values were 6.2°C and 5.8°C for STEC and *Salmonella*, respectively.

Conclusion: Thermal death times presented in this study will benefit the industry and regulators in developing appropriate risk assessment and mitigation strategies to improve the microbiological safety of raw pork products.

Keywords: STEC, inactivation, thermal resistance, pork

130 COMPARING SALMONELLA ENTERICA TO TWO NON-PATHOGENIC SURROGATES IN AN UNCOOKED, FERMENTED, AND DRIED SAUSAGE PROCESS

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Objectives: The purpose of this research is to aid microbiological safety validation for fermented and dried sausages, comparing the control of 2 potential lethality validation surrogates with that of pathogenic *Salmonella enterica* in a fermented and dried sausage product.

Materials and Methods: This experiment employed a randomized block design with 4 inoculum treatments: *E. coli* (ATCC BAA-1427, BAA-1428, and BAA-1430) (EC), *Enterococcus faecium* NRRL-B2354 (EF), *Salmonella enterica* (SE), and a non-inoculated control group (CG). A beef/pork summer sausage was formulated with a lactic acid starter culture, and a base batch was prepared and ground (1.27 mm). The meat was split into aliquots (5.4 kg/treatment), which were left un-inoculated (CG), inoculated with pathogen (SE) or with one of the surrogates (EC or EF) at 10^6 CFU/g, and mixed for 1.5 min. Meat batters were reground (4.76 mm) and stuffed into fibrous casings (38mm*305mm). Twelve 0.45 kg sausages were made per treatment group. Sausages were placed into a converted incubator and processed for 24 h of fermentation at 37°C and 95% RH until pH ≤ 5.0 was reached. The chamber was then set to 18°C and 80% RH for 3 d post-fermentation and lowered to 18°C and 70% RH for the remaining 18 d. Two 25 g samples were taken from all treatments for analysis post-stuffing (Day 0), post-fermentation (Day 1), and after 7, 14, and 21 d of drying. CG, EC, EF, and SE-inoculated samples were diluted with 0.1% peptone and plated in duplicate on ACP petri films, tryptic soy agar amended with 100.0 µg/mL rifampicin, KF *Streptococcus* Agar, and xylose lysine deoxycholate (XLD) agar, respectively. Additional 30 g samples were taken from CG on day 0,1,7,14, and 21 to measure proximate composition and calculate the moisture:protein ratio (M:P). Samples (15 g) were collected from all treatments for pH and a_w measurement on days 0,1,7,14, and 21. Least-squares means were analyzed by ANOVA with main effects and 2-way interactions analyzed ($P \leq 0.05$).

Results: A 2-way interaction was observed between inoculum and days for microbial populations during fermentation and drying ($P \leq 0.05$). From start of fermentation to end of drying on day 21, 4.14 and 2.01 log CFU/g reductions were observed for SE and EC, respectively. In contrast, EF increased by 2.00 log CFU/g during the same period. The final count of SE was <1.0 log CFU/g, significantly differing from EC and EF counts: 4.19 and 8.53 log CFU/g, respectively ($P \leq 0.05$). During fermentation, the pH decreased by 1.28, 1.25, 0.9, and 1.46 for SE, EC, EF, and CG, respectively. During drying, the pH decreased by 0.23, 0.23, 0.81, and 0.22 for SE, EC, EF, and CG, respectively. All treatments began with an aW value of 0.96 and decreased to 0.89 by day 21, with no significant differences found between treatments ($P \leq 0.05$). The M:P ratio of the CG was 3.53:1 on day 0 and was 1.32:1 on day 21.

Conclusion: *E. coli* counts declined similarly to SE during fermentation. However, during drying, EC outlasted SE, indicating it is not a useful surrogate during this stage. In

contrast to SE, EF numbers increased during fermentation and remained relatively constant during drying. The pH of the EF sausages declined below other treatments. Based on the data, neither inoculum tested is an effective *Salmonella* surrogate for uncooked fermented and dried sausage manufacture. This study highlights the limitations of pathogen surrogates and can help guide the industry in implementing strategies to validate microbiological safety protection of fermented and dried sausages.

Funding Source: Texas A&M Agrilife Research

Keywords: microbiology, pathogen, *Salmonella*, summer sausage, surrogate

131 ANTIMICROBIAL RESISTANCE PATTERNS OF NON-TYPHOIDAL SALMONELLA FROM RETAIL MEAT IN CALIFORNIA, 2019

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Objectives: Antimicrobial resistance (AR) is an emerging problem in the United States and worldwide. The usage of antimicrobial drugs in food animal production may unintentionally select antimicrobial-resistant bacteria (ARB), which potentially can be transmitted to humans via the consumption of contaminated animal products. Our objective was to assess the phenotypic and genotypic resistance of non-typhoidal *Salmonella* from retail meat collected in California in 2019.

Materials and Methods: A total of 879 various fresh meat were collected from Northern and Southern California retail stores from January to December 2019. *Salmonella* isolates were subjected to serotyping, antimicrobial susceptibility testing, and whole genome sequencing (WGS) to identify AR patterns.

Results: *Salmonella* was recovered from 130 out of 879 collected samples. The prevalence of *Salmonella* was higher ($P < 0.001$) in chicken samples (24.00%) compared to ground turkey (5.41%) and pork samples (3.07%). No *Salmonella* isolates were recovered from ground beef samples. The prevalence of *Salmonella* in meat samples (20.24%) with reduced antibiotic usage production claim was higher than that in conventional meat samples (12.47%). *Salmonella* isolates were classified into 24 serotypes. The predominant serotypes were *S.* Kentucky (47.72%), *S.* Typhimurium (11.36%), and *S. Alachua* (7.57%). Thirty-two (24.24%) out of 132 *Salmonella* isolates were susceptible to all the tested antimicrobial drugs, while 75.76% were resistant to at least one drug, 62.87% to at least 2 drugs, and 10.60% to at least 3 or more drugs. Isolates from samples with reduced antibiotic usage production claim (82.35%) exhibited higher resistance to at least one drug than those with conventional production claim (68.75%). Antimicrobial drugs that *Salmonella* isolates were highly resistant to were tetracycline (62.12%) and streptomycin (59.84%). A total of 22 resistant genes and a D87Y mutation of *GyrA* were identified from resistant *Salmonella* isolates. Additionally, 26 plasmid replicons were found. The replicon *IncFIB*(*pN55391*), which has been reported to promote dissemination of multidrug-resistant (MDR) *Salmonella,* was found in 5 MDR *S.* Infantis isolates in our study. WGS results correlated with phenotypic resistance with an overall sensitivity of 96.66%.

Conclusion: This study highlights the importance of the National Antimicrobial Resistance Monitoring (NARMS) retail meat surveillance.

Funding Source: This work was made possible, in part, by the U.S. Food and Drug Administration through grants 1U01FD006248-01 and 5U01FD0005796-03. The views expressed in this article are those of the authors and do not necessarily reflect the official policies of the Department of Health and Human Services, nor does any mention of trade names, commercial practices, or organization imply endorsement by the United States Government.

Keywords: retail meat, *Salmonella*, antimicrobial resistance, whole genome sequencing, NARMS

132 BIG 7 STEC DETECTION CORRELATION OF mRBA AND REAL-TIME q-PCR ON PRE-HARVEST FLOORS IN HOLDING PENS IN A COMMERCIAL BEEF FACILITY

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Objectives: The study objectives were as follows: (1) to evaluate the correlation between Shiga toxin-producing *Escherichia coli* (STEC) non-O157 such as O26, O45, O103, O104, O111, O121, O145, and O157:H7 gene detection by q-PCR amplification assay compared to cultural-based isolation method on pre-harvest naturally

contaminated samples; (2) to establish the frequency of STEC non-O157 and O157 on holding pen boot swabs in a commercial beef facility.

Materials and Methods: A total of 53 boot swabs were taken from the pre-harvest cattle holding pens in the lairage area of a cattle holding facility. Boot samples were taken throughout the production day by placing an individual non-woven shoe cover over each shoe and walking around the cattle holding pens in a "Z" pattern. Then, the boot swabs were removed and placed individually in a filtered Whirl-Pak bags with 100 ml of Buffered Peptone Water and incubated at 42°C for 24 h. All samples were processed in the ICFIE laboratory at Texas Tech University for microbiological analysis. The presumptive big 7, non-O157 STEC and O157 were detected in holding pen boot swabs samples ($n = 53$). As recognized by the USDA, the big 7 STEC included *E. coli* serotypes O111, O121, O103, O45, O145, O26, and O157. STEC screening was also conducted using the BAX® System Q7 real-time PCR assays, which consisted of 3 separate testing kits; the first one is known as "Panel one," which screens for STEC O111, O121, and O26, while the second one is "Panel two," which screens for STEC O103, O145, and O45. And the last one, known as "O157:H7 Exact," screens for STEC O157:H7. In parallel, each selective pre-enriched sample from BAX SYSTEM Q7 was subjected to culture isolation following the FDA-BAM method. The statistical analysis was conducted within RStudio v4.1.3 using Cramer's V coefficients and chi-square analysis to compare STEC presence and method associations.

Results: The most prevalent non-O157 serotypes detected by both methods were O121, O45, and O26, with percentages of 98.11 ± 1.87 (52/53), 92.45 ± 3.63 (49/53), and 75.47 ± 5.91 (40/53), respectively. O111 was not detected in this study. Based on Cramer's V coefficients, the association between the presence of the big 7 STEC detected by both methods mRBA and BAX SYSTEM Q7 is comparatively the strongest for O45, O103, and O26 with a coefficient of association of 0.574 ± [0.313-0.843] 95% CI, 0.464 ± [0.225-0.700] 95% CI, and 0.37 ± [0.088-0.633] 95% CI, respectively. This indicates a very strong association between the phenotypical and molecular methods.

Table 1. The Cramer's V coefficients association of the big 7 STEC O26, O45, O103, O104, O111, O121, O145, and O157:H7 between m-RBA and BAX SYSTEM Q7.

Serotypes	*Cramer's V*	*IC 95%*
O157	0.257	0.017-0.534
O26	**0.37**	**0.088-0.633**
O121	0.211	0.001-0.494
O45	**0.574**	**0.313-0.843**
O103	**0.464**	**0.225-0.700**
O145	0.210	0.001-0.490
O111	NA*	NA*

*Non-applicable

Conclusion: These data suggest that the Cramer's V association statistics demonstrated a higher association of O45, O103, and O26 detection between mRBA and BAX SYSTEM® Q7; however, agar cultivation must be followed at least by a biochemical confirmation and agglutination tests and further final molecular confirmation. The absence of O111 did not make it possible to correlate using the Cramer's V association because of the nature of the study, which was a naturally contaminated environment and not controlled for O111 presence in the pre-harvest holding pens.

Funding Source: Funding was provided by International Center for Food Industry Excellence (ICFIE).

Keywords: mRBA, STEC, real-time PCR, Big 7, pre-harvest

133 SALMONELLA PREVALENCE IN BOVINE LYMPH NODES

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Objectives: *Salmonella* is one of the leading causes of foodborne illness in the United States, with approximately 80 million cases per year, globally. Normally associated with poultry and egg products, *Salmonella* resides within the gastrointestinal system of livestock as a commensal microorganism. Lymph nodes (LN) are key structures within the lymphatic system and contain important immune cells. Fluid from tissues, known as lymph, may contain pathogens and pass through the LN for cleansing. As a result, *Salmonella* have been found within LN. The objective of this study was to determine the prevalence of *Salmonella* within bovine LN throughout the early cool season (ECS) (November through February), late cool season (LCS) (March through April), early warm season (EWS) (May through August), and late warm season (LWS) (September through October) in the BIFSCO microbiological monitoring regions of the United States.

Materials and Methods: The BIFSCO monitoring regions consisted of region 1 (northwest US), region 2 (west US), region 3 (southwest US), region 4 (Rocky Mountains), region 5 (north US), region 6 (central US), region 7 (south US), and region 8 (east Atlantic and Midwest US). Six LN were identified for microbiological analysis: Axillary, Prescapular, Superficial Inguinal, Subiliac, Popliteal, and Coxalis. Sample collection took place 3 d of the week, and 5 samples of each LN were collected on each day of sampling. This provided a total of 90 LN per facility per collection and accounted for daily variation within the facility and respective regions. With 12 facilities, 4 sample collections at each facility, and 90 LN per collection, Food Safety Net Services arranged

for the collection of 4300 LN. All LN collected were trimmed of fat, briefly dipped in boiling water to decontaminate the exterior surface, and then pulverized. The microbiological analysis was completed using 4 different Real-Time BAX PCR and SalQuant BAX PCR tests accounting for prevalence, quantification, and confirmation.

Results: Tests of hypotheses concerning the differences in prevalence of *Salmonella* between season, type of LN, and region were conducted at $P = 0.05$ using chi-square analysis for comparison of the observed and expected prevalence percentages. For the seasonal differences, the EWS (5.7% versus 4.2%) and LCS (4.6% versus 4.2%) had higher than expected incidences ($P = 0.005$) of *Salmonella* prevalence as compared to the ECS (3.4% versus 4.2%) and LWS (3.0% versus 4.2%). Lymph node differences included a higher than expected prevalence ($P < 0.001$) of *Salmonella* in the Popliteal (5.5% versus 4.2%), Prescapular (5.9% versus 4.2%), and Superficial Inguinal (6.6% versus 4.2%) than the Axillary (0.8% versus 4.2%), Coxalis (2.8% versus 4.2%), and Subiliac (3.6% versus 4.2%) LN. Lastly, regional differences observed a higher incidence of positive cases than expected ($P < 0.001$) of *Salmonella* in regions 2 (5.8% versus 4.2%), 3 (8.5% versus 4.2%), and 8 (4.4% versus 4.2%), whereas regions 1 (2.2% versus 4.2%), 4 (3.7% versus 4.2%), 5 (3.4% versus 4.2%), 6 (2.6% versus 4.2%), and 7 (1.9% versus 4.2%) were lower than expected.

Conclusion: Overall, the results of this study illustrate the proximity of *Salmonella spp.* in raw beef trim within bovine LN. Therefore, these results indicate the significance to the industry and will aid in the decrease of *Salmonella* contamination in ground beef products through packing plant knowledge and understanding of potential risks.

Funding Source: FSNS/NCBA

Keywords: beef, lymph nodes, *Salmonella*, seasons

134 BACTERIOPHAGE GR-026 LYSES SURROGATE INDICATOR STRAIN ATCC-BAA-1428

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Objectives: In-house validation studies are commonly conducted in processing plants to test the efficiency of food-safety processing aids. When conducting validation studies, technical personnel uses surrogate indicator organisms that may not be lysed by phages specifically isolated to lyse stx1 and stx2 *E. coli*. In this study we tested the lysing ability of a novel lytic bacteriophage on stx1 and stx2 *E. coli* O26 and on a strain commonly used in validation studies.

Materials and Methods: A lytic phage GR-026 targeting *E. coli* O26 was isolated from raw sewage using the ATCC strain BAA-2196. The phage was purified and amplified to reach a 1×10^8 PFU/ml concentration. Killing efficiency was estimated by plating the O26 BAA-2196 and the surrogate BAA-1428 with the isolated phage on LB plates. The effects of bacteriophage applications on beef were estimated by inoculating cultures that yielded approximately 4 Log of O26 and surrogate strains on a 10×10 cm^2 *m. Cutaneous trunci* (Rose Meat, IMPS 194). After inoculation by pipetting, samples were wrapped with oxygen permeable film and kept at 5°C for 30 min for bacterial attachment. Subsequently, samples were treated with 1000 µL of Buffered Peptone Water (Control) or a GR-O26 phage solution (Phage). Solutions were uniformly pipetted and evenly distributed throughout the whole surface area by using a sterile plastic rod. After treatments were applied, samples were rewrapped and kept under refrigeration (5°C) for 1 h. Bacteria were sampled by swabbing the meat surface using a non-hydrated Q-swab (QS1000, Hygiena, Camarillo, CA). For bacteria enumeration, swabs were homogenized, and the homogenate was vortexed, serially diluted, and spread-plated onto LB agar plates. Plates were analyzed in duplicate and incubated inverted overnight at 37°C, and *E. coli* and surrogate colonies were enumerated (CFU/cm^2). The trial was repeated 3 times using 3 samples per treatment per replication. Data were analyzed as a 2 x 2 factorial, whereas the strain types and treatments were the fixed effects. Means were analyzed and separated using the GLIMMIX procedure of SAS at a $P \leq 0.05$ significance level.

Results: Killing efficiency in plates for *E. coli* O26 (BAA-2196) and surrogate (BAA-1428) was 92.5% and 93.3%, respectively. Applications of phage GR-O26 led to a similar statistical decrease of both strains in meat (Control = 4.17^A and Phage = 3.19^B, for BAA-2196; and Control = 4.09^A and Phage = 3.26^B, for BAA-1428, respectively; Log/cm^2). Overall, no interaction between the fixed effects were detected, whereas treatment means were 4.13^A and 3.22^B Log/cm^2, for Control and Phage, respectively.

Conclusion: Bacteriophage validations using surrogates during meat processing depend on the spectra of the bacteriophage. Since phages are isolated for specific bacteria, they may not lyse surrogates. In order to validate phage interventions during meat production, bacteriophages must be able to lyse both stx1 and stx2 strains and surrogates.

Keywords: bacteriophage, beef

135 IN-PLANT STUDY DEMONSTRATING THE EFFICACY OF LACTIC ACID AND OZONATED WATER AS AN ANTIMICROBIAL INTERVENTION IN BEEF VARIETY MEAT PRODUCTION

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Objectives: Multiple studies have characterized the microbial population of variety meats, suggesting the need for decontamination technologies. This in-plant study was conducted to determine the efficacy of lactic acid and ozonated water as an antimicrobial intervention on 3 different types of beef variety meat components (head/cheek, heart, and liver) in a packing plant in the United States.

Materials and Methods: The processing plant uses a 2-step antimicrobial intervention for variety meats, consisting of a spread with a lactic acid solution at 4.5% at 43°C to 48°C with a visual inspection of a uniform spray pattern, followed by an ozonated water spray with a concentration of 1.5 to 2.3 ppm and an ORP (oxidation-reduction potential), between 700 and 900 mV, at 10°C to 24°C and pressure ≥20 psi. Sampling collection was done over 4 mo (April to June of 2022). For each replication, 15 swabs were taken before and after the antimicrobial interventions for each variety meat (head/cheek, heart, and liver). A total of 4 replications were conducted over the course of 3 mo, with 90 samples taken in each replication (total swabs = 45 before and 45 after). For the samples before and after the antimicrobial intervention, a 25 mL EZ-Reach™ buffered peptone water swab was used to sample an area of 100 cm^2, stored with ice packs, and overnight shipped to the Texas Tech microbiology laboratory. The microbial analysis consisted of total aerobic counts (AC), Enterobacteriaceae (EB), and generic *E. coli* (EC) enumeration using the Biomérieux TEMPO® system. All data were analyzed using R (Version 4.0.4) statistical analysis software to evaluate the reduction of microbial loads after each intervention for all variety meats tested. A *t*-test was performed to determine differences between before and after antimicrobial interventions using an α of 0.05 to determine significant differences.

Results: Total AC for the 3 beef variety meats (head/cheek, hearts, and livers) were reduced ($P < 0.05$) on average by 1.01, 1.29, and 0.81 LogCFU/cm^2 after lactic acid and ozonated water interventions. For EB and EC, counts were transformed to LogCFU/sample for statistical analysis as counts were considerably low when analyzed on a LogCFU/cm^2 basis (quantification limit = 0.25 CFU/cm^2).

Table 1. Aerobic Plate Counts (APC) on three different variety meats before and after the treatment application.

	Aerobic Plate Counts (Log CFU/cm^2) (Mean ± SE*)		
Trim	Before	After	*P*-value
Head/Cheek	2.90±0.13[a]	1.89±0.13[b]	< 0.001
Heart	1.32±0.10[a]	0.03 ± 0.05[b]	< 0.001
Liver	1.08 ± 0.08[a]	0.27 ± 0.14[b]	< 0.001

[ab]columns with different letters in each row within the same microorganism represent statistical difference ($P < 0.05$).

*Standard Error

Detection Limit (0.01 CFU/cm^2)

Table 2. Enterobacteriaceae (EB) Counts on three different variety meats before and after the treatment application.

	Enterobacteriaceae Counts (Log CFU/sample) (Meant±SE*)		
Trim	Before	After	*P*-value
Head/Cheek	2.96±0.17[a]	1.57±0.10[b]	< 0.001
Heart	2.57±0.15[a]	1.28±0.06[b]	< 0.001
Liver	2.18±0.20[a]	1.18±0.04[b]	< 0.001

[ab]columns with different letters in each row within the same microorganism represent statistical difference ($P < 0.05$).

*Standard Error

Detection Limit (0.005 CFU/cm^2)

Table 3. *Escherichia coii* counts on two different variety meats before and after the treatment application.

	Escherichia coii Counts (Log CFU/sample) (Mean ± SE*)		
Trim	Before	After	*P*-value
Heart	2.68±0.18[a]	1.16±0.03[b]	< 0.001
Liver	1.84±0.15[a]	1.23±0.05[b]	< 0.001

[ab]columns with different letters in each row within the same microorganism represent statistical difference ($P < 0.05$).

*Standard Error

Detection Limit (0.01 CFU/cm^2)

Enterobacteriaceae counts were reduced ($P < 0.05$) on average by 1.39, 1.29, and 1.00 LogCFU/sample after lactic acid and ozonated water intervention, respectively. Lastly, EC counts were reduced ($P < 0.05$) for hearts and livers by 1.52 and 0.61 LogCFU/sample after the lactic acid and ozonated water intervention, respectively. However, no significant reduction was observed for EC on beef head/cheek.

Conclusion: Overall, based on the data in this study, it is reasonable to conclude that the use of lactic acid and ozonated water are effective to reduce the bacteria counts on the 3 variety meats, which will improve the safety of the meat product.

Keywords: beef variety meats, intervention, lactic acid, ozonated water

136 GROWTH MODELING OF FOODBORNE PATHOGENS IN CELL-BASED MEAT MEDIA

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Objectives: The study objective was to determine the growth rate of several foodborne pathogens that may be reasonably likely to occur in a cell-based meat production environment.

Materials and Methods: Isolated colonies of *Listeria monocytogenes*, *Staphylococcus aureus*, and *Salmonella* from pure cultures were raised on tryptic soy agar, and individual colonies were picked to inoculate culture tubes containing tryptic soy broth (TSB). The inoculated TSB was incubated for 18 to 24 h whence an 100 µL aliquot was removed and added to a fresh culture tube of TSB. After an additional 18 to 24 h, an aliquot from the second TSB tube was added to a series of dilution tubes of buffered peptone water achieving a 10^{-6} dilution. A 5 mL aliquot of the 10^{-6} was then added to 45 mL of Dulbecco's Modified Eagle Medium (DMEM) in a 100 mL dilution bottle, achieving an approximate 1 cfu/mL concentration. Additionally, some trials replaced 2.5 mL of the DMEM with 2.5 mL of Fetal Bovine Serum (FBS). These bottles of inoculated DMEM with and without FBS were then incubated at 37°C, 20°C, and 10°C and kept in a rotary shaker operating at 120 rpm. Aliquots of the inoculated DMEM were then enumerated at various times using spread plate and microdilution and drop plate techniques. The timing of the sampling depended on the temperature the cultures were held at. Time points were initially chosen using the ComBase predictive modeling and adjusted in subsequent trials using the acquired data. The resulting plate counts were then used to determine the growth rate of each strain under the described conditions. *S. aureus* strains included ATCC strains 43300, 25178, 31885, 44, BAA 41, and 29213. *Salmonella* strains included Typhimurium 14028, Enteritidis 13076, Newport 6962, a wildtype strain TTU 360, and Heidelberg. *Listeria monocytogenes* strains included ATCC strain 19118 and the following strains: N1-023, N1-031, N1-054, and N1-079 provided by Dr. Kendra Nightingale's lab at the Department of Animal and Food Science, Texas Tech University.

Results: All pathogens exhibited growth at 37°C and at 20°C. At 10°C, growth was inconsistent for some strains of *Salmonella* and *S. aureus.* Predictably, *L. monocytogenes* grew well at 10°C.

Conclusion: DMEM with and without 5% FBS can support the growth of some foodborne pathogens. Cell-based food establishments will need to develop effective hygiene and sanitation programs to mitigate the risks of inadvertently incubating such pathogens. In addition, good environmental monitoring practices can catch certain environmental niches before a pathogen can propagate in the establishment.

Funding Source: New Harvest, 1401 21st Street, Suite 4556 Sacramento, CA 95811-5226, USA info@new-harvest.org

Keywords: cell-based, foodborne pathogens, growth modeling, *Listeria*, *Salmonella*

137 PREVALENCE OF ESCHERICHIA COLI AND ENTEROCOCCUS IN RETAIL POULTRY MEAT IN SOUTHERN CALIFORNIA FROM 2018 TO 2022

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Objectives: Poultry is an important source of proteins and nutrition but also can be a potential vehicle for transmission of foodborne pathogens. To reduce the contamination of poultry meat products with foodborne bacteria, it is important to conduct retail meat surveillance. The objective of this study was to determine the prevalence of fecal indicator bacteria—generic *E. coli* and *Enterococcus*—in retail poultry meat from southern California using National Antimicrobial Resistance Monitoring System (NARMS) samples.

Materials and Methods: From January 2018 to December 2022, samples including retail cuts of chickens and ground turkey were purchased from randomly selected grocery stores in southern California and tested for *E. coli* and *Enterococcus*. Information (e.g., packaging claims of organic and/or antibiotic-free, packaging status and type) associated with each of the samples were also recorded. The samples were transported on ice to the laboratory and processed within 96 h. Both bacteria were isolated according to the NARMS Retail Meat Surveillance Protocol. Statistical analysis was conducted using R-studio, with Fisher's exact test and post hoc analysis performed to determine significant differences in prevalence among different types of samples. The alpha level was set at 0.05.

Results: The overall prevalence of generic *E. coli* was 56.68% across all tested samples and years, including a significant ($P < 0.05$) difference between chicken (45.89%) and ground turkey (67.52%). Generic *E. coli* prevalence in chicken samples was significantly lower ($P < 0.05$) in the last 3 y compared to 2018 and 2019. Meanwhile, generic *E. coli* prevalence in turkey samples in 2018, 2019, 2020, 2021, and 2022 was 72.22%, 81.67%, 71.11%, 64.58%, and 57.29%, respectively. For *Enterococcus*, the overall prevalence was 74.72% with higher recovery ($P < 0.05$) in turkey meats (90.31%) than in chicken (59.21%). For the study period, *Enterococcus* prevalence in both chicken and turkey was significantly lower in the recent 3 y with the lowest ($P < 0.05$) at 31.25% and 80.21% in chicken and turkey in 2022, respectively. In turkey meats, the lowest prevalence of *E. coli* was observed in the fall (52.69%), whereas the highest prevalence of *Enterococcus* was found in the winter (96.55%). A significantly lower ($P < 0.05$) prevalence of *E. coli* was found in "organic" labeled

products (48.09%). *Enterococcus* prevalence was also found to be lower in organic chicken (46.9%) but higher in organic turkey (97.14%). Antibiotic-free claimed chicken was observed to have lower ($P < 0.05$) *Enterococcus* prevalence. Both *E. coli* and *Enterococcus* prevalence was significantly different ($P < 0.05$) among chicken products (breast, legs, wings, thighs, whole chicken, and mixed parts) sampled, with the highest prevalence in mixed parts and whole chicken. Types of packaging were also found to affect the prevalence of both bacteria with the highest in vacuum-packaged products. *Enterococcus* prevalence was found to be higher in the meats that were packaged in the store compared to the meats that were packaged before, but *E. coli* prevalence was lower for these samples.

Conclusion: The findings of the study emphasize the necessity of following proper handling and cooking techniques to reduce the likelihood of foodborne enteric bacterial transmission. Moreover, this study reinforces the significance of ongoing retail meat surveillance by the NARMS.

Funding Source: This work was made possible, in part, by U.S. Food and Drug Administration through grants 1U01FD006248 and 1U01FD007162. Views expressed in this presentation do not necessarily reflect the official policies of the Department of Health and Human Services; nor does any mention of trade names, commercial practices, or organization imply endorsement by the United States Government.

Keywords: chicken, *Enterococcus*, *Escherichia coli*, prevalence, turkey

138 IDENTIFICATION AND MITIGATION OF SALMONELLA RISK THROUGH BIOMAPPING AND LYMPH NODE REMOVAL IN COMMERCIAL RAW PORK PROCESSING

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Objectives: The objective of this study was to utilize biomapping strategies to determine *Salmonella* prevalence in a large-scale pork processing facility to identify the highest risk parts, which were then subjected to various degrees of lymph node and gland removal to mitigate *Salmonella* risk.

Materials and Methods: Swab samples from the round, side, and shoulder of the carcass were taken on the harvest floor, and 2-pound trim and ground product samples were collected and shipped overnight to Texas Tech University. Samples were analyzed for AC, EB, and EC with the BioMérieux TEMPO® enumeration system. *Salmonella* was evaluated using the BAX® System Real-Time Salmonella SalQuant™ assay. Microbial counts were converted to Log CFU prior to statistical analysis using R. To evaluate the efficacy of lymph node removal, boneless picnic samples were obtained from the same facility and divided into 3 treatment groups: 1) untreated control, 2) topical glands removed before final processing, and 3) topical, jowl, and internal lymph nodes and glands removed before final processing. Samples were processed utilizing the same methodology as previous, using the BAX® System Real-Time *Salmonella* and the SalQuant™ for *Salmonella* quantification and the BioMérieux TEMPO® for microorganism enumeration. This study was repeated for a total of 5 replications over 4 mo to account for seasonality and natural variation of the microorganisms, resulting in a total sample size of 450.

Results: Bio-mapping of the facility concluded that post scalding, there was a 75% prevalence of *Salmonella* with enumeration being at 1.7 Log CFU/mL. Prevalence significantly declined to non-detectable numbers until after chilling. However, there were 25% positives with enumerable *Salmonella* for picnic and neck trim. A total of 11% of the belly trim samples were positive for *Salmonella*, but they were not enumerable, and no *Salmonella* was detected in loin trim. Based on collected data, boneless picnic trim posed the greatest risk, so the lymph nodes were removed from these samples. The removal of the topical, internal, and jowl lymph nodes was effective at significantly ($P < 0.05$) reducing the prevalence of both *Salmonella* and the indicator organisms in both trim and ground pork. For *Salmonella* prevalence, a total of 72/450 samples tested positive. Of these samples, 38 were suitable for enumeration, the majority detected from the control group. From enumerable samples, 20% were estimated to be between 0.97 and 1.97 Log CFU/sample, while the rest were within the 2.00 to 4.02 Log CFU/sample range. Samples from treatments 2 and 3 showed an average of a 2.5 Log and 3 Log reduction of *Salmonella,* respectively, when compared to the control samples.

Conclusion: Recently pork performance standards were proposed by FSIS to monitor *Salmonella* presence in pork production facilities and were based on exploratory sampling programs in parts and comminuted products. However, there is no specificity on the part or comminute product that is utilized for sampling. There are clearly differences in the *Salmonella* risk based on sampling location in a facility as determined by this study. The differences in enumerable and detectable *Salmonella* in parts also illustrate the variation that occurs and should be considered in decision-making for mitigation strategies as well as for regulatory sampling.

Funding Source: The funding for this research project was provided by the International Center for Food Industry Excellence.

Keywords: beef, biomapping, performance standards, pork, *Salmonella*

139 IDENTIFICATION OF ANTIMICROBIAL RESISTANT GENES IN VIBRIO SPP. IN RETAIL SHRIMP MEAT IN NORTHERN CALIFORNIA

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Objectives: Shrimp is one of the most consumed seafood products globally. While antimicrobial drugs play an integral role in disease mitigation, there are growing public health concerns regarding the potential emergence and spread of antimicrobial resistant bacteria. The objective of this study was to identify the antimicrobial resistant genes (ARG) that conferred previously observed phenotypic drug resistance in pathogenic non-cholera *Vibrio* spp. found in shrimp from grocery stores in Northern California. Additionally, we aimed to investigate how ARG prevalence varied across production types and geographic origin characteristics of the shrimp samples.

Materials and Methods: A total of 400 raw shrimp samples were purchased from randomly selected grocery stores in the Sacramento area between September 2019 and June 2020. *Vibrio* was isolated from samples based on the National Antimicrobial Resistance Monitoring System Retail Meat Surveillance Laboratory Protocol and Food and Drug Administration Bacteriological Analytical Manual. Whole genome sequencing (WGS) was done on a subset of 42 PCR-confirmed *Vibrio* isolates after antimicrobial susceptibility testing to identify species and ARG. WGS was performed on the Illumina MiSeq DNA sequencing system using the MiSeq reagent kit version 2 (2 × 250-bp paired-end reads) per CDC PulseNet guidelines. Identification of ARG for the sequencing data was done using the ResFinder database, with genes determined as present if sequences met thresholds of 90% identity and 60% minimum length. Concordance between phenotypic resistance and genotypic resistance was also evaluated by calculating the sensitivity and specificity.

Results: Whole genome sequencing (WGS) of isolates identified the most common species as *V. metschnikovii* (24/42; 57.14%) and *V. parahaemolyticus* (12/42; 28.57%). Additionally, 27 ARG from the 42 *Vibrio* isolates were also identified. The predominant ARG were *qnr*VC6 (19.05%, 8/42), dfr_{A31} (11.90%, 5/42), dfr_{A6} (9.5%, 4/42), and *qnr*VC1 (9.5%, 4/42). This study found that the most common ARG found were *qnr* genes which encode for pentapeptide repeat proteins and confer reduced susceptibility to quinolones. Additionally, there were more unique ARG found that related to beta-lactam and penicillin resistance than any other antimicrobial classes. Isolates from wild caught shrimp contained between zero and 16 ARG (mean = 2.26), and isolates from farmed shrimp contained between zero and 5 ARG (mean = 0.93). Similarly, domestic isolates averaged fewer ARG than imported isolates, 0.29 and 1.63, respectively, though the sample sizes and species compositions of these subgroups were distinct and limited the utility of their comparison. When comparing phenotypic antimicrobial resistance (AMR) and resistant genes identified via WGS, the overall sensitivity and specificity were 11.54% and 96.08%, respectively, indicating a low sensitivity and an imperfect specificity.

Conclusion: The findings of the project provide valuable information on the prevalence and distribution of AMR in *Vibrio spp.* from retail shrimp in California. Additionally, the study provides significant insights into food safety and public health, and it highlights the importance of continued AMR monitoring of seafood products and the value of utilizing WGS in conjunction with antimicrobial susceptibility testing for more comprehensive AMR assessment.

Funding Source: Funding for this work was made possible, in part, by the USDA National Institute of Food and Agriculture Animal Health Formula Funds project no. CALV-AH-395.

Keywords: antimicrobial resistance, seafood, shrimp, *Vibrio*, whole genome sequencing

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140 INHIBITORY EFFECT OF COMMERCIAL DRY VINEGAR OR CULTURED SUGAR-VINEGAR BLENDS ON CLOSTRIDIUM PERFRINGENS AND BACILLUS CEREUS DURING EXTENDED COOLING OF MODEL UNCURED BEEF AND POULTRY PRODUCTS

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Objectives: The 2021 FSIS Stabilization Guidelines for Meat and Poultry Products (Appendix B) limits Phase 1 cooling from 48.8°C to 27°C in uncured meats to 1 h. However, this time restriction is impractical for use in large diameter whole muscle products. The study objective was to compare the inhibitory effect of dry vinegars (DV) and cultured sugar-vinegar blends (CSV) on *Clostridium perfringens* (*C. perfringens*) and *Bacillus cereus* (*B. cereus)* in uncured beef and poultry products during extended cooling.

Materials and Methods: Treatments (beef: 72%–73% moisture, pH 6.2–6.3, 0.85%–0.95% NaCl; turkey: 76%–77% moisture, pH 6.5–6.7, 1.3%–1.6% NaCl) included

Control without antimicrobials, plus 4 DV and 4 CSV tested at 0.75% and 1.25%. Sub-batches were inoculated with 2.5-log *C. perfringens* or *B. cereus* spores, vacuum-packaged, and cooked to 73°C. Packages were cooled from 48.8°C to 27°C (Phase 1) in 3, 4, and 5 h; Phase 2 (27°C to 12.8°C) and Phase 3 (12.8°C to 4°C) were standardized for 5-h cooling each. Pathogens were enumerated on selective agar in triplicate samples assayed at pre-cook, post-cook, and at the end of phase 1, 2, and 3 cooling. Each set of experiments was conducted twice. Analysis of variance for the repeated measures for each treatment were performed using JMP statistical software. The difference between means were analyzed via analyses of variance to test significance of each antimicrobial and interactions for each meat type and pathogen.

Results: *B. cereus* did not grow (<0.5-log increase) in any treatment when Phase 1 cooling was extended to 5 h. As expected, *C. perfringens* grew rapidly (2.5 to >4.5 log increase) in Control treatments when Phase 1 cooling was extended to ≥3 h. 1.25% DV (all treatments) limited growth to ≤1-log increase when Phase 1 cooling was extended to 3 h but demonstrated >1-log increase when Phase 1 cooling was extended to 5 h in both turkey and beef. 1.25% CSV (all treatments) inhibited *C. perfringens* growth during 3-h Phase 1 cooling in both turkey and beef; 1.25% CSV-A and ≥0.75% CSV-D inhibited growth in Turkey during 5-h Phase 1 cooling, but inhibition among the treatments was inconsistent in beef.

Conclusion: Formulating uncured meats with 1.25% DV or certain CSV can extend Phase 1 cooling to 3 h from 1 h in uncured turkey and beef products. Greater variability of inhibition was observed among CSV than for DV, although all ingredients inhibited growth when used at 0.75% or greater compared to a control. This will allow meat producers more flexibility in cooling their large diameter products if they incorporate 1.25% DV or certain CSV.

Funding Source: NAMI grant

Keywords: *B. cereus*, *C. perfringens*, cooling, vinegar

141 IMPACT OF PACKAGING AND THE SHORT TEMPERATURE ABUSE ON E. COLI O157:H7 GROWTH IN BEEF AND PLANT-BASED MEAT

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Objectives: In recent years, plant-based meat products have become increasingly popular. But there is very little research available on the foodborne pathogen survival and growth in plant-based meat products during short time-temperature abuse. Therefore, the objective was to identify the impact of various storage temperatures and packaging materials on the growth of *E. coli* O157:H7 in ground beef and plant-based meat products.

Materials and Methods: Plant-based meat analogs (PB) and ground beef were obtained from a local grocery store in Stillwater, Oklahoma. Both PB and beef were inoculated with a 5-strain mixture of *E. coli* O157:H7 to achieve approximately 2.3 logs CFU/g final pathogen concentrations. Inoculated PB and beef were weighed and subjected to vacuum, Ziplok®, or overwrap packaging to represent the typical ground beef packaging methods. Half of the inoculated packages were temperature abused for a short time period by exposing them to 42°C ± 2°C for 1 h to mimic the consumer transport of the refrigerated products from a grocery store to a home in a car trunk. All samples were stored at 4°C ± 1°C for 4 d and analyzed for *E. coli* O157:H7 at days 0, 2, and 4. All experiments were repeated 3 times, and data were analyzed using a protected pairwise *t*-test by the day of storage at the probability level of $P \leq 0.05$.

Results: The study identified that the vacuum package PB and beef had significantly lower *E.coli* O157:H7 recoveries of 0.41 and 0.38 less for overwrap and 0.45 and 0.42 Log CFU/g less for Ziploc stored products at the end of the 4-d storage period, respectively. The short temperature abuse did not impact the pathogen growth over the storage period, but on day 4, ground beef had significantly more *E. coli* O157:H7 growth than plant-based meat products across all the packaging types studied.

Conclusion: An increased *E. coli* O157:H7 growth was observed in ground beef compared to plant-based beef. However, the plant-based meat product used in the study contained multiple ingredients, including salt (less than 2%), that may have impacted the bacterial growth. The findings of our study could the first step in identifying the fate of *E. coli* O157:H7 during short-term temperature abuse of plant-based meat products. Future studies are needed to further explore the impacts of plant-based meat formulations on pathogens and spoilage microbes.

Funding Source: The research was supported by Virgil & Marge Jurgensmeyer Endowed Professorship, Oklahoma State University

Keywords: *E. coli* O157:H7, ground beef, plant-based meat

142 BIOMAPPING STUDY OF MICROBIAL INDICATORS IN POULTRY CARCASS AND PART RINSES COLLECTED AT DIFFERENT STAGES IN A COMMERCIAL BROILER FACILITY USING CONVENTIONAL AND PORTABLE METHODOLOGIES

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Objectives: To develop a poultry biomapping study in order to create a microbiological baseline based on aerobic plate counts (APC) and *Enterobacteriaceae* counts (EB) in 2 different processing lines from a commercial broiler facility, using 2 different commercial methodologies for the enumeration of indicator microorganisms.

Materials and Methods: Rinses of whole chicken carcass and wing-composites from 2 different processing lines ($n = 180$) were collected from post-pick (PP); re-hanger (R); post-evisceration (PE); post-chill (PC) locations; and wings samples (W) with 400 mL of buffer peptone water. Microbial indicators APC and EB were enumerated using 2 different methods: the TEMPO™ system, based on the Most-Probable-Number, and the MicroSnap™ system, a rapid bioluminogenic test. The detection and enumeration with the MicroSnap™ system was obtained by a 2-step test procedure, first 1 mL of the rinse was added to the MicroSnap™ Incubation Device and incubated in the portable Dry Block Incubator at 30°C for 7 h for APC and 37°C for 6 h for EB. After the incubation, the enrichment sample was transferred to the MicroSnap™ Detection Device, and the results were immediately read with the EnSure™ Touch. Rinses enumerated with the TEMPO™ system for APC and EB were incubated at 35°C for 22–28 h. Counts from the TEMPO™ system and the MicroSnap™ system were transformed into Log CFU/mL, and ANOVA analysis followed by pairwise comparison *t*-test adjusted Tukey ($P < 0.05$) was used for microbial indicators. Data were analyzed with R statistical analysis software.

Results: Both methodologies showed similar enumeration results for APC counts at R and PE locations for Line 1 and at PP and R locations for Line 2. The methodologies were statistically different ($P < 0.05$) at PP and PC locations in Line 1 of 0.74 Log CFU/mL and 1.49 Log CFU/mL, respectively. The methodologies were statistically different ($P < 0.05$) at PE, PC locations in Line 2, and W locations of 0.74 Log CFU/mL, 1.61 Log CFU/mL, and 1.53 Log CFU/mL, respectively. For EB counts, both methodologies showed similar enumeration results at PP locations for Line 1 and at PP and PE locations for Line 2. The methodologies were significantly different ($P < 0.05$) at R, PE, and PC locations in Line 1 of 0.62 Log CFU/mL, 0.68 Log CFU/mL, and 1.32 Log CFU/mL, respectively. At R, PC locations in Line 2, and W locations of 1.13 Log CFU/mL, 1.03 Log CFU/mL, and 0.81 Log CFU/mL, respectively.

Conclusion: Most of the statistically significant differences found between the 2 methodologies were in low concentrations; this may be due to the different limit of detection (LOD) of the 2 systems. The MicroSnap™ system has a LOD of 10 CFU/mL at the hour of detection, whereas the TEMPO™ system has a LOD of 1 CFU/mL. For both methodologies, microbial indicators APC and EB showed a consistent reduction from PP to PC locations, with an increase at the W location. The trend observed was similar to other poultry biomapping studies. The microbiological baseline obtained will help the facility identify the differences between the 2 processing lines and support continuous improvement decisions for food safety management.

Keywords: aerobic plate counts, Enterobacteriaceae counts, microbial baseline, MicroSnap system, Tempo System

143 SURVIVAL OF E. COLI O157:H7, L. MONOCYTOGENES, AND SALMONELLA SPP. IN SALAMI MANUFACTURED WITH VARIOUS SOURCES OF NITRITE

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Objectives: Sodium nitrite, a common ingredient in cured meat products, is known to inhibit pathogens. Usage of nitrites from fruits and vegetables for "cleaner" labels has raised concerns of antimicrobial efficacy. A gap in literature exists investigating pathogen growth and survival in naturally cured, fermented meat products. A study was designed to determine the survival of *E. coli* O157:H7 (EC), *L. monocytogenes* (LM), and *Salmonella spp.* (S) in salami manufactured with various sources of nitrite.

Materials and Methods: Three replications of 4 treatments were manufactured: no nitrite (negative control; NC), conventional nitrite (positive control; PC), Swiss chard (SC), and Natpre T-10 Cur SB (T-10). Single colonies of EC (EDL933, Sakai, and PA-2), LM (Scott A, 1/2a isolate FSL R2-603, and 4b isolate H3396), and S (Typhimurium, Montevideo, and Derby) were individually inoculated into 50 mL of tryptic soy broth and incubated at 35°C for 24 h. Twenty-four-hour cultures (50 mL of each serovar) then were centrifuged at 20°C for 5 min at 11,000 × *g*. The pellets of each strain ($n = 3$ for each pathogen type) were combined and resuspended in 2.5 mL Buffered Peptone Water (BPW) forming a mixed culture. Pork shoulder butts (IMPS 406) were deboned, cubed, and ground (~5 mm). Ground pork was mixed with inocula (~7 $\log_{10}$ CFU/g target inoculation), dry ingredients, and Safepro® B-LC 007 starter culture (CHR Hansen, Milwaukee, WI). The meat batter was stuffed into 55 mm fibrous casings, hung in a salami cabinet to ferment (pH < 5.0), dried to a target water activity (a_w) of 0.88, and then vacuum packaged and stored at ~20°C. Three salami were randomly evaluated for pathogen concentrations, pH, and a_w ($n = 9$; $N = 396$) on days 0, 1, 2, 3, 7, 14, 21, 28, 35, and 49. Three 20 g salami portions were combined, diluted, homogenized, and plated onto Sorbitol MacConkey supplemented with Cefixime-Tellurite,

Modified Oxford, and Xylose Lysine Deoxycholate agar for EC, LM, and S enumeration, respectively. Pathogen concentrations and total reductions (TR) were analyzed using a mixed model procedure in SAS (SAS OnDemand Version 9.4). The model included comparisons between treatment groups on a sampling day. pH and a_w were included as fixed effects. A significance level of $P < 0.05$ was assigned to determine statistical significance.

Results: The fixed effects of pH and a_w was not significant ($P > 0.05$) for pathogen concentrations throughout the investigation; however, treatment was significant ($P < 0.001$) across all pathogens for the duration of the study. All NC pathogen concentrations on D49 differed significantly ($P < 0.05$) from the other treatments. Only PC achieved a TR ≥ 5 $\log_{10}$ of EC. TR of EC ranged from 3.95 $\log_{10}$ (NC) to 5.38 $\log_{10}$ (PC). TR of EC were not significantly different ($P > 0.05$) between treatments. Final LM concentration for NC on D49 was 5.00 ± 0.23 $\log_{10}$ CFU/g. TR of LM for NC, PC, SC, and T-10 were 2.12, 4.31, 2.96, and 3.05 $\log_{10}$, respectively. TR of LM for NC and PC were significantly different ($P = 0.0033$) but were not significantly different ($P > 0.05$) from SC and T-10. PC, SC, and T-10 all achieved a 5 $\log_{10}$ TR of S and were not significantly different ($P > 0.05$). TR of all pathogens were not significantly different ($P > 0.05$) between PC, SC, and T-10.

Conclusion: This study displayed the significance of curing in combination with other hurdles to achieve adequate reductions of EC, LM, and S in salami manufactured without a thermal lethality step.

Funding Source: Hatch Project #: 4696

Keywords: *E. coli* O157:H7, *Listeria monocytogenes*, natural nitrite, salami, *Salmonella*

144 DOES VITAMIN E SUPPLEMENTATION MITIGATE SALMONELLA PREVALENCE IN THE LYMPH NODES OF FEEDLOT CATTLE?

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Objectives: The objective of this study was to assess the effectiveness of vitamin E supplementation as a strategy to mitigate *Salmonella* prevalence in lymph nodes (LNs) of beef cattle as a potential pre-harvest solution for the beef industry.

Materials and Methods: This research was conducted under Texas A&M AgriLife Research Animal Use Protocol #2020-020A. Two calf crops (warm and cool seasons) of 100 calves each were split into 2 groups housed separately: (1) TRT cattle ($n = 100$; warm $n = 50$; cool $n = 50$) were fed an average of 1,348 IU/head/day of vitamin E, and (2) CNTRL cattle ($n = 100$; warm $n = 50$; cool $n = 50$) were fed a typical feedlot ration averaging 240 IU/head/day of vitamin E. Live weights were recorded on days 0 and 100 for each crop at the commercial feedlot location. The average days on feed for each crop were 242 and 273, respectively. At harvest, carcass weights were recorded, along with liver and lung scores. Left and right superficial cervical and subiliac LNs ($n = 764$) were removed from all carcasses and pooled by type ($n = 382$ LN samples). Lymph nodes then were processed and prepared for isolation and detection of *Salmonella*. Presumptive positive samples were subjected to traditional cultural microbiological methods, and confirmed positive isolates were serotyped. Data were analyzed using JMP Pro version 16.0. Least-squares means were calculated for live cattle weight, carcass weight, and liver and lung data. Differences were determined using contingency tables between harvest seasons and treatment groups for *Salmonella* prevalence data. Means were separated using an $\alpha = 0.05$ where appropriate.

Results: Out of the 382 LN samples, 186 were confirmed as positive for *Salmonella*. The *Salmonella* percentages for positive LN samples collected in the warm season, crop 1, were 58.16% (57/98 LN) and 61.22% (60/98 LN) for CNTRL and TRT, respectively ($P > 0.05$). The rate of *Salmonella*-positive LN samples from CNTRL, harvested in the cool season, crop 2, was 23.33% (21/90 LN) and from TRT was 50.0% (48/96 LN). TRT cattle had a higher prevalence rate of *Salmonella*-positive LN for both seasons. Of the 186 samples that were confirmed positive for *Salmonella*, 14 unique serovars were identified. The most common serovars were *S*. Anatum (22.6%; 42/186), *S*. Kentucky (18.8%; 35/186), *S*. Muenchen (17.7%; 33/186), *S*. Montevideo (16.6%; 31/186), and *S*. Lille (7.0%; 13/186). Antimicrobial susceptibility results showed that only one *Salmonella* serovar was resistant, *S*. Montevideo.

Conclusion: Results from this study are consistent with other work showing seasonal differences in *Salmonella*-positive bovine LN. The hypothesis that vitamin E and its antioxidant properties could reduce *Salmonella* in the bovine LN through small intestine absorption and subsequent transfer to the lymphatic system was not proven. Serovar and antimicrobial susceptibility data provide new information to address rising concerns of antibiotic-resistant non-typhoidal *Salmonella*. Identifying how *Salmonella* interacts in the gut biome of bovines could provide more answers regarding the antimicrobial susceptibility of antibiotics used to treat humans. Identifying how and why *Salmonella* exposure differs between feedlot environments would be beneficial to producers, and processors, and help increase consumer confidence in the U.S. beef industry.

Funding Source: Funded, in part, by the Beef Checkoff and the Beef Promotion and Research Council of Texas.

Keywords: antibiotic resistance, beef, lymph nodes, *Salmonella*, serovars

146 COMPARISON OF SALMONELLA SEROTYPE PROFILES RECOVERED FROM PEN SURFACE FEEDYARD SAMPLES AND CECAL AND LYMPH NODE SAMPLES COLLECTED FROM A BEEF PROCESSING FACILITY

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Objectives: The study objective was to compare the *Salmonella* serotype profiles from pen surface samples collected in different cattle feedyards as well as the corresponding cecal content, mesenteric lymph nodes (LN), peripheral LN (popliteal, subiliac, superficial cervical) sampled in cattle sourced from the same pens and processed in a commercial beef processing facility.

Materials and Methods: For pen surface samples, 10 pens at 10 different feedyards were sampled by dividing each pen in 4 quadrants, and surface material (10 g) from multiple locations in each quadrant was collected. Mesenteric LN, peripheral LN (popliteal, subiliac, superficial cervical), and cecal swab samples were collected from 200 animals sourced from the same pens during 6 wk at a beef processing facility. *Salmonella* isolates were sent to USMARC-Nebraska Laboratory for further PCR analysis. Serotypes were identified using traditional slide agglutination (O typing) and tube agglutination (flagellar H typing) techniques with commercial antisera. In addition, each isolate was subjected to an 8-gene multiplex PCR assay targeting genes linked to human pathogenicity potential named *Salmonella* Pathogenicity Gene (SPG) PCR. *Salmonella* isolates with more than 4 copies of the genes targeted by the SPG PCR assay were labeled as highly pathogenic (HPS).

Results: *Salmonella* serotypes were recovered from different cattle feedyards and samples from a commercial beef processing facility. A total of 17 serotypes were found in cecal swab samples, with 13 different combinations of virulence factors identified. *Salmonella* Muenchen was the most common serotype isolated in this study. Mesenteric LN presented 15 serotypes with 15 combinations (most common serotype Agona), popliteal LN with 8 serotypes with 11 combinations, subiliac LN showed 9 serotypes with 10 different combinations, and superficial cervical LN with 12 serotypes and 11 combinations of virulence factors. Montevideo was the most common serotype found in popliteal, subiliac, and superficial cervical LN. The cattle feedyards presented 17 different serotypes with 10 possible combinations of virulence factors, with Anatum being the most common serotype found.

Conclusion: The study provides an overall serotype diversity profile of *Salmonella* where less than 1% of the total amount of serotypes of *Salmonella* were found in the different samples collected in the feedyards and processing facility. These results showed a possible relationship between the serotypes found from feedyards and the prevailing serotypes usually found in LN and cecal content samples collected during harvest in the processing facility.

Keywords: beef lymph nodes, highly pathogenic *Salmonella*, PCR assay, serotypes, virulence factor

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147 USE OF STATISTICAL PROCESS CONTROL TO CONTINUOUSLY MONITOR MICROBIAL INDICATOR CONCENTRATION THROUGHOUT A BEEF PROCESSING FACILITY

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Objectives: The objective was to establish an ongoing statistical process control methodology with dynamic visualization for analysis of microbial indicator data and identification of actionable information for food safety management in a beef processing facility.

Materials and Methods: Pre-hydrated EZ-Reach™ swabs with 25 mL of Buffered Peptone Water were used to sample 100 cm^2 area within a beef processing plant throughout 4 processing stages. A total of 784 samples were taken per microbial indicator (aerobic [APC], coliforms [CC], and *E. coli* [EC]) evaluated at the Hot Carcass ($n = 180$), Cold Carcass ($n = 100$), Subprimals ($n = 324$), and Beef Trim ($n = 180$) stages of a beef processing plant, totaling 2,352 observations for a 1-y period. At each stage, Lactic Acid (2%–5%) intervention was applied. A total of 6 subprimals and 3 types of trim were evaluated. After sampling, swabs were immediately chilled and shipped overnight to the International Center for Food Industry Excellence (ICFIE) Food Microbiology Laboratory at Texas Tech University. Samples were homogenized at 230 rpm for 1 min and plated onto 3M™ Petrifilm plates to quantify APC, CC, and EC counts following manufacturer instructions. Microbial concentrations were determined and converted to LogCFU/cm^2 or LogCFU/sample prior to statistical analysis. XmR charts, also known as Shewhart individual observation control charts, that included the use of sequential standard deviations for the upper control limits (UCL) and lower control limits (LCL) calculation based on $\mu \pm 3\sigma$ were developed.

Results: Significantly lower statistical process control parameters (mean, UCL, and LCL) were observed after

intervention ($P < 0.05$). The hot carcass stage before intervention presented multiple observations below process control limits within all indicators. Root cause analysis for lower than LCL observations must be performed to identify possible improvements to the line by understanding the lower microbial concentration for these observations. Stages with multiple microbial concentration at lower than limit of detection were more sensitive at encountering out of control observations. This was observed after lactic intervention at the hot carcass stage for APC, CC, and EC, and throughout the processing line after intervention for EC. Stability of individual observation control charts was reached when closer to 100 samples were analyzed. As such, a moving window for at least 100 samples should be evaluated to constantly assess whether microbial concentrations at each stage are within control based on the in-plant data collected in this study. Statistical process control monitoring procedures identified upward shifts in APC concentration at the shoulder clod stage due to reduced concentration of Lactic Acid intervention solution, identified as a root cause.

Conclusion: Microbial indicator data collected through routine sampling already being conducted within a beef processing plant may be used to implement statistical process monitoring of each indicator microorganisms for data-driven decision making. Root cause analysis of out-of-control observations visualized in the XmR dynamic charts may lead to optimization of food safety systems, deeper understanding of areas of improvement, and risk mitigation throughout the processing line. Conducting statistical process control monitoring identified out of control observations within a beef processing plant allowing for the implementation of corrective actions in a proactive manner to support continuous improvement initiatives.

Funding Source: International Center for Food Industry Excellence (ICFIE)

Keywords: beef, indicator microorganism, statistical process control

148 USE OF SALMONELLA PREVALENCE AND QUANTIFICATION DATA IN CECAL AND LYMPH NODE SAMPLES TO ESTABLISH STATISTICAL PROCESS CONTROL PARAMETERS FOR FOOD SAFETY MANAGEMENT IN A COMMERCIAL BEEF PROCESSING FACILITY

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Objectives: The objective was to develop statistical process control (SPC) parameters that can be used for food safety management in a beef processing plant, using *Salmonella* quantification of cecal swab samples and 4 types of lymph nodes (LN) through 6 wk of continuous operation.

Materials and Methods: A total of 250 carcasses were sampled individually to collect 1 cecal swab sample, 1 mesenteric LN, and 3 peripheral LN (Popliteal, Subiliac, Superficial Cervical) for 50 animals during 4 wk and 25 for 2 wk for a total of 6 wk of continuous operation in a commercial beef processing facility. Collected samples were analyzed for *Salmonella* prevalence and quantification; the BAX Real-time PCR *Salmonella* assay and BAX System SalQuant were used, respectively, to develop SPC parameters. The mean of the prevalence for each sample type for each week was used to calculate SPS parameters. All data were analyzed using R (Version 4.2.2) software to evaluate the change in *Salmonella* prevalence for sample type through 6 wk. A statistical quality control chart (X chart) was developed to estimate SPC parameters for each of the different samples. The center line or grand average (p) parameter was estimated by calculating an average per type of sample ($n = 250$, this represents the total of all samples of each type for the 6 sampling days), and then the average of each of the 5 types of samples means was estimated for each of the 6 wk. The other 2 parameters, upper control limit (UCL) and lower control limit (LCL), for each type of sample were estimated using equation 1 and 3 where the average standard deviation was used, given that 250 samples were collected on each sampling day for 6 wk. Quantification data were analyzed; however, the low level of results does not allow the development of SPC parameters. Chi-square analysis was performed to measure the differences between sample types. Pairwise comparisons were done using the Wilcox-test.

$$\text{Upper control limit (UCL)} = p + 3\sqrt{((p(1 - p)/n))} \quad (1)$$

$$\text{Central line (grand average)} = p \quad (2)$$

$$\text{Upper control limit (UCL)} = p - 3\sqrt{((p(1 - p)/n))} \quad (3)$$

Results: Statistical process control parameters were estimated for *Salmonella* prevalence and are presented as a table (Table 1) for each sample type. The *Salmonella* prevalence process control graphs were constructed using the mean of each type of sample represented by the solid line and error line calculated with ±3 standard deviations (UCL and LCL) around the mean using a sample size of 50 samples for sample type collected during 6 wk. Chi-square analysis showed a p-value = 0.2202 for all sample types; however, the mean separation analysis showed differences in prevalence between sample types. Quantification data were not sufficiently high to establish SPC parameters based on pathogen load.

Conclusion: The development of SPC parameters as a tool for food safety management can be applied to the prevalence of *Salmonella* on beef LN collected during processing.

Table 1. Statistical process control parameters.

SAMPLE TYPE	PREVALENCE	SE	LCL	UCL
Cecal Sponge	0.60	0.03	0.50	0.70
Ileocecal LN	0.35	0.03	0.25	0.45
Popliteal LN	0.19	0.03	0.10	0.27
Subiliac LN	0.20	0.03	0.12	0.29
Superficial Cervical LN	0.17	0.03	0.09	0.25

The upper limits can provide processors with a threshold to identify out of control lots and determine root causes associated with specific lots of animals.

Keywords: BAX System, beef lymph nodes, *Salmonella*, statistical process control (SPC)

149 IN-PLANT INTERVENTION VALIDATION STUDY AT THREE INDEPENDENT STAGES OF A BEEF PROCESSING PLANT HARVEST FLOOR

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Objectives: The objective of this study was to conduct an in-plant study to validate the efficacy of 3 intervention cabinets in a meat processing facility harvest floor.

Materials and Methods: Beef carcasses were randomly swabbed before ($n = 120$) and after ($n = 120$) antimicrobial intervention at 3 independent stages of a beef processing plant harvest floor (Pre-evisceration, Pre-Containment, and Hot Water). The selected carcasses were sampled in a 100 cm^2 area using sterile, pre-hydrated sponges with 25 mL of Buffered Peptone Water. Samples were immediately chilled and shipped to the Texas Tech University Food Microbiology laboratory for analysis. The sponges were homogenized in a paddle blender at 230 RPM for 1 min. The samples were plated to determine generic *Eschecheria coli* (EC), Enterobacteriaceae count (EB), and aerobic counts (AC) using the TEMPO ® System by BioMérieux. Statistical analysis was performed to determine differences between before and after each intervention, based on an alpha of 0.05 using R v2023.03.0.

Results: According to the obtained results the pre-evisceration intervention significantly reduced the AC ($P < 0.001$) with an average of 5.00 ± 0.08 log CFU/sample before and 4.14 ± 0.12 log CFU/sample after the intervention. Enterobacteriaceae counts were significantly reduced ($P < 0.001$) with an average of 1.92 ± 0.05 log CFU/sample before and 1.34 ± 0.04 log CFU/sample after the intervention. *E. coli* counts were significantly reduced ($P < 0.001$) with an average of 2.00 ± 0.07 log CFU/sample before and 1.43 ± 0.04 log CFU/sample after the intervention. For pre-containment intervention, the results showed that the intervention significantly reduced the AC ($P < 0.001$) with an average of 3.49 ± 0.09 log CFU/ sample before and 2.92 ± 0.09 log CFU/sample after the intervention. Enterobacteriaceae counts were significantly reduced ($P < 0.001$) with an average of 1.73 ± 0.01 log CFU/ sample before and 1.16 ± 0.01 log CFU/sample after the intervention. *E. coli* counts were significantly reduced ($P < 0.001$) with an average of 1.31 ± 0.04 log CFU/ sample before and 1.12 ± 0.01 log CFU/sample after the intervention. The obtained results for hot water did not show any significant difference in AC ($P = 0.15$), and for EC and EB the counts were below the detection limit of 0.25 CFU/cm^2 before the intervention; therefore, no significant reduction can be established if no natural microbiota is quantifiable on the carcass.

Conclusion: There is sufficient evidence to validate that pre-evisceration and pre-containment interventions are effectively reducing AC, EB, and generic EC. There is no sufficient evidence to confirm that hot water is an effective treatment to reduce AC in the carcass; however, it has been observed in the past to improve the effect a subsequent lactic acid treatment has on the carcass surface. Thus, a multi-hurdle approach to intervention validation must always be considered.

Keywords: antimicrobial intervention, TEMPO ®, indicator microorganisms, beef

150 EVALUATION OF THE ANTIMICROBIAL EFFECTS OF ACIDIFIED PEROXYACETIC ACID AGAINST SHIGA TOXIN-PRODUCING ESCHERICHIA COLI AND SALMONELLA ENTERICA ON BEEF CHEEK MEAT

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Objectives: Beef variety meats, such as cheek meat, carry high levels of microbial contamination, and the presence of pathogens on these products can pose food safety concerns. Therefore, continued research efforts are needed to find strategies to control pathogen contamination on variety meats. This study evaluated the efficacy of peroxyacetic acid acidified with a sulfuric acid and sodium sulfate blend (aPAA) in reducing levels of inoculated Shiga toxin-producing *Escherichia coli* (STEC) and *Salmonella enterica* on beef cheek meat. The fate of the pathogens during subsequent refrigerated or frozen storage of the cheek meat samples was also investigated.

Materials and Methods: Prerigor cheek meat (5 × 10 cm pieces) was surface-inoculated (6.0 log CFU/cm^2) with a 14-strain mixture of rifampicin-resistant (100 µg/ml) STEC or a 6-serotype strain mixture of *Salmonella.* Inoculated samples were left untreated (control) or were immersed for 10 s in water or aPAA (400 ppm, pH 1.2). Samples were then individually packaged in Whirl-Pak bags and stored for 60 d at 4°C or 150 d at −20°C. Meat samples were analyzed for inoculated pathogen populations and aerobic plate counts (APC) on day 0 and on at least 6 subsequent time points during storage. The experiment was repeated on 2 separate days, and 3 samples were analyzed per treatment and sampling time in each trial ($n = 6$). The study was designed as a factorial, blocked by trial, with treatments and sampling days as factors for each storage temperature (4°C or −20°C), pathogen (STEC or *Salmonella*), and culture medium (selective or non-selective). Data were analyzed using R, with a significance level of $\alpha = 0.05$.

Results: Treatment with aPAA reduced ($P < 0.05$) initial (day 0) pathogen populations on cheek meat samples by 1.0 (STEC) and 1.1 to 1.2 (*Salmonella*) log CFU/cm^2. Initial pathogen reductions of 0.4 to 0.5 log CFU/cm^2 were obtained with the water treatment, irrespective of inoculum type. As expected, STEC and *Salmonella* levels did not increase ($P \geq 0.05$) during storage of cheek meat at 4°C, irrespective of the treatment. Pathogen counts of aPAA-treated samples analyzed on day 60 of refrigerated storage were 0.8 (STEC) and 2.2 (*Salmonella*) log CFU/cm^2 lower ($P < 0.05$) than the initial counts. Regardless of the treatment and inoculum type, APC of samples increased ($P < 0.05$) during storage at 4°C due to spoilage microflora growth. Pathogen counts of aPAA-treated samples decreased ($P < 0.05$) during frozen storage. Specifically, counts of samples on day 150 were 1.1 (STEC) and 1.5 (*Salmonella*) log CFU/cm^2 lower ($P < 0.05$) than the day 0 counts. For the untreated and water-treated samples, recovered pathogen counts on day 150 were 0.4 to 0.5 (STEC) and 0.7 (*Salmonella*) lower ($P < 0.05$) than those obtained initially. In general, APC of aPAA-treated samples decreased ($P < 0.05$) during the frozen storage period, regardless of inoculum type, whereas those of the control and water-treated samples remained relatively unchanged ($P \geq 0.05$).

Conclusion: Overall, this study demonstrated that aPAA can effectively reduce initial STEC and *Salmonella* contamination levels on beef cheek meat. Subsequent chilled or frozen storage of samples can further reduce pathogen loads. Findings of this study should be useful to the meat industry as they consider antimicrobial interventions against STEC and *Salmonella* on cheek meat.

Funding Source: Foundation for Meat and Poultry Research and Education

Keywords: acidified peroxyacetic acid, antimicrobial, beef cheek meat, *Salmonella*, Shiga toxin-producing *Escherichia coli*

151 EVALUATION OF AN ANTIMICROBIAL TREATMENT FOR REDUCTION OF PATHOGEN POPULATIONS ON BEEF TONGUES STORED AT 4°C OR −20°C

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Objectives: When compared to whole muscle cuts, beef variety meats are known to have higher levels of microbial contamination. Beef tongues harbor many bacteria, some of which may be pathogenic. This study evaluated the antimicrobial effects of peroxyacetic acid acidified with a blend of sulfuric acid and sodium sulfate (aPAA) against inoculated populations of Shiga toxin-producing *Escherichia coli* (STEC) and *Salmonella enterica* on beef tongues stored at 4°C or −20°C.

Materials and Methods: Prerigor whole beef tongues were surface-inoculated (48 cm^2 area; 5–6 log CFU/cm^2) with a 14-strain mixture of rifampicin-resistant (100 µg/ml) STEC or a 6-serotype strain mixture of *Salmonella.* Inoculated samples were left untreated (control) or were immersed for 10 s in water or aPAA (400 ppm, pH 1.2), and were subsequently individually vacuum-packaged and stored at 4°C (90 d) or −20°C (150 d). Samples were analyzed for inoculated pathogen populations and aerobic plate counts (APC) on day 0 and on at least 6 subsequent storage days per storage temperature. The experiment was repeated on 2 separate days, and 3 samples were analyzed per treatment and sampling time in each trial ($n = 6$). The study was a factorial design, blocked by trial day, with treatments and sampling days as factors for each storage temperature (4°C

or −20°C), pathogen (STEC or *Salmonella*), and culture medium (selective or non-selective). Data were analyzed using R statistical software, with a significance level of $\alpha = 0.05$.

Results: Initial (day-0) STEC and *Salmonella* populations of 5.3 log CFU/cm^2 were reduced ($P < 0.05$) by 1.6 and 1.8 log CFU/cm^2, respectively, immediately following treatment with aPAA. For the water treatment, initial pathogen populations were reduced ($P \geq 0.05$) by 0.3 (STEC) and 0.5 (*Salmonella*) log CFU/cm^2. Irrespective of inoculum type and treatment, pathogen levels decreased during the 90-d and 150-d storage time at 4°C and −20°C, respectively. More specifically, for aPAA-treated tongues held at 4°C for 90 d, recovered STEC and *Salmonella* populations were 0.4 ($P \geq 0.05$) and 2.3 ($P < 0.05$) log CFU/cm^2, respectively, lower than the corresponding initial pathogen levels. For samples that were treated with water, pathogen counts at the end of the chilled storage period were 1.7 (STEC) and 2.2 (*Salmonella*) log CFU/cm^2 lower ($P < 0.05$) than the day-0 counts. *Salmonella* and STEC populations of samples treated with aPAA and held at −20°C for 150 d were >3.3 and 1.6 log CFU/cm^2, respectively, lower ($P < 0.05$) than the counts obtained on day 0. For water-treated tongue samples, pathogen counts at the end of the frozen storage period were 0.8 (*Salmonella*; $P < 0.05$) and 0.6 (STEC; $P \geq 0.05$) lower than those recovered on day 0. Irrespective of inoculated pathogen, APC of aPAA-treated samples held at −20°C decreased ($P < 0.05$) during storage.

Conclusion: The results of the study indicated that aPAA was an effective intervention for reducing initial contamination levels of both pathogens on beef tongues. Irrespective of the treatments, populations of both pathogens decreased during refrigerated and frozen storage. The aPAA-treated tongue samples had the lowest APC, STEC, and *Salmonella* populations following 150 d of frozen storage. Findings of this study may be valuable to the meat industry as they seek approaches to reduce pathogen contamination on beef tongues.

Funding Source: Foundation for Meat and Poultry Research and Education

Keywords: acidified peroxyacetic acid, antimicrobials, beef variety meats, *Salmonella*, Shiga toxin-producing *Escherichia coli*

152 EFFICACY OF A NOVEL BUFFERED LACTIC ACID SOLUTION AS SURFACE TREATMENT AGAINST SALMONELLA ENTERICA IN FRESH PORK

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Table 1. *Salmonella* spp. survival in fresh pork ham after spray application

Treatment	log CFU/cm^2
Untreated (UT)	4.09±0.08[a]
Distilled Water (W)	3.75±0.03[b]
Buffered Lactic Acid (Verdad® N210)	3.08±0.08[c]

Values presented in the table are mean ± standard deviation

[a-c]Values with a different letter are significantly different (p<0.05)

Objectives: The objective of this study was to evaluate the efficacy of a novel buffered lactic acid solution (Verdad® N210) on the surface of fresh pork ham inside pieces to increase *Salmonella* mortality.

Materials and Methods: Fresh pork ham inside muscles (*semimembranosus*) were received from a commercial processor and denuded in a 2.2°C temperature-controlled processing facility. Denuded ham pieces were portioned into 10 cm x 10 cm squares. All samples were brought to ambient temperature before inoculation and spray treatment application. Each square was inoculated with a 5-strain cocktail of *Salmonella* spp. at ca. 5 log CFU/cm^2. The inoculated samples were placed in the biosafety cabinet for 30 min for bacterial attachment. Samples for one treatment were left untreated (UT), while samples from the other 2 treatments were sprayed using a pressurized spray system set to 25 psi to deliver approximately 1 mL of 50°C solution per cm^2 of the sample. The 2 treatments sprayed consisted of distilled water (W) or a buffered lactic acid solution (Verdad® N210). Samples were left on drying racks at a 45° angle to drip for 5 min in ambient conditions. Following drip time, samples were placed in 100 mL Dey Engley neutralizing buffer and stomached for 1 min. Serial dilutions were made in Butterfield's Buffer and plated in duplicate on XLT-4 agar. Plates were incubated at 35°C for 24 h. Two replications of the study were conducted. Minitab 20.2 was used to perform Tukey's test to determine any significant difference between the treatments at $\alpha = 0.05$.

Results: The *Salmonella* population in the UT samples had a survival of 4.09 log CFU/cm^2, whereas W-treated samples had a survival of 3.75 CFU/cm^2 (Table 1). Samples treated with Verdad® N210 had significantly ($P < 0.05$) lower *Salmonella* population of 3.08 CFU/cm^2 among treatments. Overall, the application of Verdad® N210 resulted in a 1.01 and 0.67 log reduction of *Salmonella* compared to the UT and W treatments.

Conclusion: The use of antimicrobials as a processing aid can influence the food safety of fresh meat by reducing the survival of pathogenic bacteria such as *Salmonella.* The application of Verdad® N210 resulted in a 1-log reduction of *Salmonella* on the surface of fresh pork. This study validates the efficacy of a novel buffered lactic acid solution as a processing aid for the fresh meat industry.

Funding Source: Corbion

Keywords: antimicrobial, food safety, fresh meat, *Salmonella*

153 THE IMPACT OF PRODUCTION SYSTEM THE GROUND BEEF MICROBIOME AND RESISTOME

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Objectives: Concerns over the potential transfer of antimicrobial resistance (AMR) to humans via the consumption of meat products have raised questions about the use of antimicrobial drugs in food-animal production. These concerns have increased consumer demands for meat products from cattle raised without antimicrobials. Prior studies have demonstrated that beef processing interventions effectively remove the vast majority of antimicrobial resistance genes (ARG). However, the impact of raised without antibiotics practices on the retail ground beef microbiome and resistome has not been examined. Therefore, the objective of this study was to evaluate the impact of live animal production systems, retail locations, and packaging type on ground beef bacterial communities and ARG presence.

Materials and Methods: Ground beef products were collected from metropolitan areas across the United States (Atlanta, Dallas, Fort Collins, New York, San Francisco, and Seattle). From each metropolitan area, ground beef packages of various packaging types (chub, tray-lid, tray-overwrap, and vacuum), and different live animal production systems [conventionally raised [CON; $n = 50$] or raised without antibiotics [NAT; $n = 50$]) were purchased. Samples were subjected to DNA extraction and were sequenced using both 16S rRNA amplicon sequencing to characterize microbial diversity and composition and AMR target-enriched metagenomic sequencing. 16S rRNA gene sequencing data were then processed with the QIIME2 pipeline and AMR-TE data were processed with the AMR++ pipeline and the MEGARes database.

Results: When evaluating the effect of packaging type, differences ($P < 0.05$) for both sequencing approaches were found between tray-overwrap and vacuum-packaged products community richness and makeup. Due to limited sampling, only tray-overwrap samples were selected for further analysis. Sampling location influenced ($P < 0.05$) the composition of both the microbial community and AMR gene pool of tray-overwrap packages, suggesting that the retail environment where the products are purchased or produced can influence the communities and ARG present. When evaluating CON and NAT production systems, differences in the composition of microbial communities ($P < 0.05$) were identified, e.g., *Photobacterium* was in higher relative abundance ($P < 0.05$) in NAT samples while Lactobacillales was in higher relative abundance ($P < 0.05$) in CON. However, there were no differences ($P > 0.05$) in the composition or diversity of the AMR gene pools between CON and NAT, suggesting that the use of antibiotics in the live animals does not have an impact on the presence of ARG in ground beef products at the retail level.

Conclusion: Overall, factors such as location and packaging impacted both microbial community structure and AMR gene pool composition, whereas production system (CON or NAT) did not impact the ARG gene pool. Therefore, future studies regarding the ground beef microbiome should consider location, and packaging sampled in design when comparing products.

Funding Source: Beef Checkoff

Keywords: conventional, microbiome, natural, resistome, retail meat

154 THE AGRICULTURAL MARKETING SERVICE MANUAL CLOTH SAMPLING OF BONELESS BEEF TRIMMINGS UTILIZED IN FEDERAL NUTRITION ASSISTANCE PROGRAMS: DESIGN, IMPLEMENTATION, AND FINDINGS

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Objectives: The Agricultural Marketing Service (AMS) sought to validate an improved, non-destructive surface sampling methodology, the cloth manual sampling device (MSD), for the microbiological testing requirements associated with boneless beef trimmings procured by AMS and distributed through federal nutrition assistance programs.

Materials and Methods: In 2022, AMS conducted an in-field study, to validate the efficacy of MSD for recovering pathogenic bacteria from boneless beef trimmings as compared to the IEH N60 Plus Sampler™ (N60+) methodology. Trained AMS contractor personnel collected both MSD and N60+ samples on 2,286 individual boneless beef trim lots (~2,000 lb. individual combo; 85% lean) for the detection of *Escherichia coli* O157:H7, non-O157 Shiga toxin-producing *E. coli* (non-O157 STEC; *E. coli* O26, O45, O103, O111, O121, and O145), and *Salmonella*. Microbiological analyses were done according to the Food Safety and Inspection Service Microbiology Laboratory

Guidebook at an AMS-Designated Laboratory. A McNemar's chi-square test was used on the resulting test data to determine whether the 2 methods were statistically different. Moreover, a Kappa statistic was computed to examine the degree of agreement in *E. coli* O157:H7, non-O157 STEC, and *Salmonella* results between the MSD and N60+ methods.

Results: Microbiological test results of the 2,286 lots of boneless beef trimmings yielded the recovery of no *E. coli* O157:H7 or non-O157 STEC for either sampling methodology. This was not unexpected as prevalence rates in AMS produced boneless beef are typically low (<1.0%). Conversely, *Salmonella* results produced 29 (1.26%) MSD positives and 20 (0.87%) N60+ positives out of the 2,286 samples, suggesting that there is not a statistically significant difference (χ^2 [1, $N = 2{,}286$] = 2.7931, $P = 0.0947$) between the 2 sampling methods. The amount of agreement between the 2 sampling methods for *Salmonella* is moderate (10 positives). The Kappa statistics were 0.402, and the 95% confidence interval was (0.227, 0.577).

Conclusion: Data collected from this study support the use of MSD as being equivalent to N60+ when recovering pathogenic bacteria from boneless beef trimmings.

Keywords: Agricultural Marketing Service, beef, cloth sampling, *E. coli* O157:H7, *Salmonella*

155 IMPACT OF GRASS-FED AND GRAIN-FED FEEDING SYSTEMS ON THE TRANSFERRABLE ANTIMICROBIAL RESISTANT GENES AND BIOCIDE AND METAL RESISTANCE GENES IN BEEF CATTLE IN WESTERN UNITED STATES

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Objectives: Although the beef industry has employed antibiotics, antimicrobial metals, and antimicrobial biocides to enhance animal health, this practice can contribute to the emergence of antimicrobial resistance (AMR) and biocide and metal resistance (BMR). BMR may further contribute to the selective pressure for AMR and increase the risk of transmission of AMR genes (ARG) to humans through fecal-contaminated meat. However, it remains unclear whether grass-fed and grain-fed feeding systems affect ARG and BMR genes (BMRG) in cattle feces, and thus this study aimed to characterize and compare the transferrable ARG and BMRG profiles of fecal microbes collected from cattle raised in various grass-fed and grain-fed feeding systems in the Western United States.

Materials and Methods: Fecal samples were gathered from cattle at 14 mo and before harvest. Treatments included: 1) feedyard-finished steers (CON), 2) 20-mo grass-fed steers (20GF), 3) 20-mo grass-fed steers with a 45-d grain finish (GR45), and 4) 25-mo grass-fed steers (25GF). All the animals received minerals in their diet. Only CON and GR45 steers received Monensin, and some of them also received therapeutic antibiotics. Microbial DNA was extracted and sequenced, and qualified reads were analyzed for transferrable ARG and BMRG. Shannon's and Chao's diversity indices were calculated and compared using two-way ANOVA in R with a 0.05 alpha level.

Results: The number of transferable ARG detected in CON, 20GF, GR45, and 25GF were 54, 29, 42, and 24, respectively, with 14, 5, 2, and 2 unique transferable ARG identified, respectively. Interestingly, 18 common transferable ARG were found in all treatments. Among these, 8 of them exhibited resistance to tetracycline, 2 were resistant to beta-lactam, 2 were resistant to lincosamide, and 2 showed resistance to chloramphenicol-florfenicol. A total of 753 BMRG were identified, with 170 BMRG located on plasmid and transposon retained for further analysis after filtration. No significant differences ($P > 0.05$) in the Chao index were detected for the relative abundance of BMRG among treatments, regardless of feeding or age effects. However, a smaller ($P < 0.05$) Shannon index of transferrable BMRG was observed for GR45 compared to 20GF and 25GF. The NMDS ordination plot (Stress = 0.14, $R = 0.20$, $P = 0.16$) did not demonstrate significance in feeding systems on the transferrable BMRG profiles.

Conclusion: This study determined the profiles of transferrable ARG and BMRG in cattle feces from various production systems with different antibiotic use management practices. The findings suggested that minerals, as the sources of heavy metals in animals' diets, may contribute to the development of metal resistance in bacteria. As the development of BMRG occurred regardless of the exposure to the biocides, it is plausible that residues or naturally occurring sources in the environment could also have triggered their development. Additionally, the findings also demonstrated that animal feces from grain-fed feeding systems harbor more transferrable ARG. On the other hand, those from grass-fed systems exhibit greater diversity in transferrable BMRG, which may create selective pressure and promote the development of ARG, even in grass-based feeding systems where antibiotics were not administered.

Funding Source: Funding for this work was made possible, in part, by the California Department of Food and Agriculture through grant A21-3745-001.

Keywords: antimicrobial resistant genes, biocide and metal resistance genes, cattle

Muscle and Lipid Biology and Biochemistry

156 THE CHANGE IN COLOR STABILITY BETWEEN THREE DEGREES OF DONENESS OF THREE MUSCLES

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Objectives: Understanding cooked color stability is imperative, as it impacts the final pigment seen before consumption by consumers. It explains differences in the internal appearance of a steak moments after slicing compared to the initial appearance. It is well established that this visual component of the cooked steak is crucial to satisfy the eating experience for the consumer, and the final internal appearance is dictated by color stability. Therefore, understanding cooked color stability warrants further investigation. The objective of this study was to determine the changes in color stability between 3 different muscles cooked to different degrees of doneness.

Materials and Methods: Beef strip loins ($n = 12$) and top butts ($n = 12$) were collected at a beef processing plant and brought to Kansas State University. The strip loins (LL) were denuded, and the top butts were separated into the *Biceps femoris* (BF) and *Gluteus medius* (GM) and sliced into 2.5-cm steaks. Steaks from each primal were randomly assigned to one of the following treatments: raw, medium rare (MR), medium (MED), or well done (WD). All steaks were aged for 28 d at 4°C and frozen and held at −20°C. The steaks were cooked to the assigned degree of doneness (DOD) to an internal peak temperature of 62.8°C (MR), 71°C (MED), or 76.7°C (WD) monitored with a Thermapen. Immediately, cooked samples were powdered for all lab assays, including metmyoglobin-reducing activity (MRA). MRA is a measure of color stability and was determined using a protocol provided in the AMSA color guidelines. Briefly, samples were weighed with a sodium phosphate buffer into bead homogenizer tubes. Metmyoglobin, potassium ferrocyanide, deionized water, EDTA, and sodium citrate buffer were added to a 96-well plate. Then the samples were homogenized and centrifuged before being added to the prepared 96-well plate. Immediately, NADH was added to the plate and was evaluated with a spectrophotometer at 525 nm every 60 s. The change in absorbance was used to calculate the MRA of each sample using Beer's law.

Results: Metmyoglobin-reducing activity decreased ($P < 0.05$) with increasing DOD. The raw treatment resulted in the highest MRA with 3.03 nmol*min^{-1}*g^{-1} of sample. On the other hand, there was still MRA activity even at the WD DOD. The WD sample resulted in an MRA of 0.85 nmol*min^{-1}*g^{-1} of sample. Muscle type also impacted MRA. The BF and GM resulted in a greater ($P < 0.05$) MRA than the LL, but the BF and GM did not differ ($P > 0.05$) across all DOD.

Conclusion: The current study found MRA to gradually decline with increasing DOD, but even at the WD DOD, there was a level of MRA remaining. These results indicate the ability for myoglobin to be reduced even after an extensive cooking process, further indicating an intimate link between MRA and DOD. Conversely, the raw color stabilities of the 3 muscles have been determined in previous works, with the LL having the highest color stability in raw product. Therefore, our study indicates the raw color stability is not synonymous to cooked color stability. Metmyoglobin-reducing activity could be used to help explain differences in cooked color stability, especially when evaluating other factors impacting cooked color including the oxidation state of myoglobin, aging method, differing muscles, display period, freezing techniques, and aging periods.

Keywords: beef, color stability, cooked color, metmyoglobin-reducing activity, myoglobin

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157 INVESTIGATING BEEF LOIN STEAKS VARYING IN QUALITY GRADE, AGING TIME, AND DEGREE OF DONENESS USING UNTARGETED METABOLOMICS

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Objectives: Flavor precursors are essential to flavor development, yet little is known about the intrinsic products of metabolism in raw and cooked meat related to quality grade, aging, or degree of doneness. Our objective was to use untargeted metabolomics to elucidate whether these small molecules are impacted by quality grade, aging, or degree of doneness. We hypothesized that because these 3 factors have a profound impact on beef eating quality, that they would then have a measured impact on the metabolomics in both the raw and cooked beef samples.

Materials and Methods: USDA Select ($n = 18$) and upper 2/3 Choice ($n = 18$) beef strip loins were wet-aged for 10 or 20 d and then cut into steaks, vacuum-packaged, and frozen. Steaks were cooked to 63°C, 71°C, or 80°C end-point internal steak temperature on a 204°C grill. Frozen samples were homogenized in a blender, and 2 g was extracted with acidified acetonitrile and a solid phase extraction enhanced matrix removal system. Samples were analyzed using a high-performance liquid chromatography quadrupole time-of-flight mass spectrometer. The mobile phase consisted of Solution A–acidified water and Solution B–acidified methanol utilizing a gradient from

Solution A to Solution B over 15 min. Data for metabolomics were analyzed using Agilent MassHunter Qualitative Workflow, Profinder, and Mass Profiler Professional. The results were log-10 transformed, filtered using qualitative factors, and analyzed using multivariate analyses to determine partial least squares–discriminant analyses, hierarchical clustering in a heat map, and constellation diagrams to describe the metabolomic data.

Results: Raw steaks had 69 small-molecule metabolomic compounds shared across all 4 quality grade x aging combinations, and discriminant analysis correctly categorized ($P < 0.05$) these metabolites. Metabolites in raw and cooked meat were significantly affected by USDA Quality Grade, aging time, and degree of doneness, which may be used to help describe sensory characteristics and especially flavor. The discriminant analysis correctly categorized ($P < 0.05$) the metabolites into 4 treatment combinations of quality grade and aging time. It is worth noting that those compounds in Choice steaks aged 20 d clustered away and to the right separating by canonical 1, whereas Choice steaks aged 10 d were pulled upward by canonical 2. A hierarchical cluster analysis of the 69 compounds showed again that the steaks from the Select quality grade clustered together, whereas Choice steaks aged 10 d tended to have lower abundance values of most of the compounds clustered near the middle of the second clustering factor.

Conclusion: Metabolites show strong relationships with aging, quality grade, and degree of doneness with metabolomics able to distinguish among quality grades and aging times which are useful in creating differences in flavor. The results presented here show that untargeted metabolomics has potential for elucidating factors that indirectly serve as precursors to beef flavor or as non-volatile compounds directly influencing beef flavor.

Funding Source: Funding provided by the Beef Checkoff.

Keywords: aging, beef, degree of doneness, metabolomics, quality grade

158 A PRELIMINARY STUDY TO DETERMINE THE APPLICATION OF RESAZURIN AND METHYLENE BLUE ASSAY TO UNDERSTAND BIOCHEMICAL STATE OF BEEF LONGISSIMUS LUMBORUM AND PSOAS MAJOR STEAKS

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Objectives: Oxygen consumption and metmyoglobin reducing activity are 2 important inherent biochemical processes that influence beef color. Both approaches are routinely used in meat color research. Resazurin sodium salt has been used to assess cell viability and cellular metabolic activity but has never been utilized in a fresh muscle to assess metabolic activity. Methylene blue has been utilized to evaluate cellular oxidation reduction potential but has not been used in meat-based applications. Therefore, the objective was to conduct a preliminary study to determine the application of resazurin and methylene blue assays to understand biochemical state of beef *longissimus* and *psoas* steaks.

Materials and Methods: Beef porterhouse steaks ($n = 4$) were procured from a local retailer on separate occasions to ensure porterhouses were from different lots. The *longissimus lumborum* (LL) and *psoas major* (PM) were cut from each steak. The interior of each muscle was cut into four 2.54 cm x 2.54 cm x 1.2 cm squares (approximately 3 g) and placed into small plastic dishes to bloom for 1 h at 2°C. After the blooming period, one square of each muscle was randomly designated for one of 4 analysis methods: resazurin, methylene blue, oxygen consumption, or metmyoglobin reducing activity. Incubation time and concentrations were selected based on preliminary studies. For the resazurin method, a 0.05% resazurin sodium salt solution was poured over the muscle sample and submerged for 10 min. Methylene blue analysis samples were dipped in a 0.4% methylene blue solution and submerged for 20 min. For metmyoglobin reducing activity, the samples were submerged in a 0.3% sodium nitrite solution for 20 min. For all the above 3 methods, samples were blotted dry, vacuum packaged, and incubated for 2 h. Oxygen consumption samples were vacuum packaged after 1 h bloom. After vacuum packaging, samples were immediately read with a HunterLab Miniscan handheld spectrophotometer. All samples except for those designated for the resazurin sodium salt method were incubated at 30°C, and the resazurin samples were incubated at 37°C. Both L^*, a^*, b^*, and spectral data from 400 to 700 nm were recorded using a HunterLab MiniScan spectrophotometer every 20 min over a period of 2 h. The data were analyzed using the Glimmix procedure of SAS.

Results: For the resazurin method, peaks at 630 and 670 nm showed maximum changes for both muscles (LL > PM; $P < 0.05$). In addition, LL steaks had a greater ($P < 0.05$) slope in a^* value over 120 min than PM steaks for the resazurin method. Methylene blue method resulted in no differences ($P > 0.05$) between muscles at 480 nm; however, LL had a greater ($P < 0.05$) slope for a^* value than PM. Furthermore, there was greater ($P < 0.05$) oxygen consumption in the PM than LL when evaluating the oxygen consumption method. Finally, there were no differences ($P > 0.05$) in metmyoglobin reducing activity between muscles.

Conclusion: The preliminary study demonstrated the capability of both resazurin sodium salt and methylene blue to be used in meat color research. Both methods responded differently with the LL and PM muscles and might provide

more insights into the metabolic activity of muscles. However, further research is required to determine how each assay will perform with changes in retail storage.

Keywords: biochemistry, color, enzymatic activity, oxygen consumption

159 INFLUENCE OF OXYGEN EXPOSURE ON METABOLOME AND BIOCHEMICAL PROPERTIES OF LONGISSIMUS LUMBORUM, PSOAS MAJOR, AND SEMITENDINOSUS MUSCLES DURING RETAIL DISPLAY

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Objectives: The color stability of muscles varies depending on the proportion of oxidative or glycolytic fiber types. A predominant oxidative metabolism found in the *psoas major* (PM) has been reported to have less color stability in comparison to a dominant glycolytic metabolism in the *longissimus* (LL) and *semitendinosus* (ST) muscles. These variations in metabolism also influence the muscle-specific response to oxidative stress. However, the influence of oxygen in relation to color stability and the oxidative changes of specific muscles has not been determined. The objective of the current study was to assess the influence of oxygen exposure on the metabolome of the LL, PM, and ST muscles.

Materials and Methods: Six USDA Low-Choice ST, LL, and PM muscles were collected as boxed beef at 5-d postmortem from Creekstone Farms LLC (Arkansas City, KS). Muscles were processed at 7-d postmortem, sliced into 1.91-cm steaks, and packaged into polyvinyl chloride overwrap trays. Steaks were placed into a retail display for 6 d, and instrumental color was determined using a HunterLab spectrophotometer daily. To evaluate the effects of oxygen exposure, steaks were sliced parallel to retail surface (oxygen exposed [OE]) to expose the non-oxygen exposed (NOE) surface. Steaks were analyzed on day 0, 3, and 6, including oxygen consumption (OC), metmyoglobin reducing activity (MRA), and metabolomics. Metabolites were identified using gas-chromatography-mass spectrometry. The retail data were analyzed using the Glimmix procedure of SAS with the fixed effects of retail day, oxygen exposure, and their interactions. Least-squares means were calculated and separated with the pdiff option. To compare the 3 muscles and different oxygen exposure, an analysis of variance was completed using MetaboAnalyst 5.0. Significance was considered as a $P < 0.05$ for both metabolomic and retail data analysis.

Results: For all muscles, the a^* values decreased ($P < 0.05$) during display time. The NOE surface had greater ($P < 0.05$) MRA than the OE surface. On day 6, the OE surface of the PM had lower ($P < 0.05$) OC than the NOE surface. Furthermore, the OE surface of the LL and ST had greater ($P < 0.05$) OC than the OE surface of the PM at the end of display. Mannose-6-phosphate was more abundant ($P < 0.05$) in the OE surface of the LL and ST muscles than the OE surface of the PM as well as greater ($P < 0.05$) abundance in the NOE surface of the PM muscle compared with the OE surface of the PM. The differences in mannose-6-phosphate could indicate the greater enzymatic activity of the color stable muscles and NOE surface. Fumarate was greater ($P < 0.05$) in abundance in the NOE surface than the OE surface of the PM and ST muscles supporting the greater MRA in the NOE surface. In addition, the ST and LL muscles had greater ($P < 0.05$) fumarate than the PM muscles, indicating their greater color stability. Succinate was reported to be greater ($P < 0.05$) abundance in the NOE surface of the LL muscle compared to the NOE surface of the PM, supporting greater color stability of the LL muscle.

Conclusion: In conclusion, oxygen exposure has muscle-specific implications on the metabolome and subsequent biochemical activity. Hence, the meat sample location (exposed to oxygen or interior) during metabolomics and biochemical analysis is important to understand muscle-specific color traits.

Keywords: meat color, metabolome, muscle-specific, oxygen

160 EFFECTS OF LIGHT AND DARK STORAGE CONDITIONS ON REDOX INSTABILITY INDUCED BY 4-HYDROXY-2-NONENAL ADDUCTION IN BEEF MYOGLOBIN

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Objectives: Meat color is an important quality attribute that influences consumers' perceptions. Myoglobin is a water-soluble heme protein responsible for meat color. Numerous factors can increase meat discoloration, including lipid oxidation. Previous studies have shown that lipid and myoglobin oxidation are interrelated. 4-hydroxy-2-nonenal (HNE) is an α-, β-unsaturated aldehyde derived from the oxidation of n–6 polyunsaturated fatty acids. HNE-induced beef oxymyoglobin (OxyMb) oxidation is influenced by pH,

temperature, and atmospheric oxygen partial pressure. However, limited knowledge is available on the effects of HNE on myoglobin redox stability under light and dark storage conditions. We hypothesized that energy rays from display light will increase HNE-induced OxyMb oxidation. Therefore, the objective of this study was to examine the effects of light and dark storage conditions (experiment 1) as well as to compare open and closed systems (experiment 2) on HNE-induced beef OxyMb oxidation at 4°C and pH 5.6.

Materials and Methods: Beef OxyMb (0.650 mM; pH 5.6) was mixed with HNE (0.6 mM), whereas controls received an equal volume of ethanol equivalent to deliver HNE. Following mixing, the samples were incubated at 4°C under a continuous florescent light source (800 lux) or dark conditions (experiment 1). Metmyoglobin (MetMb) formation was measured spectrophotometrically on 0, 2, 4, 6, and 8 d of incubation (experiment 1). In experiment 2, FireflySci Type 46 semi-micro spectrophotometer cuvette cells with SEPTA closed screw caps were used for open (allowing exposure to atmospheric oxygen) and closed (no diffusion of oxygen from outside) systems. MetMb formation was calculated spectrometrically on 0, 1, 2, 3, and 4 d of incubation. The experiments were replicated 3 times ($n = 3$). The data were analyzed using the MIXED procedure of SAS, and the significance was considered at $P < 0.05$ level.

Results: The presence of light and HNE increased ($P < 0.05$) MetMb formation. Additionally, HNE-induced MetMb formation was greater ($P < 0.05$) in samples incubated in light than those incubated in darkness. HNE-induced beef OxyMb oxidation was greater ($P < 0.05$) in an open system than in a closed system.

Conclusion: The results suggest that light acted as a pro-oxidant and promoted redox instability in beef myoglobin. Additionally, lipid oxidation-induced beef OxyMb oxidation was greater in the presence of light and oxygen. These findings indicated the potential impact of retail display conditions on lipid oxidation-induced meat discoloration.

Keywords: 4-hydroxy 2-nonenal, beef myoglobin, light, dark storage, lipid oxidation, meat color

161 ENDOGENOUS AND EXOGENOUS FACTORS AFFECTING HEMOGLOBIN MEDIATED LIPID OXIDATION IN MELEAGRIS GALLOPAVO

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Objectives: Hemoglobin (Hb) is one of the most widely studied proteins in biological systems, with unique functional and redox characteristics. Some meat producing species present multiple Hb isoforms. The current work aimed to understand the dissimilar reactivity of Hb $\alpha^{A}{}_2\beta_2$ (HbA) and $\alpha^{D}{}_2\beta_2$ (HbD) of *Meleagris gallopavo*, in their native and free fatty acid (FFA) modified states.

Materials and Methods: Anticoagulated blood was washed, and cells were lysed to obtain hemolysate composed of ~3 parts HbA to 1 part HbD. Anion exchange chromatography using DEAE Sepharose was used to separate HbA and HbD. Oxidation of Hb was performed using excess potassium ferricyanide, and the purity of both the oxy and met Hb was determined using intact ESI-MS on a Thermo Fisher LTQ-Orbitrap Elite™ equipped with an HESI™ electrospray source. To elucidate the divergent reactivity of the native HbA and HbD, ferrous proteins were allowed to autoxidize (k_{ox}) at pH 5.8 and 6.3 in the presence and absence of superoxide dismutase and catalase. Results were obtained by electronic absorption measurements from 400 to 700 nm, using a Shimadzu UV-2600 Spectrophotometer. Additionally, HbA and HbD in the oxy and met forms were analyzed for their ability to oxidize lipid of washed muscle as measured by thoibarbituric acid reactive substances (TBARS). To perform reactions between metHb and FFA, FFA were either isolated from the total lipids of turkey skin using solid phase extraction on Discovery® DSC-NH2 column or purchased as linoleic acid (LA). FFA and metHb were allowed to react at room temperature for 30–100 min, in the presence of 0.1% Tween20, at pH 7.4. Electronic absorption was measured during the reaction to track Hb redox and ligation status. The modified proteins were isolated using Amicon® Ultra 10K centrifugal concentrators, Econo-Pac 10DG columns, and DetergentOUT™ spin columns. Isolated proteins were then added to washed muscle to determine their capacity to oxidize lipids. To further understand the interaction of FFA with Hb, molecular docking was performed using UCSF Chimera with AutoDockVina plug-in. Statistical analysis was performed in JMP Pro via one-way ANOVA ($\alpha = 0.05$).

Results: Interestingly, metHbA displays extensive heme-crosslinking as seen by ESI-MS. HbD shows elevated ($P < 0.05$) k_{ox} compared to HbA only in the presence of SOD/CAT. Similarly, HbD displays increased ($P < 0.05$) propensity to oxidize lipids in its oxy and met states, compared to HbA. Met hemolysate reacted with FFA mixture and LA, displaying a significant inhibition ($P < 0.05$) of TBARS compared to unreacted met hemolysate.

Conclusion: Turkey Hb isoforms display differing redox activity despite their 59% sequence identity. The lesser degree of heme crosslinking in HbD may partly explain its greater lipid oxidation capacity than HbA. HbA and HbD in their FFA modified state form an antioxidative, bis-histidyl ferric Hb specie. Docking studies positioned linoleic acid at the α/β interfaces. Further work should be performed to confirm the FFA binding site, understand the

heme-iron electronic environment in this modified state, and understand the kinetics of this interaction.

Keywords: bis-histidyl ferric Hb, hemoglobin, intact ESI-MS, lipid oxidation, molecular docking

162 INFLUENCE OF WET AGING TEMPERATURE AND DURATION ON VACUUM-PACKAGED BEEF LONGISSIMUS AND EXUDATE

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Objectives: The objective of this study was to evaluate the influence of beef wet aging temperature and duration on the metabolome of beef *longissimus lumborum* and exudate.

Materials and Methods: Paired USDA Choice strip loins ($n = 60$) were collected from a commercial beef processing facility. Each carcass was assigned to a storage temperature (−2°C, 0°C, 4°C). Strip loins were portioned into half loins and assigned to an aging duration (14, 28, 42, 56 d). Loins were aged in commercial upright refrigerators. At each fabrication day, exudate was collected, and a 2.54 cm steak was assigned to biochemical analyses. *Longissimus* tissue was snap frozen and pulverized into a fine powder. Both exudate and tissue were frozen at −80°C until analysis. Metabolites were extracted from 30 µL or mg of sample using 80% methanol. Resulting extracts were dried and reconstituted with methoxyamine hydrochloride and *N*-methyl-*N*(trimethylsilyl)trifluoroacetamide. Samples were analyzed via gas chromatography-mass spectrometry. Mass spectral data were acquired in full scan mode within a range of 50 to 650 m/z. Data were deconvoluted, aligned, and annotated using MS-DIAL. Annotated data were analyzed using MetaboAnalyst. Feature intensities were normalized by the internal standard (ribitol) and log2 transformed prior to univariate and multivariate statistical analyses. Significance was determined at false discovery rate (FDR) adjusted $P < 0.05$.

Results: For *Longissimus* tissue, 165 features were annotated. Of these 165 features, none were influenced by temperature duration interaction or temperature (FDR $P > 0.05$). However, 69 features, including amines, amino acids, carboxylic acids, fatty acids, nucleotides, peptides, and sugars, were influence by aging duration (FDR $P < 0.05$). Generally, aging for 14 d resulted in metabolite accumulation (FDR $P < 0.05$). The univariate data are echoed by agglomerative cluster analysis which produced 2 clusters: Cluster 1 included product aged for 14 at −2°C, 0°C, and 4°C, and Cluster 2 included the remaining treatment combinations. In exudate, 164 features were identified, and 92 of these features were influenced by either the aging temperature, duration, or their interaction (FDR $P < 0.05$). Unlike the *Longissimus,* increased aging temperature and/or duration resulted in decreased metabolite abundances in exudate (FDR $P < 0.05$).

Conclusion: These data indicate that aging duration has more influence on the metabolome of vacuum-packaged beef *Longissimus*, compared with temperature. However, both temperature and duration influenced metabolites present in exudate. The reported metabolite changes are the result of various postmortem biochemical processes that can influence beef quality.

Keywords: beef, exudate, gas chromatography/mass spectrometry, metabolomics, wet aging

163 INTRAMUSCULAR, SUBCUTANEOUS, AND VISCERAL ADIPOSE TISSUES HAVE DEPOT-SPECIFIC TRANSCRIPTIONAL AND ADIPOCYTE FUNCTIONAL PROFILES IN FINISHED BEEF CATTLE

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Objectives: Intramuscular adipose tissue (IMAT; marbling) deposition is a highly desired trait and a primary factor influencing beef quality grading in the US. However, this trait is difficult to achieve. The linear relationship between IMAT content and the deposition of subcutaneous (SCAT) and visceral (VIAT) adipose tissue (AT) poses a great challenge to the beef industry, as large amounts of "waste fat" are generated for every percent of IMAT. We hypothesized that IMAT, relative to SCAT and VIAT, has defects on adipogenesis and insulin pathways at the transcriptional and functional levels. Our objective was to assess depot-specific characteristics and gene profile of IMAT, SCAT, and VIAT in beef cattle.

Materials and Methods: IMAT and SCAT samples from the *longissimus* muscle (9–11th ribs) and VIAT from the greater omentum were collected from 6 beef animals at harvest. Flash frozen AT samples were RNA-sequenced on an Illumina Novaseq 6000 platform to generate 150 bp paired-end reads. DESeq2 R package was used for differential gene expression analysis (DEG) and DEG ($P \leq 0.05$, log2FC ≥ 1) were evaluated for Kyoto Encyclopedia of Genes and Genomes (KEGG) enrichment pathways. Adipocyte size and cell typing were performed after collection and collagenase digestion of AT using a K2 Cellometer and flow cytometry, respectively. To assess adipocyte metabolic function in

vitro, proliferation, insulin-stimulated glucose uptake (GUA), and lipolysis assays were performed on cultured IMAT, SCAT, and VIAT adipocytes.

Results: Transcriptome analysis revealed over 4000 DEG between IMAT and SCAT, over 3000 DEG between VIAT and IMAT, and 1018 DEG between VIAT and SCAT, thus indicating substantial transcriptional diversity among AT depots. Top upregulated genes in SCAT versus IMAT were associated with enhanced adipogenesis and lipid accumulation, such as *ADIPOQ*, and *PPARG*. Accordingly, enrichment analysis revealed an activation of *PPARG* signaling pathways and fatty acid metabolism in SCAT versus IMAT, which are key for AT growth. Transcriptional findings were further confirmed by the increased adipocyte size in SCAT versus IMAT and VIAT, implying higher lipid accumulation. IMAT showed activation of pathways for insulin resistance and oxidative phosphorylation, and dysregulated lipolysis compared to both SCAT and VIAT. Consistently, in vitro, we observed a tendency for IMAT to have reduced insulin-stimulated GUA ($P = 0.12$) compared to SCAT and increased beta-adrenergic stimulated lipolysis compared to SCAT ($P = 0.13$) and VIAT ($P = 0.13$). In VIAT, top DEG were primarily associated with immune response (*TENM2* and *TNFRSF9*), suggesting a pro-inflammatory profile of visceral adiposity. Enrichment analysis also showed an activation of the immune function in VIAT compared to IMAT and SCAT. This was further validated by number of immune cells in VIAT versus IMAT ($P = 0.009$), as evaluated by flow cytometry.

Conclusion: In summary, these results indicate that AT anatomical location impacts AT transcriptome, which translates into functional differences in adipocyte function and AT growth. Understanding transcriptional and metabolic differences among IMAT, SCAT, and VIAT can help in the identification of target genes to modulate AT deposition in distinct areas of the body, thus improving quality of beef carcasses and industry profitability.

Funding Source: USDA-NIFA Grant

Keywords: adipose tissue, beef cattle, intramuscular fat, marbling, transcriptome

164 ACCELERATED AGING: A NOVEL METHOD TO ENHANCE ENZYMATIC ACTIVITY TO POTENTIALLY IMPROVE TENDERNESS OF LOWER QUALITY BEEF CUTS

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Objectives: As beef prices increase, consumers are more willing to explore lower-priced cuts. However, the lower-priced options tend to have higher amounts of connective tissue and are tougher than the traditional middle meat cuts. A fairly new technique known as accelerated aging (AA) has shown to improve beef tenderness through submerging vacuum packaged beef in warm water bath for just a few hours (Aufdemberge et al., 2022); nonetheless, there is little information available on the mechanism behind AA of beef. Hence, this study aimed to investigate the effect AA at different time points and temperatures on sensory characteristics and proteolytic activity of lower-quality beef cuts.

Materials and Methods: *Triceps brachii* (TB) and *semimembranosus* (SM) were fabricated from the shoulder clod and top round of 10 USDA choice beef carcasses. Both muscles were cut into 2.54 cm steaks, vacuum packaged, and assigned to one of 6 treatments: 1) 3 d postmortem (control); 2) 21 d cooler aging; 3) AA 49°C for 2 h; 4) AA 49°C for 3 h; 5) AA 54°C for 2 h; and 6) AA 54°C for 3 h. Ten sous vide systems were utilized to generate the AA samples, and purge was collected for collagen analysis. Panelists were recruited and trained to evaluate myofibrillar tenderness, connective tissue amount, and overall tenderness on a continuous line scale. Total collagen in purge as well as soluble/insoluble collagen, transitional temperature and enthalpy from extracted perimysium, cathepsin activity, and troponin-T degradation were measured.

Results: Trained panelists rated 21 d cooler aged samples with the greatest myofibrillar and overall tenderness, followed by AA 54°C for 3 h, with the rest not different from each other ($P < 0.01$). Connective tissue content was rated lowest in AA 54°C for 3 h and cooler aged 21 d treatments compared to the rest of the treatments ($P < 0.01$). In TB, soluble and total collagen was highest in AA 54°C samples ($P < 0.01$), and all AA treatments displayed greater insoluble collagen and total collagen content in the purge ($P < 0.05$) regardless of muscles. Peak perimysium denaturation temperature decreased for 21 d cooler aged samples but increased for AA 54°C for 2 h samples compared to the control ($P < 0.01$). Both AA 54°C treatments had lower enthalpy but higher onset temperature of denaturation compared to the control ($P < 0.05$). Three bands were distinguished in cathepsin zymography: band 1 (~60 kDa), band 2 (~50 kDa), and band 3 (~30 kDa). In general, AA 49°C treatments had highest cathepsin activity, and the control had the lowest ($P < 0.05$). In regard to troponin-T degradation, the AA treatments resulted in a slightly different degradation pattern compared to the cooler aged samples, which the AA sample had a set of further degraded bands (23 and 21 kDa) below the traditional cooler aging degraded band (28 kDa). The 21 d cooler aged samples had a greater relative % of traditional degraded bands (28 kDa) compared to the rest of the treatments ($P < 0.01$). However, all AA samples had more relative % of the further degraded bands (23 and 21 kDa; $P < 0.01$).

Conclusion: This investigation revealed that AA can enhance cathepsin activity of lower-quality beef cuts leading to collagen solubilization and protein degradation. Further studies are needed to better understand the changes in collagen structure and identify the isoforms of cathepsin that were active at these temperatures.

Funding Source: The authors would like to thank the Kansas Beef Council for funding this project.

Keywords: cathepsin, collagen, degradation, sous vide, trained panel

165 INVESTIGATING THE METABOLIC CHANGES THAT ACCOMPANY SKELETAL MUSCLE MATURATION

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Objectives: The objective of this study was to investigate changes in skeletal muscle metabolism that accompany porcine muscle hypertrophy through the evaluation of key metabolic enzymes and implementing an *in vitro* [$^{13}C_3$]-pyruvate tracing model.

Materials and Methods: To define the metabolic changes in skeletal muscle that accompany maturation, samples were collected from the *longissimus dorsi* (LD, glycolytic muscle), *latissimus dorsi* (LAT, mixed muscle), and *masseter* (MS, oxidative muscle) at 20, 53, 87, 120, and 180 d of age from 5 DNA 600 x 241 (DNA Genetics) castrated male pigs ($n = 5$) that weighed an average of 5.7, 20.8, 42.2, 83.4, and 130.5 kg, respectively. Ages correspond to the end of each phase diet typical of those fed in commercial production, which are formulated to meet nutrient requirements to support each period of growth. Muscles were assessed to determine the abundance of several metabolic enzymes through western blotting. Additionally, mitochondria were isolated immediately after sample collection and incubated with [$^{13}C_3$]-pyruvate in an *in vitro* tracing model to analyze isotopomer enrichment patterns of tricarboxylic acid cycle (TCA) intermediates.

Results: Glucose-6-phosphate dehydrogenase decreased at 87, 120, and 180 d in MS compared to LAT and LD ($P < 0.01$), which suggests glycolytic muscles increase intermediate allocation to the pentose phosphate pathway at this time whereas oxidative muscles do not. Moreover, pyruvate carboxylase (PC) increased at 53 d compared to 20, 87, 120, and 180 d ($P < 0.01$), whereas pyruvate dehydrogenase increased at 120 d compared to 53 d ($P < 0.05$), indicating there was a shift in pyruvate entry into the TCA cycle. Oxaloacetate M3 mole percent excess and citrate synthase increased at 120 d ($P < 0.01$), whereas citrate M3 mole percent excess decreased at 120 d ($P < 0.01$). These data suggest pyruvate-derived citrate exits the TCA cycle at 120 d by an unidentified cataplerotic reaction. Additionally, alpha-ketoglutarate M3 mole percent excess increased at 180 d in LD and LAT compared to MS ($P < 0.01$), and abundance of glutamate dehydrogenase increased at 180 d ($P < 0.01$), which indicates a portion of pyruvate-derived carbons could be exiting the TCA cycle at 180 d through glutamate dehydrogenase.

Conclusion: These findings have established a metabolic fingerprint associated with muscle hypertrophy and highlight potential pathways in mitochondria metabolism that may be necessary for optimal nutrient utilization during lean deposition. Uncovering the regulatory mechanism that modulates nutrient allocation to major metabolic pathways in growing muscle will aid in developing innovative strategies to improve feed efficiency in the swine industry.

Funding Source: Kansas State University Global Food Systems Seed Grant Program

Keywords: feed efficiency, nutrient utilization, skeletal muscle metabolism, swine

166 MECHANISMS OF TENDERNESS FORMATION IN BISON LONGISSIMUS MUSCLE

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Objectives: The objective of this study was to characterize the influence of finishing system (grain-finished vs. grass-finished) on the mechanisms of tenderness formation (protein degradation, collagen content and solubility, and sarcomere length) in the *longissimus* muscle of bison bulls.

Materials and Methods: Bison bulls were randomly assigned to 2 finishing treatments: grain-finished ($n = 30$, backgrounded on pasture and finished for 130 d with ad libitum access to whole corn, grass hay, and alfalfa) or grass-finished ($n = 30$, remained on pasture until slaughter). Bulls were slaughtered at 29 mo of age. Striploins were collected from both sides of each carcass and fabricated into 2.54-cm steaks. Four steaks were vacuum packaged, aged for 4, 7, 14, or 21 d, and frozen (−20°C) for 3 mo prior to Warner-Bratzler shear force analysis. One steak was divided into quadrants, and each quadrant was assigned to age for 4, 7, 14, or 21 d and used to analyze postmortem proteolysis of desmin and troponin-T using SDS-PAGE and western blotting techniques. One steak was aged for 4 d and designated

for analysis of collagen content and solubility. An additional steak was aged for 4 d for determination of sarcomere length using an immunoassay to fluorescently label alpha-actinin in the Z-lines. All data were analyzed using the MIXED procedure of SAS. Shear force and western blot data were analyzed as repeated measures with aging day, finishing treatment, and their interaction as fixed effects. Peak temperature was included as a covariate for shear force. Collagen measures and sarcomere length were analyzed for main effect of finishing treatment. Separation of least-squares means was performed using LSD with a Tukey's adjustment, assuming $\alpha = 0.05$.

Results: Warner-Bratzler shear force was influenced ($P < 0.05$) by the interaction of finishing treatment with aging period. Shear force values decreased ($P < 0.05$) for steaks from the grain-finished treatment as aging time increased from 4 to 14 d, whereas shear force of steaks from grass-finished bulls did not differ ($P > 0.05$) during this period. Steaks from grass-finished bulls had lower shear force values ($P < 0.05$) than grain-finished at day 4 (2.95 vs. 3.66 ± 0.137) and 7 (2.77 vs. 3.30 ± 0.137), but treatments were similar ($P > 0.05$) at days 14 and 21. Steaks from grass-finished bulls had less ($P < 0.05$) intact desmin compared to steaks from grain-finished bulls. Additionally, the amount of intact desmin decreased ($P < 0.05$) over the aging period. Finishing treatment did not influence ($P > 0.05$) degradation of troponin-T. However, the amount of intact troponin-T decreased ($P < 0.05$) over the aging period. Finishing system did not influence ($P > 0.05$) sarcomere length or the content of insoluble, heat-soluble, or total collagen.

Conclusion: Steaks from grass-finished bison bulls were more tender earlier in the aging period compared to grain-finished steaks. While it is well established in many livestock species that postmortem proteolysis, collagen content and solubility, and sarcomere length collectively regulate meat tenderness, these factors have not been studied in bison. This study characterizes these mechanisms in bison *longissimus* muscle and reveals that postmortem proteolysis is likely the primary mechanism responsible for tenderness differences between grass- and grain-finished bison bulls.

Funding Source: Turner Institute of EcoAgriculture (grant #3P0510) and the South Dakota State Experiment Station

Keywords: bison, grain-finished, grass-finished, proteolysis, tenderness

167 EVALUATING THE IMPACT OF MYOGLOBIN FORMS ON METMYOGLOBIN REDUCING ACTIVITY AND OXYGEN CONSUMPTION

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Objectives: Meat color is an important sensory quality that influences consumer preference at the time of purchase. The meat industry uses various types of packaging, such as vacuum packaging (VP), polyvinyl chloride (PVC) overwrap, and carbon monoxide modified atmosphere packaging (CO-MAP). Metmyoglobin reducing activity (MRA) and oxygen consumption (OC) are the two important inherent processes that impact meat color. Published studies utilized both internal and external surfaces for measuring MRA and OC. However, limited knowledge is available on the impact of myoglobin forms on MRA and OC. The objective of this study was to evaluate the effects of different packaging or myoglobin forms on MRA, OC, and lipid oxidation.

Materials and Methods: Six 28 d aged strip loins were fabricated into steaks and randomly assigned to one of the following treatments/packaging types: day 0 analysis, CO-MAP (0.4% CO, anaerobic), VP (anaerobic), NP (anaerobic, nitrite-embedded film; FreshCase®), and PVC. After packaging, samples were stored in dark storage at 2°C for 5 d, where surface color was measured daily using a HunterLab MiniScan™ spectrophotometer. Internal and external OC, MRA, and lipid oxidation were measured on day 0 and 5 of storage for each packaging type. Changes in oxymyoglobin values after VP bloomed steaks were used to determine OC. Nitrite-induced metmyoglobin reduction method was utilized to determine MRA. The data were analyzed using the GLIMMIX Procedure of SAS and considered significant at $P < 0.05$.

Results: On day 5 of storage, CO-MAP had greater redness than other packaging types ($P < 0.05$). VP was the least red ($P < 0.05$), whereas NP and PVC were similar in color ($P > 0.05$). There were no differences ($P > 0.05$) in interior OC between packaging. However, surface OC differed among myoglobin forms, with VP having the most oxygen consumed ($P < 0.05$), followed by CO-MAP and PVC. NP had the least oxygen consumed ($P < 0.05$) compared with other packaging types. Steaks packaged in VP had more ($P < 0.05$) MRA than other treatments on day 5 (VP > CO-MAP > NP > PVC; $P < 0.05$). PVC had the most ($P < 0.05$) lipid oxidation on day 5 compared with other treatments.

Conclusion: The effects of different forms of myoglobin on MRA and OC are not well understood. The current research indicates that myoglobin form can influence both MRA and OC. Therefore, the researchers might consider using both exterior and interior sections when measuring MRA and OC with different packaging types as they depict different forms of myoglobin. By utilizing both interior and exterior, there can be more understanding of meat color development and how various packaging strategies can affect the MRA or OC.

Keywords: deoxymyoglobin, meat color, nitric oxide myoglobin, oxymyoglobin, packaging

168 SUPPLEMENTING SUPRANUTRITIONAL LEVEL OF ZINC IN FEEDLOT DIET MAY INCREASE COLLAGENASE MMP-9 ACTIVITY IN BEEF

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Objectives: Past research has shown that the addition of Zn ion may significantly improve the activity of collagenase matrix-metalloproteinases (MMP) in a model system, in which the degradation of collagen in meat can lead to improved tenderness and greater consumer satisfaction in beef. Koulicoff et al. (2022) identified MMP-9 as the primary type of collagenase MMP that contributes to collagen degradation during postmortem aging of beef. In a separate study, Schulte et al. (2021) found that steaks from steers supplemented with supranutritional level of Zn were more tender than those from the control steers despite there being no differences in myofibril protein degradation. Thus, researchers from Kansas State University and Iowa State University have collaborated to determine the effect of supranutritional level of Zn supplementation on MMP-9 activity in beef.

Materials and Methods: The feeding trial portion of this study was conducted at Iowa State University. Twenty Angus steers (~516 kg initial body weight) were fed one of 4 treatment diets for 89 d. The diets consisted of 1) Control (CON; 36 mg Zn/kg DM); 2) Supranutritional Zn (SUPZN; CON+ 60 mg Zn/kg DM [$ZnSO_4$] + 60 mg Zn/kg DM [Zn-amino acid complex; Availa-Zn; Zinpro, Eden Prairie, MN]); 3) Ractopamine hydrochloride supplementation (RAC; CON + 300 mg of ractopamine hydrochloride [Actogain45] per steer per day); 4) SUPZN+RAC (SUPZN + 300 mg of Actogain45 per steer per day) with all RAC treatments beginning 28 d prior to harvest. After harvest, steaks were fabricated to contain only *longissimus thoracis* (LT) from the left side of each carcass and aged for 1, 3, 7, or 14 d ($n = 80$). After aging, all samples were homogenized, pulverized in liquid nitrogen, and shipped overnight on dry ice to the Kansas State University Meat Chemistry and Muscle Biology Laboratory. Sarcoplasmic proteins were extracted from all samples and adjusted to a concentration of 3 mg protein/mL. A collagen zymography was conducted to evaluate MMP-9 activity. MMP-9 activity was expressed as fold changes relative to the reference sample's enzymatic activity on each gel. Finally, free Zn and Ca concentrations were determined on day 1 samples only. Data were analyzed in a 4 x 2 x 2 factorial design. The model included the fixed effects of aging time, SUPZN and RAC and their interactions with each individual carcass used as the experimental unit.

Results: LT from cattle fed SUPZN had higher levels of MMP-9 activity than those fed CON ($P < 0.05$). An interaction was observed between aging time × RAC ($P < 0.01$). At day 1 of aging, the LT of RAC-fed cattle had lower activity of MMP-9 than those not supplemented with RAC ($P < 0.01$). However, RAC did not continue to diminish MMP-9 activity, as aging periods 3, 7, and 14 d had similar MMP-9 activity between animals with or without RAC supplementation ($P > 0.05$). As expected, SUPZN samples had greater free Zn concentration than CON samples ($P < 0.01$). However, it was interesting to note that the CON samples had greater free Ca concentrations than SUPZN samples ($P < 0.01$).

Conclusion: The inclusion of RAC in the diet decreased MMP-9 activity, which could lead to reduced connective tissue breakdown during postmortem aging. Additionally, the inclusion of SUPZN in the diet of cattle can increase free Zn availability in beef leading increased activity of native collagenases. Further research is needed to evaluate the effect of increased MMP-9 activity on tenderness, eating quality, and consumer satisfaction of beef.

Funding Source: Funded in part by the Beef Checkoff.

Keywords: beef, collagenase, matrix-metalloproteinases, MMP-9, zinc

169 UNTARGETED METABOLOMICS IN GROUND BEEF WITH DIFFERENT LEAN SOURCES AND FAT CONTENT FROM A COMMON FAT SOURCE

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Objectives: Defining metabolite differences due to carcass or breed type differences could provide evidence of up- or down-regulation of muscle metabolomics. Our objective was to measure small-molecule metabolites in raw and cooked ground beef samples from different lean sources with a common fat source of 10% or 20% fat. We hypothesized that differences in carcass or breed type and ground beef fat content would affect untargeted metabolomic compounds in the raw and cooked lean portion of ground beef.

Materials and Methods: Beef inside rounds were procured from commodity upper two-thirds choice (HC), heart-healthy-branded (HEART), natural grass-fed (NATURAL), and commodity USDA Select (SELECT) beef. Rounds were

ground and supplemented with commercially sourced, pre-ground commodity fat trim to form batches containing 10% or 20% total fat. Patties (112 g) were vacuum packaged and frozen until analyzed when they were thawed for 24 h (4°C), then cooked on a flat top grill (177°C) to 35°C, turned, and then removed at 71°C. Raw and cooked meat samples were extracted with methanol:water (80:20 v/v). Samples were analyzed using an HPLC-qTOF utilizing a gradient of Solution A (acidified water) to Solution B (acidified methanol) over 15 min. Data for metabolomics were analyzed with Agilent MassHunter software using multivariate analyses.

Results: Metabolites ($n = 64$) from raw samples accurately segregated the lean source using discriminate analysis. Hierarchical clusters were identified both across treatment combinations and also across metabolites. Whereas the raw patties with either 10% or 20% fat clustered together across HEART, HC, and NATURAL lean sources, both the heat map as well as the constellation plot shows that SELECT patties with 20% fat clustered with the remaining 10% fat lean sources and vice versa for the SELECT patties with 10% fat. Linear, partial least squares regression discriminate analyses with common covariance was used to cluster treatment metabolomic means with 0.0% misclassified, an entropy r^2 of 0.9999, and a -2 log likelihood of 0.153. Clusters of treatment combination means showed that only the lean source main effect accurately clustered raw patty metabolites into the 4 lean source categories. Patties made with SELECT lean clustered by themselves and generally had the opposite reaction to metabolite concentration as the other lean sources. Metabolites ($n = 138$) from cooked patty 2-way hierarchical cluster analyses showed clusters by lean source for HC, HEART, and NATURAL within 10% and 20% fat treatments. The patties with 10% and 20% fat in the SELECT lean source clustered together and apart from the other treatment combinations. The remaining lean sources with 10% fat and those with 20% fat each clustered together. The discriminate analysis showed very tight clustering of cooked ground beef patty small-molecule metabolites across all fat content by lean source interaction means.

Conclusion: Both raw and cooked samples analyzed by metabolomic profiling had compounds contributing to differences in ground beef lean and fat content treatments. With these metabolomic findings, future research should focus on correlating these compounds with sensory and flavor traits. Metabolomics is a valuable tool to help describe meat quality, and it can be used to determine these traits in lean before sensory testing.

Funding Source: Funding provided by the Beef Checkoff.

Keywords: fat content, ground beef, lean source, metabolomics

170 METABOLOMIC PROFILING OF THE LONGISSIMUS DORSI OF WEANED PIGLETS FOLLOWING PRE- AND POSTNATAL LIPOPOLYSACCHARIDE CHALLENGES

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Objectives: The objective of this study was to evaluate the metabolomic profile of the *longissimus dorsi* (LD) of weaned pigs following a low-dose lipopolysaccharide (LPS) challenge to gestating sows.

Materials and Methods: Pregnant Camborough sows were randomly assigned to receive LPS (LPS; $n = 7$) at a dose of 2.5 µg/kg or saline (CON; $n = 7$) on 78 ± 1.8 d of gestation. At weaning (21 ± 1.3 d of age), barrows (CON $n = 17$; LPS $n = 16$) from each sow treatment group received a secondary LPS challenge. After the postnatal challenge, barrows (31 ± 1.3 d of age) were euthanized, and tissue from the right LD was collected and snap-frozen in liquid nitrogen. Metabolites were extracted by weighing approximately 75 mg of sample and placed into a glass vial with 50 µL of ribitol and 1 mL of 80% methanol. The sample extract was dried with nitrogen gas and then reconstituted with 50 µL of a methoxyamine hydrochloride and 50 µL of N-methyl-N-trimethylsilyltrifluoroacetamide with 1% trimethylchlorosilane. Metabolites were injected into a gas chromatograph coupled with a mass spectrometer with a mass range of 50 to 650 m/z. Mass spectral data were deconvoluted, aligned, and annotated using MS-DIAL. Prior to analyses, data were median normalized, $\log_{10}$ transformed, and auto-scaled. Data were analyzed using MetaboAnalyst by a paired *t*-test. Pathway analysis was conducted and compared to the *Homo sapiens* pathway library. Significance for all analyses was declared at $P \leq 0.05$ and tendencies were considered at $P \leq 0.10$.

Results: Malic acid, oxalic acid, serine, and aspartic acid were increased ($P \leq 0.039$) in LPS offspring compared with CON offspring. D-panose, methyl-beta-D-galactopyranoside, inulotriose, a trisaccharide, and erythrose were increased ($P \leq 0.044$) in CON offspring compared with LPS offspring. There was a tendency for alanine, glutamic acid, inosine, dihydroxyacetone, and fumaric acid to be increased ($P \leq 0.096$) in LPS offspring compared to CON offspring. There was a tendency for 3-deoxyhexitol, cholesterol, and phosphoethanolamine to be increased ($P \leq 0.092$) in CON offspring compared with LPS offspring. Differential metabolites were used to conduct a pathway analysis, resulting in 10 pathways associated

within the skeletal muscle of weaned pigs ($P \leq 0.039$) including the citric acid cycle.

Conclusion: This study showed that an *in utero* immune stimulation using LPS in gestating sows and a subsequent postnatal LPS challenge alters the metabolomic profile of weaned pigs. These results may indicate mechanisms that can alter both pre- and postnatal skeletal muscle growth and development. Furthermore, by altering the metabolome of these offspring, there is potential to alter the production efficiency of growing barrows.

Funding Source: USDA-ARS

Keywords: fetal programming, lipopolysaccharide, metabolomics, skeletal muscle